2023-2024 Effectiveness Monitoring Committee Request for Research Proposals on California Forest Practice Rules: TreePeople Proposal # EMC-2023-001

Title: Climate-Adaptive Post-Fire Oak Restoration through Upslope Migration and Seed Provenance in the Angeles National Forest

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Project Duration: 08/23 – 03/26

1. Project Description

1.a Background and Justification

Foundational to California ecosystems, oak stands provide habitat for tremendous native biodiversity (Standiford et al. 2002; Pavlik et al. 1991), including thousands of invertebrates, extensive avian fauna such as endemic woodpeckers and cavity-nesting owls, over 60 species of herptiles, and more than 100 mammal species. Soils beneath oak trees can be richer in nutrients than open grassland, leading to the designation of oak stands as "islands of fertility" (Dahlgren et al. 1997). Oaks mitigate climate change by sequestering carbon in their biomass, and by facilitating soil carbon storage (Carey et al. 2020). Deep-rooted oaks pull water into shallower soil layers, and their extensive upper canopies provide shaded understories, increasing moisture available to co-occurring species (McLaughlin et al. 2017). These ecosystem services benefit a vast acreage of working lands across California, where creating healthy forests has been explicitly recognized as a goal in the California Department of Forestry and Fire Protection's Forest Practice Rules (FPRs; 14 CCR § 897 (b)(1)). Finally, oaks are part of the Californian identity, from the locational names of California cities (e.g. Oakland, Thousand Oaks, Paso Robles, and Encino) to their essential nutritional and cultural value to California tribes.

Despite the ecological and cultural value of oaks, their survival and regeneration is directly threatened by climate change and indirectly threatened by climate change's influence on disturbance regimes. Ecosystems across California are expected to become warmer and drier (Flint and Flint 2012), whereby some regions of California may no longer experience a Mediterranean-type climate (Klausmeyer et al. 2009). As a result, many California oak species are projected to lose a large fraction of their range by 2100 (Keuppers et al. 2005; Conlisk et al. 2012). Recent shifts in climate have already impacted California oaks, including (i) documented climate-related recruitment decline (McLaughlin et al. 2014; McLaughlin and Zavaleta 2014; Davis et al. 2016), (ii) adult dieback at the xeric edges of species distributions (Brown et al. 2018; Huesca et al. 2021), and (iii) trends toward reduced acorn mass in xeric-edge populations, where acorn mass is correlated with higher seedling survival (McLaughlin et al. 2022). Together with increasing human ignitions (Balch et al. 2017), climate change impacts oaks indirectly by altering wildfire regimes. In recent years, climate change-induced decreased fuel moisture (Abatzglou et al. 2016) and longer fire seasons (Balch et al. 2017) have contributed to some of the largest fire seasons on record(CALFIRE Incident Records 2021).

Even where models predict oak populations to remain stable, populations may not have the necessary local adaptations to persist under projected warming and drying (Gotelli et al. 2015). Evolution over millions of years has led to plant populations with specific adaptations to local conditions (Leimu et al. 2008). The genetic diversity across these populations defines the breadth of species' characteristics that can be drawn upon to adapt to current and future climate change. Local adaptation can confer advantage under equilibrium conditions, but in long-lived species, such as oaks, local adaptation to historical conditions may become maladaptive with rapid climate shifts (Moran 2020). Oaks appear to be locally-adapted to climate (McLaughlin et al. 2020; Sork et al. 2010; Rice et al. 1997), where species distribution model predictions that account for local adaptation suggest even larger range restrictions than predictions for the entire species (Sork et al. 2010). Further, preserving the genetic resources at species' xeric edges may offer resilience to multiple climate change disturbances important to California ecosystems. For example, oaks' ability to resprout after a fire has been hypothesized to have evolved due to drought adaptations such as an investment in underground resources to access water (Bradshaw et al. 2011).

Trailing-edge populations – defined as populations near the receding margin of a shifting species' range – are often genetically distinct (Eckert et al. 2008) and adapted to climate extremes (Sork et al. 2010; Rehfeldt et al. 2002). Because of these unique genetics, trailing edge populations have been disproportionately important to species' survival during earth's past epochs of climatic change (Hampe and Petit 2005). Climate futures modeling suggests that these trailing edge populations may be similarly essential in future adaptation to anthropogenic climate change (Rehm et al. 2015). Further, oaks at the trailing edge of their range often compete with adjacent vegetation that is better adapted to the predicted future climate and has alternative disturbance regimes. For example, California oaks frequently occur within or adjacent to shrublands. Many shrublands have seen increasing fire frequency (Schwartz and Syphard, 2021) due to human ignitions (Balch et al. 2017), where human-ignited wildfires tend to have more extreme wildfire behavior (Hantson et al. 2022). Thus, the ability to survive or regenerate after a wildfire will be critically important to future oak populations and traits that increase survival during dry conditions – such as high root/shoot ratios – benefit regrowth after a wildfire (Keeley et al. 2011).

Taken together, these studies suggest the urgent need for climate-resilient conservation and restoration activities to support California oak populations. Specifically, field gene banking projects can introduce climate-targeted genetic diversity – typically genetic diversity taken from trailing edge populations – into recipient populations, where introduced potential genes can facilitate adaptation to climate change. Such efforts are especially important for oaks, because acorns are recalcitrant; namely, they cannot tolerate conventional seed storage and have no soil seed bank. Thus, the only way to preserve the oak genetic diversity necessary to respond to climate change is to cultivate living trees. Immediate action is needed to take advantage of remaining "good precipitation years" to collect and outplant xeric edge acorns, before progressing climate change makes such efforts impossible, especially given the potential for declining seed production before adult trees reach mortality.

Initial field gene banking has been shown successful for blue oaks, where seeds sourced from arid sites have high survival when transplanted to higher latitude sites (McLaughlin et al. 2022). Compared to local seed sources, seeds from arid sites showed lower survival, but improved defenses against herbivory predation and pathogens. However, this study did not consider the survival of local and arid-adapted seed sources (provenances) under warming. This is an important research gap, given that increased warming should allow drought-adapted seeds to outcompete their local counterparts. We propose to address this research gap, focusing on different seed sources of *Quercus agrifolia* and *Quercus wislizeni*, with and without experimental warming. The proposed work will help guide general restoration practices by comparing the efficacy, under the current and projected climate, of different seed sources across two species with different climatic niches.

We focus on *Q. agrifolia* and *Q. wislizeni* in Southern California, because, similar to many species in the California Floristic Province, Southern California represents the southern, trailing edge of *Q. agrifolia* and *Q. wislizeni*'s distributional ranges. Further, nowhere are the problems of climate and altered disturbance more pressing than in Southern California, where increasing wildfire frequency dominates low-elevation shrublands, adjacent to the low-latitude limit of Western forests. Oak populations are contending with increasingly severe fires as the result of increasing human ignitions, longer wildfire seasons, and, in some locations, historical fire suppression (Schwartz and Syphard 2021, Balch et al. 2017, Abatzglou et al. 2016). Studies that address post-fire recruitment, conservation, and restoration for oaks are critical to operationalizing climate-resilient forest management.

1.b Research Questions, Objectives, and Scope

Questions: Together with partner researchers, we propose to augment our existing oak restoration activities, to minimize the projected upslope expansion of shrublands, following high-severity fires at the shrub-forest transition. Post-restoration monitoring is an often-neglected, but absolutely essential component of building the knowledge base for effective climate-resilient restoration practices. In particular, to engage in effective restoration, we need studies that provide answers to the following questions:

1. *Where should new populations be planted: In the center of their historical range or, because of projected climate change, at the cool edge of their range?*
2. *Where should seeds be collected: From local populations, or from populations at the warm, dry edge of a species range?*
3. *How do the answers to these two questions change, given projected climate change?*

We propose to study these questions across two species with very different elevational ranges – *Quercus agrifolia* and *Quercus wislizeni* – at a Southern California fire-affected site (namely, by the 2002 Copper and 2013 Powerhouse fires). At 1400 meters elevation, our existing Grass Mountain restoration site is within the 30- to 1760-meter elevation range of *Q. agrifolia*, and the 60- to 3060-meter elevation range of *Q. wislizeni*. (These elevation ranges were defined by the elevations where 95% of Calflora occurrences are located.)

The TreePeople Grass Mountain project site is located within the leading edge of *Q. agrifolia*'s range – where the leading edge is defined by populations near the expanding margin of a shifting species' range. Thus, under future projected climate change, we expect that *Q. agrifolia* will be well within its climatic niche at our study site. Figure 1 below (left column) shows model predictions of expanded suitability for *Q. agrifolia* in the region surrounding our site, under the Hades climate model projections in 2050 and the RCP4.5 emissions scenario. In this model, for *Q. wislizeni*, projected climate change is likely to push the species beyond its climatic niche at the Grass Mountain site. Figure 1 (right column) shows very little suitability for *Q. wislizeni* in the region surrounding our site in 2050.

Beyond comparing two species with different elevational ranges, we also seek to compare the potential benefits of field gene banking. Specifically, we will compare the survival of transplanted oaks between two seed sources: a local seed source and seeds collected at sites where the current climate matches the projected 2050 climate at the Grass Mountain site. Whereas we might expect oaks propagated from local seed sources to survive better under the current climate, we expect oaks propagated from warm- and dry-adapted seed sources to survive better under warming. Thus, we will introduce a warming treatment to determine if survival differences across species and provenances are different under warming versus control conditions.

<u>*Objectives*</u>: Our goal is to monitor seed survival of oaks across different species, provenances, and control/warming conditions, in order to inform the Z'Berg-Nejedly Forest Practice Act Provision 4512.5, which states: "*...there is increasing evidence that climate change has and will continue to stress forest ecosystems, which underscores the importance of proactively managing forests.*" Effective restoration requires that we modify best practices to adapt to our evolving understanding of the impacts of climate change. However, many questions remain as to how to operationalize climate-resilient restoration. This proposal is designed to address this research gap, for species important to California ecosystems and forest health.

Our first objective is to determine best practices for designing species palettes, consistent with projected climate change. Specifically, we seek to explore whether a species at the cold-edge of its range is better suited to the warmed treatment, consistent with the projected future climate. In contrast, under control conditions, survival should be higher for the species at the center of its range. The overall survival of both species is also critically important, because restoration activities should not include species that have very low probability of surviving to reproductive maturity, either now or in the future. The results of these experiments will provide general guidance to amend relevant Forest Practice Rules for all California forest species, as well as detailed recommendations for oaks.

Our second objective is to revisit the "local seed is best" general restoration guideline, because this recommendation may need to be modified under rapid climate change. While understanding the need for warm- and dry-adapted propagules is an important restoration first step, it is not the same as knowing the correct seed sources to survive the transition from current to future climate conditions. Studies are needed to help quantify the degree of allowable mismatch between the climate at a restoration site and the climate at a seed source, where an allowable mismatch still yields adequate survival to allow the climate at a restoration site to "catch up" to the warm- and dry-adapted propagules' climate preferences. Few studies explicitly test allowable climate mismatches in the field.

<u>*Scope*</u>. The proposed work will have broad implications, despite a relatively local scope at one study site with seeds sourced from up to 60 km away. We believe that our work will address the Z'Berg-Nejedly Forest Practice Act Provision 4629.7(c), which states that grants should "*promote climate change adaptation strategies for the forest*." Our proposed work will take up this challenge, by providing post-fire guidelines for oaks that will help operationalize

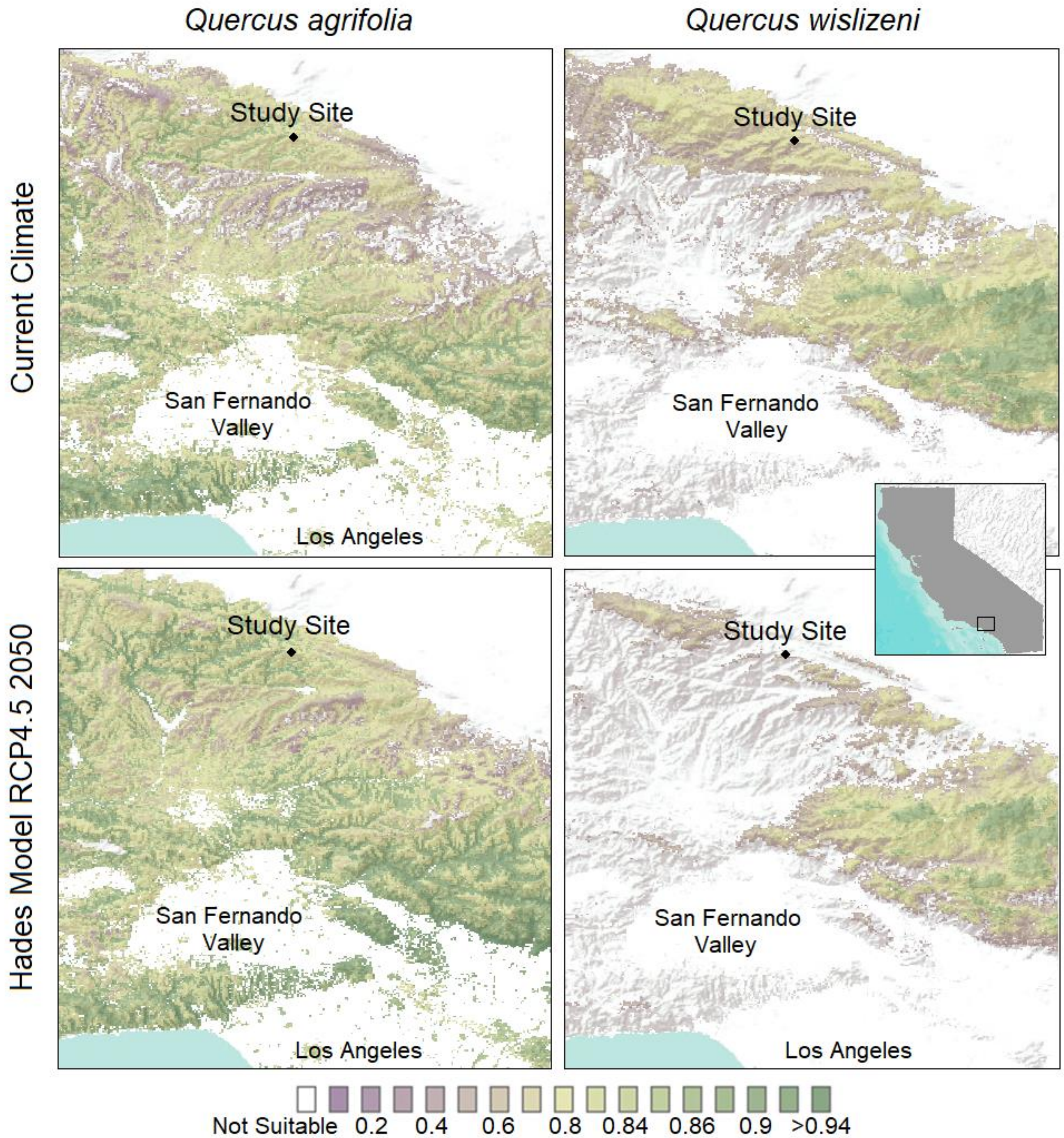

Figure 1. Predicted habitat suitability for *Quercus agrifolia* (left column) and *Quercus wislizeni* (right column) in the current climate, and under climate change in 2050, projected by the Hades model with RCP 4.5 emissions trajectories. For *Q. agrifolia*, habitat suitability in and near the study site increases (represented by more green areas) under projected climate change, because the study site is currently at relatively high elevation, compared to the elevations of existing *Q. agrifolia* occurrences. For *Q. wislizeni*, habitat suitability in and near the study site decreases (represented by fewer green and more purple areas) under projected climate change, because the study site is currently in the middle of *Q. wislizeni*'s elevation range; any warming at these sites pushes *Q. wislizeni* towards the extremes of its climatic niche. We perform habitat suitability predictions (as yet, unpublished) consistent with Rose et al. (2023).

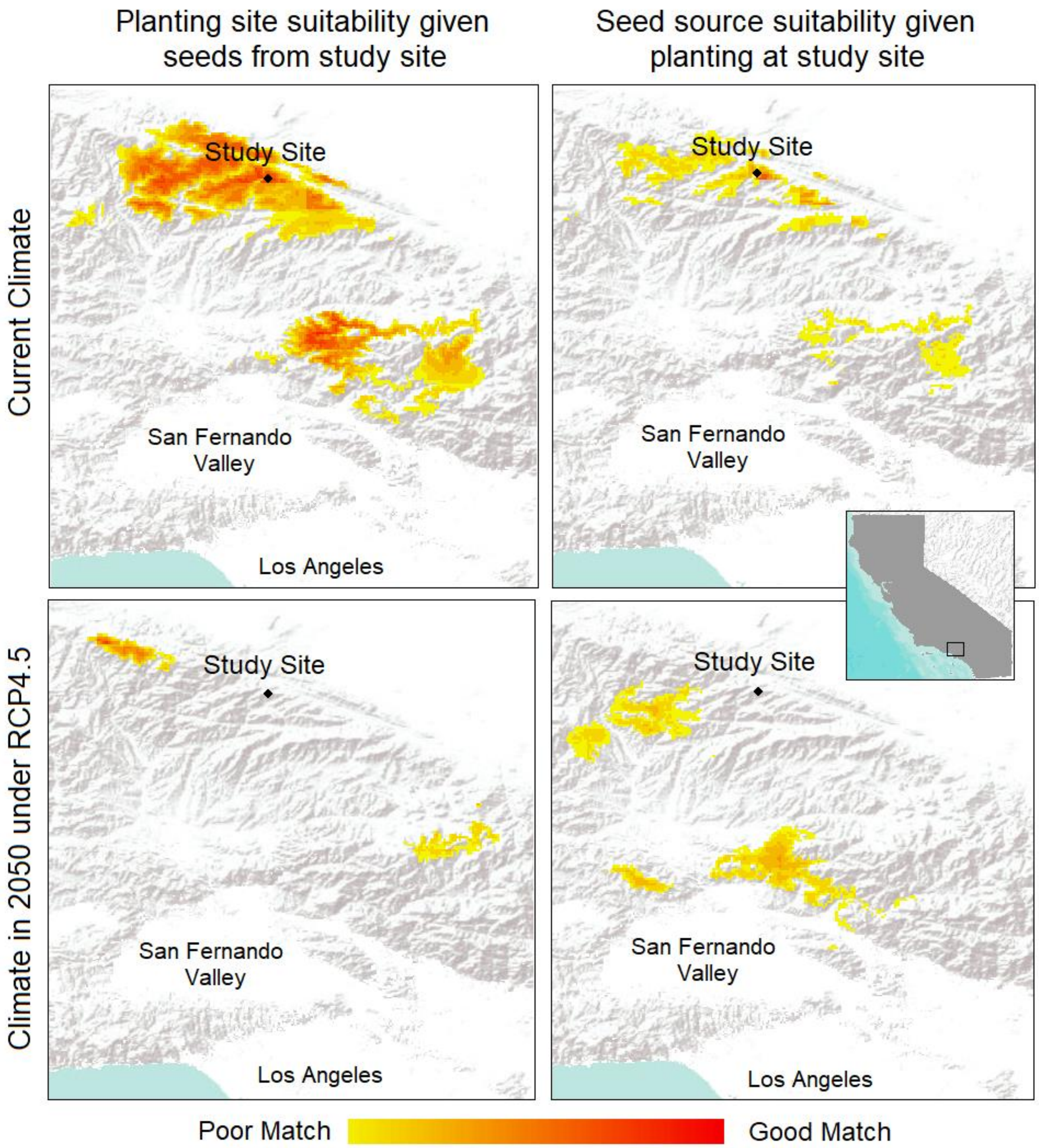

Figure 2. Species-agnostic suitability of planting sites, given that seeds come from the study site (left column), and suitability of seed source sites, given planting at the study site (right column). All seeds were assumed to be adapted to the historical climate (the 30-year window surrounding 1975). Conditions at the study site are consistent with the current climate (top row) and future climate in 2050, under the RCP4.5 emissions scenario (bottom row). The Seedlot Selection Tool (https://seedlotselectiontool.org/sst/) was used to determine seed sources given the following constraints: ± 2.75ºC in mean temperature of the coldest month, ± 2.5ºC in mean temperature of the warmest month, ± 225 mm in annual mean precipitation, ± 11 mm in summer precipitation, and ± 250 mm in climate moisture deficit.

climate-resilient restoration, a stated objective of both the FPRs and this funding opportunity. Oaks specifically are important for providing: (i) habitat for tremendous biodiversity, (ii) increased moisture availability to the surrounding ecosystem through deep roots and understory shading, (iii) ecosystem services to benefit healthy forests and rangelands throughout the State, (iv) historical vigorous recovery from disturbances (such as fire), and (v) cultural significance. While our study addresses oaks, our results are likely to benefit other species as well – including commercial species. This study will also complement existing field manipulation research, addressing the combined influences of warming and provenance in high elevation conifer systems (Keuppers et al. 2017; Conlisk et al. 2018; Conlisk et al. 2017; Reich et al. 2022). Overall, we believe that our results will be broadly relevant to forestry practitioners, restoration scientists, and ecologists in woodlands across the State.

2. Research Methods

We propose to explore the trade-offs of moving oak populations within their existing range through a comparison of different species and provenances. Specifically, the proposal team has secured funding to support the transplant of oak seedlings, *Quercus agrifolia* and *Quercus wislizeni*, within the impact area of the 2002 Copper and 2013 Powerhouse fires. We request funds to design an experiment to monitor the survival of the transplanted *Q. agrifolia* and *Q. wislizeni* seedlings. We propose to compare *Q. agrifolia* and *Q. wislizeni* transplant survival across two seed sources (provenances) and two treatments: warmed and control.

Site and Species. At 1400 meters elevation, the existing TreePeople Grass Mountain restoration site is at the leading edge of *Q. agrifolia'*s range, with approximately 90% of recorded occurrences located below 1400 meters. Thus, transplanting *Q. agrifolia* at the site represents a forward-thinking, climate-adaptive approach to restoration. We will also plant *Q. wislizeni* at the site, a common species in the middle of its elevation range, as 60% of recorded occurrences are at lower elevation. Habitat suitability predictions for these two species, now and in the future, can be seen in Figure 1.

Provenances. For both species, we will collect seeds from two different provenances – local sites and sites where the historical climate at the seed source matches the expected future climate of the Grass Mountain restoration site. To determine the best sites for collecting acorns (example in Figure 2), we will use the following Seedlot Selection Tool created through a partnership among the Conservation Biology Institute, Oregon State University, and the US Forest Service: http://seedlotselectiontool.org/sst/.

In fall of this year (2023), we will collect climate-adapted acorns from the sites identified with the Seedlot Selection Tool, as well as local acorns within 1 km of our study site. The number of trees and acorns for collection will depend on acorn production, where we expect to collect an average of 20 acorns from each of at least 10 trees. Acorns will be collected directly from the tree whenever possible, sorted for signs of non-viability, and weighed to determine seed provisioning, where increased acorn weight significantly increases first-year survival (McLaughlin et al. 2022).

Propagation and Transplant. From fall 2023 to planting in fall 2024, we will propagate oak seedlings in the TreePeople in-house Phytophthora-sanitary native plant nursery. Acorns will first be treated with a 10% bleach solution to remove potential pathogens, then will go through a period of four to six weeks of cold stratification at about 3-4° Celsius. Once acorns show radicle growth, they will be sowed about two centimeters deep in a conservation soil mix consisting of peat moss, perlite, pumice, cement sand, and Superblend (slow-release fertilizer) in "Zipset" plant bands (biodegradable paperboard containers). The containers will be installed in partial shade and the moisture level will be controlled to ensure the ideal conditions for growth. Once the first leaves open, the seedlings will receive full sun and watering cycles will be adapted to the seedlings' needs, based on moisture and temperature conditions.

In the fall of 2024, after the first significant episode of rainfall, seedlings will be transplanted into treatment plots, maximizing distance between the four individuals in each plot. Holes twice as wide as the seedling's container will be prepared and watered, prior to the installation. Each seedling will receive underground protection through a wire mesh – gopher guard – to deter underground mammal predation of the roots. After backfilling and light compacting of the soil, a water retention basin will be built around each seedling to facilitate water accumulation during rainfall and prevent runoff during supplemental watering and maintenance workdays. Mulch will be added around the seedlings to protect the soil from extreme temperatures, limit evaporation and prevent growth of competing invasive plants.

Maintenance. Once a month during the dry season of the first two years, all seedlings - in warming chambers and in control plots - will receive 3 gallons of water to assist with root establishment. During these maintenance days, competing invasive vegetation will be removed to further support the seedlings and limit groundwater depletion. The supplemental watering will be tapered off during the third year, when seedlings should have secured access to enough reliable moisture and be able to withstand the dry and warm season on their own.

Warming. In warming treatments, we will deploy passive warming chambers described in Welshofer et al. 2018 (Figure 3), which warm plots by approximately 1.8 degrees Celsius, and are tall enough to support seedling growth for the first few years. To ensure the effectiveness of the chambers, we will install soil temperature monitors to track conditions in warmed and control plots. Control plots will employ a similar dome structure, but replace polycarbonate siding with large herbivore-excluding fencing.

Protection from Herbivory. All transplanted oaks will be installed with above- and below-ground cages to prevent herbivory from small mammals. Belowground, we will use gopher cages, and above ground, we will construct 0.5 meter closed-top cages. Cage tops will be removed after the first year or when seedlings outgrow them, whichever comes first. Warming and control chambers will exclude large mammals. Herbivory is a non-trivial concern for oak seedlings, so we will conduct a pilot experiment to ensure that herbivory exclosures are sufficient (discussed further in the *Scientific Uncertainty* section below).

Experimental Design. We will arrange each of the four possible seedling types (a cross between two species and two provenances) into warming and control plot-pairs (Figure 3). Each plot in a pair will be surrounded by either the warming chamber or a similarly designed control fencing structure. We will implement a total of 160 transplants and 20 plot-pairs, where each plot-pair includes one oak for each of the eight possible combinations: two species, two provenances, and warmed or control treatments.

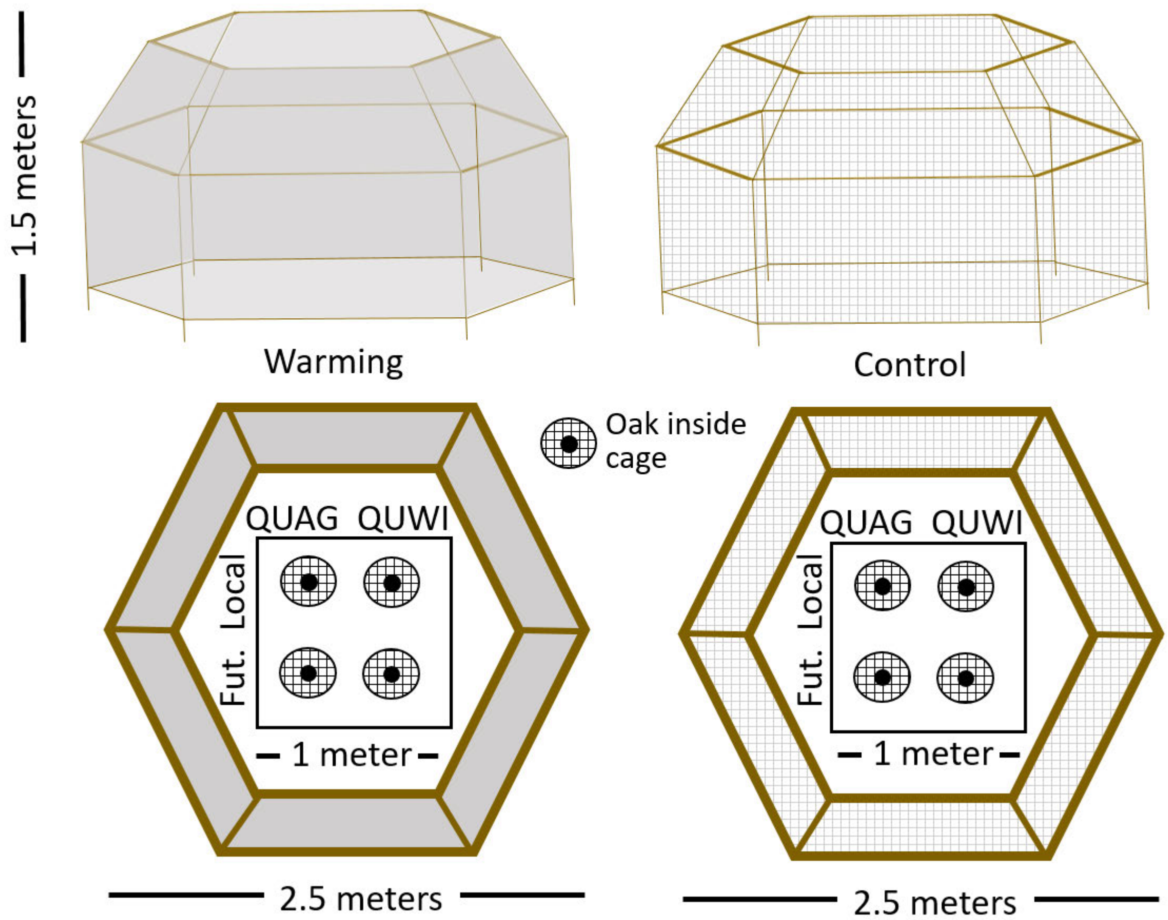

Figure 3. Schematic of a plot-pair, where the warming and control plots will be placed adjacent (within 5 meters) of one another. "QUAG" refers to *Quercus agrifolia* and "QUWI" to *Q. wislizeni*. "Local" refers to the local seed provenance and "Fut." refers to the seed provenance chosen to match the future climate at the site in 2050. The top row shows the warming chamber (left), and fenced control (right), from the perspective of an individual in the field. The bottom row shows a top-down view of the chambers. Each individual tree will be caged above and below ground to prevent herbivory by small mammals. In addition, warming chambers and control fencing will prevent herbivory by large mammals. Control fencing will be designed similarly to the warming chambers, but with fencing material instead of polycarbonate siding. Each pair will be duplicated 20 times, for a total of 160 oak seedlings. Open-top chambers are modeled after Welshofer et al. (2018).

Monitoring. Seedlings will be surveyed quarterly for the first year, and twice a year after that, with the final measurements taken in time for a final report due March 31, 2026. Consistent with measurements taken in McLaughlin et al. (2022), seedlings will be monitored for survival (presence of a rooted, living stem), stem height, and total leaf number. We will also visually inspect leaves for signs of disease and herbivory, and record the number of leaves on which disease or herbivory was observed. We assume that observed leaf herbivory will be due to insects and not small mammals, given our small mammal exclusion cages.

3. Geographic Applicability and Scientific Uncertainty

Geographic Applicability. The proposed experimental site at Grass Mountain (34.641 N, 118.414 W) is within the footprint of suitable habitat for *Q. agrifolia* and *Q. wislizeni*, based on species distribution model projections we created (Figure 1). This site occurs on the northeastern slopes of the Angeles Forest (Figures 1 and 2) within Los Angeles County, and less than 15 kilometers due south of the Antelope Valley California Poppy Reserve. The site is on Angeles National Forest (ANF) land, and is part of an existing restoration partnership between TreePeople and the US Forest Service (USFS). The site was affected by the 2002 Copper and 2013 Powerhouse fires. Given that the land is public, we will make every effort to place warming chambers away from public access, at sites not likely to be seen or visited by the public. Additionally, we will post signs to explain the purpose of the experiment.

Having been impacted by recent fire, our study site also allows for an exploration of the combined effects of wildfire and climate change. As such, the proposed project will benefit potential conservation and restoration efforts across oak woodlands in California, whereby we discuss the benefits of oak woodlands in the *Background and Justification* section of this proposal. Demonstrating the efficacy of adaptive field gene banking in the presence of warming would provide further evidence (adding to McLaughlin et al. 2022) of the appropriateness of this technique, for climate-resilient restoration of recalcitrant-seeded species (*e.g.* oaks, walnuts, buckeyes, and bay nuts).

However, the full benefit of the proposed work goes beyond oak woodlands, as part of maintaining overall ecosystem and forest health in California and the Western United States. The recognition of the importance of oaks can be seen in Theme 11 of the Effectiveness Monitoring Committee's Research Questions. Theme 11 is designed to promote research and monitoring to advance the preservation and vigor of hardwood stands. Specifically, the FPRs recognize the value of hardwood cover, in providing significant biological benefits in cumulative impacts assessments. Thus, FPRs have unique specifications for conserving and restoring hardwood stands (14 CCR § 913.4 [933.4, 953.4] I, (f); § 1038 (l)). Additionally, the FPRs identify hardwoods as an important component of riparian vegetation, overall forest health, and timber production, as well as wildlife habitat (14 CCR § 959.15).

Expectations and Scientific Uncertainties. We have no a priori expectations on whether *Q. agrifolia* or *Q. wislizeni* will have higher survival in control plots. While the site is located more solidly in *Q. wislizeni*'s elevation range, recent warming could have already shifted the site's climatic conditions away from *Q. wislizeni*'s recruitment niche. Similarly, we have no a priori expectations about which seed provenance will have higher survival under control conditions. Under warming, we expect that *Q. agrifolia* and the arid seed provenance to have higher survival.

While we expect that these results will be broadly relevant to oak ecosystems throughout California, we recognize that climate change presents a variety of uncertainties. Importantly, we are manipulating only warming in this experiment and all plots (control and warming) will receive supplemental watering. However, we know that one of the main risks with increased warming is increased drying. Thus, we are probably underestimating the impacts of drying on seedlings. Further, if our warming manipulations coincide with wet years in 2024-2026, we will likely get very different results than if our experiment coincides with drought during 2024-2026. There is also the possibility of unexpectedly extreme weather conditions that lead to very low (or very high) survival across all species, treatments, and provenances. Regardless, whatever weather conditions transpire in 2024-2026, they are likely to be only a small subset of the weather conditions that will occur in the climate of 2050. Thus, our results cannot inform the projected multi-year influences of climate change on the long lifetimes of mature oaks.

Another uncertainty, which we hope to mitigate by collecting acorns from multiple individuals, as well as measuring acorn weight, is the influence of seed provisioning on seedling survival. Mature oaks are already experiencing aridity-stress, due to the climate change that has already occurred; thus, they may be producing acorns with decreased and/or variable viability. If we unknowingly collect acorns from particularly stressed individuals, it will bias provenance comparisons. Further, as masting species, we know that variable acorn production can make the availability of high-quality seeds challenging.

Finally, we propose to propagate seedlings for transplant into the field, as opposed to sowing seeds, consistent with observed higher survival of transplanted versus sown blue oaks (McCreary et al. 1996). We will transplant seedlings between six to eight months in age, where McCreary et al. (1996) had 99% and 90% survival in four- and 12-month seedlings. By propagating seedlings, we are helping individual oaks through germination, a very vulnerable period in their life cycle. Thus, our results may underestimate the influences of climate change on oak recruitment. We made the decision to transplant seedlings based on standard practice in the majority of oak restoration efforts in our region. Thus, if we seek to inform restoration and FPRs, we must adopt the methods typically performed by practitioners.

Logistical Uncertainties. There are a number of logistical uncertainties in our proposed research, which we hope to address through the implementation of a pilot. In spring 2024, we will implement one plot-pair, deploying a single warming chamber and a fenced control. We will transplant eight oaks (all from local provenances) being propagated now into the field. We will measure soil temperature over the course of the year, to observe the functionality of the warming chamber. Finally, we will set up two camera traps to record potential herbivory or unexpected human intervention at our public study site. Based on how this set-up performs in the pilot, we will make necessary modifications to the warming chambers, herbivory exclosures, and monitoring equipment.

Adaptive Management Context. The Environmental Monitoring Committee's Strategic Plan (section 3.1) highlights the importance of adaptive management in all conservation and restoration activities. By conducting a pilot in the first year of seed collection, our project allows us to adapt to logistical issues that might arise over the course of the experiment. Namely, after defining our objectives, designing our experiment, implementing restoration activities, and monitoring survival in the pilot study, we will have collected information to evaluate our project's alignment with stated objectives. Informed by new information, we can adjust the experimental design between pilot and full project.

The resulting full experiment allows for an examination of adaptive management in climate-resilient restoration practices through a species and seed source comparison, within control and warmed conditions. Consistent with the mission of the EMC, monitoring is at the center of our proposed climate manipulation experiment. Understanding the efficacy of climate-resilient practices is essential before wide-scale implementation. Overall, our experiment will provide guidelines on how to effectively restore oaks and other forest species under climate change and in the presence of altered disturbance.

4. Critical Questions and Forest Practice Regulations Addressed:
This proposal addresses the State Board of Forestry and Fire Protection's Effectiveness Monitoring Committee (EMC) Research Theme 12: Resilience to Disturbance in a Changing Climate; with a secondary focus on Theme 11: Hardwood Values. Both themes address FPR efficacy, where FPRs and associated regulations are intended to advance sustainable forest management and increase resilience to stress factors such as fire, pests, drought, and disease.

Theme	FPRs Addressed	Questions Addressed
Theme 12: Resilience to Disturbance in a Changing Climate	No FPRs were explicitly listed in the EMC Research Theme document, but we identified: ● Z'Berg-Nejedly Forest Practice Act Provision 4512.5 ● Z'Berg-Nejedly Forest Practice Act Provision 4629.7(c) ● FPR PRC § 4528(b)	Are FPRs effective in: a. Improving overall forest wildfire resilience and the ability of forests to respond to climate change c. Meeting ecological objectives and adaptation to future climate d. Maintaining …wildlife habitats which are well adapted to future climate
Theme 11: Hardwood Values	FPRs listed: ● 14 CCR § 897 (b)(1) ● 14 CCR § 959.15	Are FPRs effective in retaining: a. Diverse forests with a mixture of tree species that includes hardwoods b. Native oaks where required to maintain wildfire habitat

In seeking to define guidelines to operationalize climate resilient forest management, Theme 12 has both broad and specific implications to Forest Practice Regulations. Broadly, the Z'Berg-Nejedly Forest Practice Act Provision 4512.5 states "*there is increasing evidence that climate change has and will continue to stress forest ecosystems, which underscores the importance of proactively managing forests*." Further, Provision 4629.7(c) states that grants should, "*promote climate change adaptation strategies for the forest.*" This statement has implications to any number of forest conservation and restoration activities. Research such as ours - which defines broader guidelines of what species should be restored, what seeds sources should be used, and where activities should occur - is urgently needed to provide evidence to support climate-resilient modifications to existing forest practice techniques. By addressing research gaps in how to match species and ecotypes to future climate, our proposal will advance efforts to operationalize more efficient and effective climate resilient restoration. Further, the EMC explicitly focuses on monitoring research, where monitoring is relatively underfunded and urgently needed to effectively make modifications to climate-resilient practices. Our proposal addresses post-restoration monitoring of two common, critically important oak species.

Beyond the general advice of Z'Berg-Nejedly Forest Practice Act Provision 4512.5 discussed above, FPR PRC § 4528(b) states that conservation and restoration activities must include species that are, "*well-suited for the area involved*." Determining suitability under climate change is challenging. Typically, "well-suited" species are those that have historically occurred at the site. However, these species may not be well-suited to future climatic conditions. Thus, guidelines are needed to determine which species provide the appropriate balance of suitability to the current and future climate. This is especially the case for long-lived species, which will have to survive the climatic transition from the current to the future climate. Looking at the vulnerable first few years of recruitment, our proposed work will help answer the critical restoration question: Is it better to plant a species that is currently in the middle of its elevation range or a species at the leading edge of its range?

Our objectives also propose to examine PRC § 4528(b), which recommends using "*a local seed source*." With a changing climate, more evidence is needed to determine how to modify this rule to allow for the introduction of genetic diversity (namely xeric-adapted individuals), which may benefit populations under a future climate. Our objective is to quantify the potential benefits of adaptive field gene-banking, through a comparison between two seed sources – a local source and a source from which the current climate is consistent with projected warming at the restoration site. Further, we will test both species and provenance suitability, under control and warming conditions in the field. Our results will contribute important justification for making exceptions to the "*local is best*" recommendations, embraced in the FPRs and beyond.

Beyond Theme 12, our research is also applicable to Theme 11, which focuses on the preservation and restoration practices associated with hardwoods. In the *Background and Justification* of this proposal, we establish the importance of oak species in a biodiverse habitat. Our proposal would provide research to inform post-fire restoration practices that promote "*native oaks where required to maintain wildfire habitat,*" and "*diverse forests with a mixture of tree species that includes hardwoods*."

Beyond the broad mandate of 14 CCR § 897 (b)(1) to "*maintain a mixture of trees*," section (D) of 14 CCR § 897 (b)(1) also states that forest management should "*maintain growing stock, genetic diversity, and soil productivity*." Our proposal is explicitly designed to explore the benefits of potential genetic diversity, through a seed source manipulation under control and warmed conditions. Reproductive adult oaks are the only way to maintain a stock of genetic diversity, as oaks have recalcitrant seeds that cannot be stored more than 4-6 months (McCreary, 1996). Additionally, 14 CCR § 959.15 states that oaks should be protected in order to provide wildlife habitat. This proposal seeks to determine how best to restore oak populations under post-fire and climate change conditions, thus ensuring the existence of high-quality wildlife habitat in the future.

5. Roles, Collaborations, and Project Feasibility

Roles and Collaborations. TreePeople will lead this project, given extensive experience in conducting applied restoration projects across Southern California, as well as an existing partnership with the Angeles National Forest (ANF). With 40+ years of wildland reforestation efforts, TreePeople is currently conducting work over more than a thousand acres of wildlands, implementing post-fire reforestation, habitat restoration, fuel management, and research studies involving multiple partners. Through this extensive regional field work, TreePeople has gained deep expertise in native tree and plant species, planting conditions for resilient habitat restoration (across different elevations, slopes, exposures, and soil types), and establishment methods to ensure project survival and sustainability. Finally, TreePeople operates an in-house, certified Phytophthora-sanitary propagation nursery, as required by the USFS to propagate seedlings.

Project partner Conservation Biology Institute (CBI), and co-PI Conlisk, will frame the ecological and restoration questions, design the experiment, help implement the experimental set-up in the field, and analyze data for dissemination to practitioner and scientific audiences. With over a quarter-century of experience in a range of integrated technological services to support ecological sustainability, scientific modeling, and conversion of research findings into data-driven, real-world solutions, CBI will add critical scientific research expertise to this project. Specifically, co-PI Conlisk has worked within California ecosystems for over two decades, and has conducted climate manipulation, common garden experiments across seed provenances in high elevation systems. Further, she has a track-record of high impact peer-reviewed publications that explore the impacts of global change on plant communities. She will attend one local conference and prepare a draft manuscript for publication by the end of the project duration. Assisting co-PI Conlisk, Gladwin Joseph, has a Ph.D. in forest science, with a focus on woody plant ecophysiology, having worked extensively in forest health and restoration in both temperate (Oregon) and semi-arid tropical systems in India.

An expert in California oak field research, collaborator McLaughlin will provide specific advice on conducting field experiments with oak species. She specializes in the impacts of global change on California oaks and blue oaks (*Quercus douglasii*) in particular. Dr McLaughlin has pioneered research on assisted field gene banking to benefit oak conservation. Further, with extensive greenhouse experiments underway, she will provide a broader scientific context for the importance of the proposed work, and help identify synergies between this project and the work of the broader oak research community.

Feasibility. The expertise of the assembled team, combined with thoughtful experimental implementation that includes a pilot study, suggests high project feasibility. Further, as part of current restoration work, TreePeople has readily available match funding, as well as all necessary field preparations to begin project implementation. Namely, TreePeople and the USFS maintain an active Master Challenge Cost Share Agreement, as well as numerous specific project agreements, for ongoing restoration work throughout ANF. All permitting for this project has been completed, and activities are projected to begin immediately upon notification.

6. Project Deliverables and Timeline

Below we provide a timeline for the project deliverables. Specifically we will produce:

- Guidelines for methods to collect seeds from climate resilient seed sources
- An analysis of the efficacy of warming chambers
- Analyses of post-transplant, first-year, and second year survival
- An interim and final project report of post-transplant survival
- Attendance at one conference to disseminate results more broadly
- A draft manuscript for publication

Beyond these product deliverables, there are a number of "soft" deliverables in this project, including increased communication among land managers, scientists, and the general public on these forest practice methods. Conducted on public lands, the results of this project and its research also have the opportunity to reach the public, promoting the importance and urgency of climate-resilient restoration efforts in the region.

Timeline for Project Deliverables

			Year 1: 2023		Year 2: 2024				Year 3: 2025				Year 4: 2026
	Act.	Del.	AS	OND	JFM	AMJ	JAS	OND	JFM	AMJ	JAS	OND	JFM
Determine Seed Collection Sites		x											
Collect Climate-Resilient Seeds for Greenhouse Cultivation	x												
Build Passive Warming Chambers	x												
Deploy Pilot Pair of Plots	x												
Analyze Pilot		x											
Cultivate Oaks for Future Transplant*	x												
Transplant Oaks in Field	x												
Deploy Passive Warming Chambers	x												
Deploy Temperature and Moisture Sensors	x												
Analyze Efficacy of Warming Chambers		x											
Collect Quarterly Survival and Growth	x												
Analyze Quarterly Survival and Growth		x											
Project Update to Collaborators/Funders		x											
Conference Presentation		x											
Final Update to Collaborators/Funders		x											
Draft of Peer-reviewed publication		x											

Letter codes are as follows: "JFM" for "January, February, March", "AMJ" for "April, May, June", "JAS" for "July, August, September", and "OND" for "October, November, December."

* The activity timeline is based on the timing of the step before. For example, all seeds will be sown at the same time, once the seed collection has finished. Cultivation will begin dependent on seed availability (winter 2023) and will end after 6-8 months propagation and after the first large rains at the site (fall 2024).

7. Requested Funding Line Item Budget:

Over the project duration, we request $116,835 for experimental set-up and field labor; $16,290 in supplies, $56,450 for subcontracts with Conservation Biology Institute (CBI), UC Santa Cruz, and carpentry labor to cut and assemble fencing and warming chambers, and $19,968.75 in indirect (15% of non-contractor total costs) for a total of $220,226. Please see the following budget table which summarizes the labor, supply, and subcontractor costs associated with this project.

Category	**Description**	**Year 1**	**Year 2**	**Year 3**	**Total**
Personnel	Greenhouse and field labor for collecting acorns, growing oak seedlings, transplanting oak seedlings into the field, and assembling cages and warming chambers[1]	$17,308	$47,110	$29,050	$93,468
Fringe	Benefits on all staff above at 25%	$4,327	$11,777.50	$7,626.50	$23,367
Labor Subtotal		*$21,635*	*$58,887.50*	*$36,312.50*	*$116,835*
Other Supplies Subtotal	Warming chambers[1] , restoration supplies, gopher guards, temperature/ humidity trackers, camera traps, etc. to ensure operational consistency and efficiency	*$1,500*	*$14,350*	*$440*	*$16,290*
Indirect Subtotal	15% of all non-subcontractor budget items	*$3,470*	*$10,985.63*	*$5,512.88*	*$19,968.75*
Subcontract Subtotal	Conservation Biology Institute and Collaborators[2]	*$24,150*	*$11,870*	*$20,430*	*$56,450*
Travel Subtotal	Pickup truck at 23-24 CalTrans vehicle rate	*$2,967.30*	*$4154.22*	*$3560.76*	*$10,682.28*
Total Cost		**$53,722.55**	**$100,247.35**	**$66,256.14**	**$220,226.03**
Match	CAL FIRE Forest Health Grant (Copper Woodland Restoration)	$38,016.48	$119,148.92	$123,177.64	$280,343.04

	Nursery & Restoration Work Volunteer Time and Labor	$17,068.80	$36,982.40	$36,982.40	$91,033.60
Match Subtotal	Leverage funding and volunteer labor	*$55,085.28*	*$156,131.32*	*$160,160.04*	*$371,376.64*
EMC funding requested**		**$53,722.55**	**$100,247.35**	**$66,256.14**	**$220,226.03**

1. For greater flexibility to the EMC in funding proposals, warming chamber supplies could be purchased in either the first or second year. If purchased in the first year, partners would begin assembly immediately, following deployment of a two-week pilot (to ensure warming chambers as designed are functioning properly). If purchased in the second year, we could observe performance in the field for a full year, before assembling chambers for deployment in the field.

2. Two carpenters have given estimates for wood-cutting of 40 hours, however, as an option we may instead retain co-PI Conlisk in this work. Assuming a professional carpenter, we will pay $200/hour for this skilled craft work. Subcontractor funding will provide co-PI Conlisk with 3, 2, and 4 weeks of funding in years 1, 2, and 3 of the project duration. Gladwin Joseph at CBI will be assisting co-PI Conlisk for 10 hours in each of the three years of the project. Collaborator McLaughlin will provide 20 hours of labor in each of the three years of the project.

** TreePeople respectfully acknowledges that this request has changed since the initial concept proposal submission. After full research on associated labor costs, field supplies, and subcontractor hours needed to complete the project, we feel that this adjustment is warranted under proposed deliverables. However, TreePeople and project partners remain open to reducing or re-negotiating this cost and associated scope, on the basis of EMC budgetary limitations for this program. (Full budget detail is provided in attachments.)

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Board of Forestry Effectiveness Monitoring Committee

Climate-adaptive Oak Restoration in ANF - Budget

Personnel		Unit Rate	Hrs Y1	Hrs Y2	Hrs Y3	**Total Y1**	**Total Y2**	**Total Y3**	**Overall Total**
Director of Mountain Forestry	Project oversight / CoPI T. Rivard	$ 43.00	80	100	80	$ 3,440.00	$ 4,300.00	$ 3,440.00	$ 11,180.00
Program Manager	Implementation lead for collection, planting, maintenance & monitoring	$ 32.50	100	400	300	$ 3,250.00	$ 13,000.00	$ 9,750.00	$ 26,000.00
Senior Coordinator	Implementation support for collection, planting, maintenance & monitoring	$ 24.50	80	400	300	$ 1,960.00	$ 9,800.00	$ 7,350.00	$ 19,110.00
Chamber builder	Chambers assembly and maintenance	$ 30.00	40	250	50	$ 1,200.00	$ 7,500.00	$ 1,500.00	$ 10,200.00
AmeriCorps crew members	Plant installation and maintenance	$ 12.00		400	200	$ -	$ 4,800.00	$ 2,400.00	$ 7,200.00
Nursery Manager	Collection & propagation	$ 32.00	80	40		$ 2,560.00	$ 1,280.00	$ -	$ 3,840.00
Nursery Coordinator	Collection & propagation	$ 26.00	64	40		$ 1,664.00	$ 1,040.00	$ -	$ 2,704.00
Grant Manager	Grant admnistration and reporting	$ 32.00	32	40	40	$ 1,024.00	$ 1,280.00	$ 1,280.00	$ 3,584.00
Marketing & Communication	Photography, documentation, communication	$ 31.00	20	30	30	$ 620.00	$ 930.00	$ 930.00	$ 2,480.00
Accounting	Expense tracking and reimbursement	$ 27.50	20	40	40	$ 550.00	$ 1,100.00	$ 1,100.00	$ 2,750.00
Administrator Asst	General administration & support	$ 26.00	40	80	50	$ 1,040.00	$ 2,080.00	$ 1,300.00	$ 4,420.00
Total Personnel						**$ 17,308.00**	**$ 47,110.00**	**$ 29,050.00**	**$ 93,468.00**
Fringe Benefits									
Benefits on all staff above at 25%					25%	$ 4,327.00	$ 11,777.50	$ 7,262.50	$ 23,367.00
Total Labor (Personnel + Fringe Benefits)						**$ 21,635.00**	**$ 58,887.50**	**$ 36,312.50**	**$ 116,835.00**
Other									
Nursery supplies for seedlings	Soil and pots	$ 1.50	200			$ 300.00	$ -	$ -	$ 300.00
Warming Chambers	Wood, polycarbonate panels & ties	$ 240.00	2	40		$ 480.00	$ 9,600.00	$ -	$ 10,080.00
Gopher guards	Underground mammal protection	$ 1.00	200			$ 160.00	$ -	$ 40.00	$ 200.00
Above ground cages	chicken wire fencing to deter herbivory	$ 70.00	6			$ 420.00	$ -	$ -	$ 420.00
Mulch matts	Evaporation and competition protection	$ 1.00		200		$ -	$ 200.00	$ -	$ 200.00
Addtnl field supplies - gloves, flags, tools, tin snips	Individual tools and supplies for field work	$ 80.00		10		$ -	$ 400.00	$ 400.00	$ 800.00
Fire hoses	Water hoses for maintenance	$ 250.00		3		$ -	$ 750.00	$ -	$ 750.00
HOBO Humidity trackers per plots	Water temperature data logger	$ 70.00	2	40		$ 140.00	$ 2,800.00	$ -	$ 2,940.00
Cameras	Underground mammal protection	$ 150.00		4		$ -	$ 600.00	$ -	$ 600.00
Total Other						**$ 1,500.00**	**$ 14,350.00**	**$ 440.00**	**$ 16,290.00**
TreePeople Indirect Costs									
15% on all costs above					15%	**$ 3,470.25**	**$ 10,985.63**	**$ 5,512.88**	**$ 19,968.75**
Travel									
Pickup truck at 23/24 CalTrans vehicle rate	7 hrs of truck use x 36 days (10 Y1, 14 Y2, 12 Y3)	$ 42.39	70	98	84	**$ 2,967.30**	**$ 4,154.22**	**$ 3,560.76**	**$ 10,682.28**

Subcontracts									
Conservation Biology Institute	Design + field visits (PI Erin Conlisk - 3 weeks)	$ 4,280.00	3			$ 12,840.00	$ -	$ -	$ 12,840.00
Conservation Biology Institute	Planting + Monitoring (PI Erin Conlisk - 2weeks)	$ 4,280.00		2		$ -	$ 8,560.00	$ -	$ 8,560.00
Conservation Biology Institute	Monitoring & analysys (PI Erin Conlisk 4 weeks)	$ 4,280.00			4	$ -	$ -	$ 17,120.00	$ 17,120.00
Conservation Biology Institute	Design & review (Joseph Gladwin) - 10hrs/year	$ 129.00	10	10	10	$ 1,290.00	$ 1,290.00	$ 1,290.00	$ 3,870.00
USC	Collaborator McLaughlin	$ 101.00	20	20	20	$ 2,020.00	$ 2,020.00	$ 2,020.00	$ 6,060.00
Carpenter for chambers	Create frame for chambers and control plots	$ 200.00	40			$ 8,000.00	$ -	$ -	$ 8,000.00
						$ 24,150.00	**$ 11,870.00**	**$ 20,430.00**	**$ 56,450.00**
Total Cost						**$ 53,722.55**	**$ 100,247.35**	**$ 66,256.14**	**$ 220,226.03**
Matching funds									
CAL FIRE Forest Health Grant (Copper Woodland Restoration)	Restoration Staff Hours					$ 38,016.48	$ 119,148.92	$ 123,177.64	$ 280,343.04
Volunteer/Intern Support	Nursery & Restoration Volunteers Hours of Work (64 events, 4hrs, 10 vol. - 12 Y1, 26 Y2, 26 Y3)	$ 35.56	480	1,040	1,040	$ 17,068.80	$ 36,982.40	$ 36,982.40	$ 91,033.60
EMC Funding Requested						**$ 53,722.55**	**$ 100,247.35**	**$ 66,256.14**	**$ 220,226.03**

Conservation Biology Institute

[redacted]
http://www.consbio.org
http://www.databasin.org

State Board of Forestry and Fire Protection
Attn: Dr. Kristina Wolf, Environmental Scientist
P.O. Box 944246
Sacramento, CA 94244-2460
June 14, 2023

Re: Effectiveness Monitoring Committee Request for Research Proposals to Test the California Forest Practice Rules – TreePeople Letter of Support

Dear Dr. Wolf:

Conservation Biology Institute, Inc. (CBI) is in full support of TreePeople's proposal to the Effectiveness Monitoring Committee's request for research to test California Forest Practice Rules. We are excited to partner with TreePeople, given their track record of restoration and reforestation initiatives. TreePeople has had a significant impact on natural spaces in Southern California, planting millions of trees since 1974 and educating and empowering stakeholders as stewards for a sustainable future. We were introduced to TreePeople through their partnerships with research groups at UC Riverside and USFS, where they have been studying ecology and restoration science through monitoring of past projects.

We are excited to work with TreePeople to design climate-resilient restoration techniques for post-fire landscape-scale reforestation in California. CBI is among only a handful of organizations conducting applied conservation research at this scale and TreePeople is similarly uniquely suited to execute large-scale restoration for monitoring research. Partnering together, our shared expertise will produce impactful work on effective restoration in the context of global change. In support of this proposal, the identified researchers (Dr. Erin Conlisk with support from Dr. Gladwin Joseph) have committed to assisting in experimental design, data collection, and data analysis.

Since 2010, TreePeople has an existing relationship with Angeles National Forest (ANF), the land owner for our proposed research site. Given TreePeople's previous work with ANF on evidence-based post-fire regeneration for vulnerable species, we believe the proposed work will advance reforestation outcomes and be of keen interest to the ANF and beyond.

With Effectiveness Monitoring Committee funding, TreePeople and CBI will expand research efforts to effectively propagate, plant, and maintain wide-scale reforestation sites, helping regenerate burn scar areas threatened by fuel overgrowth and invasive weeds. To identify climate-resilient seed sources, we will use CBI's seedlot selection tool (https://seedlotselectiontool.org/sst/). We will also leverage supplemental funding for TreePeople's in-house Phytophthora-sanitary cultivation of oak transplants.

Your support will further our partnership with TreePeople to continue investigating innovative reforestation efforts for strategic species, sites, and ecosystems. We strongly support this project and urge your serious consideration. Please feel free to contact Dr. Gladwin Joseph (email: gladwin.joseph@consbio.org or phone: 541-602-7258) if you have any questions regarding our support.

Sincerely,

Pamela A. Frost, M.S.
Vice President & Chief Operations Officer

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State Board of Forestry and Fire Protection
Attn: Dr. Kristina Wolf, Environmental Scientist
P.O. Box 944246
Sacramento, CA 94244-2460
June 14, 2023

Re: Effectiveness Monitoring Committee Request for Research Proposals to Test the California Forest Practice Rules – TreePeople Letter of Support

Dear Dr. Wolf:

I write in support of TreePeople's proposal to the Effectiveness Monitoring Committee, titled "Climate-Adaptive Post-Fire Oak Restoration through Upslope Migration and Seed Provenance in the Angeles National Forest." I am excited to partner with TreePeople and the Conservation Biology Institute (CBI) on this innovative proposal to test the influence of species and seed provenance on success of restoration plantings in the context of climate change. The project's inclusion of a manipulative warming component allows the project to inform both restoration practices today and in the future. These kinds of empirical studies are few and far between and critical to support land management in places where climate is changing.

The proposed project team brings together the strengths of TreePeople's extensive on-the-ground restoration work, CBI's well-known expertise in conservation biology, quantitative ecology and development of a species climate-adaptive seed selection tool, and, as a collaborator, my own experience with oak climate change research and oak planting experiments. This project team has the breadth of experience and expertise to ensure that the project meets the needs of practitioners with robust science.

Please feel free to contact me if you have any questions.

Sincerely,

Blair McLaughlin, Ph.D.
blair.mclaughlin@ucsc.edu
Climate Adaptation Scientist
Conservation Science and Solutions Lab

[redacted]