Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

Oak Woodlands

Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

Vulnerability Component	Score
Sensitivity	Moderate
Exposure	Moderate-high
Adaptive Capacity	Moderate
Vulnerability	**Moderate**

Overall vulnerability of oak woodlands was scored as moderate. The score is the result of moderate sensitivity, moderate-high future exposure, and moderate-high adaptive capacity scores.

Key climate factors for oak woodland habitats include precipitation amount and timing. Precipitation volume and timing influence oak distribution, species composition, acorn production, seedling germination and survival, and tree growth.

Key disturbance mechanisms for oak woodland habitats include wildfire, insects, disease, and grazing. Oaks are fairly resilient to fire. Insects and disease affect tree health and recruitment, while grazing increases oak herbivory and reduces recruitment.

Key non-climate factors include urban/suburban development, agricultural and rangeland practices, and invasive and problematic species. Urban/suburban, agricultural, and rangeland development have destroyed and fragmented oak woodland habitat, while exotic species compete with oak seedlings for soil moisture and perpetuate shifting fire regimes.

Oak woodland habitats have a patchy distribution in the Central Valley and surrounding foothills, which may impede genetic exchange and migration ability in response to climate change. Variable inter-annual acorn production, low acorn dispersal distances, low recruitment, long life spans, and a high age of reproductive maturity undermine the resilience of oak woodlands to human and climate disturbance. Oak woodlands support high biodiversity, but loss of keystone oak species could severely affect overall habitat diversity.

Management potential for oak woodland habitat was scored as high, and includes minimizing grazing impacts, protecting remnant oak patches and genetic diversity, and using restoration plantings.

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Introduction

Description of Priority Natural Resource

Oak woodland habitat types in the Central Valley include valley oak woodlands, blue oak woodlands, and blue oak-foothill pine woodlands. These types often grade into each other, with valley oak woodlands occurring at the lowest elevations, and blue oak-foothill pine woodlands occupying higher elevations in the foothills (California Department of Fish and Game 2016a, 2016b, 2016c).

As part of the Central Valley Landscape Conservation Project, workshop participants identified oak woodlands as a Priority Natural Resource for the Central Valley Landscape Conservation Project in a process that involved two steps: 1) gathering information about the habitat's management importance as indicated by its priority in existing conservation plans and lists, and 2) a workshop with stakeholders to identify the final list of Priority Natural Resources, which includes habitats, species groups, and species.

The rationale for choosing oak woodlands as a Priority Natural Resource included the following: the habitat has high management importance. Please see Appendix A: "Priority Natural Resource Selection Methodology" for more information.

Vulnerability Assessment Methodology

During a two-day workshop in October of 2015, 30 experts representing 16 Central Valley resource management organizations assessed the vulnerability of priority natural resources to changes in climate and non-climate factors, and identified the likely resulting pressures, stresses, and benefits (see Appendix B: "Glossary" for terms used in this report). The expert opinions provided by these participants are referenced throughout this document with an endnote indicating its source[1]. To the extent possible, scientific literature was sought out to support expert opinion garnered at the workshop. Literature searches were conducted for factors and resulting pressures that were rated as high or moderate-high, and all pressures, stresses, and benefits identified in the workshop are included in this report. For more information about the vulnerability assessment methodology, please see Appendix C: "Vulnerability Assessment Methods and Application." Projections of climate and non-climate change for the region were researched and are summarized in Appendix D: "Overview of Projected Future Changes in the California Central Valley".

Vulnerability Assessment Details

Climate Factors

Workshop participants scored the resource's sensitivity to climate factors and this score was used to calculate overall sensitivity. Future exposure to climate factors was scored and the overall exposure score used to calculate climate change vulnerability.

Climate Factor	Sensitivity	Future Exposure
Air temperature	Moderate	Moderate
Extreme events: drought	Moderate	Moderate-high
Increased wildfire	-	Moderate-high
Precipitation (amount)	Moderate-high	Moderate-high
Precipitation (timing)	Moderate-high	Moderate-high
Snowpack amount	-	Moderate
Soil moisture	Moderate	-
Overall Scores	**Moderate**	**Moderate-high**

Regional climate modeling by Kueppers et al. (2005) indicates that climatically suitable blue oak and valley oak habitat may contract considerably and shift northward by the end of the century (2080-2099) due to warmer temperatures and declines in growing season (April-August) precipitation, contributing to high soil moisture deficits. Under a “business-as-usual” emissions scenario, blue oak is projected to have only 59% of current range size available, and valley oak, only 54% (Kueppers et al. 2005). Thorne et al. (2016) project that 24-59% of current California foothill and valley forests and woodlands will not be climatically suitable by the end of the century, particularly along the eastern margin and northern half of the study area. The only habitat areas in the Central Valley projected to potentially become newly suitable for oak woodlands occur in the southwestern corner of the study area in coastal foothills (Thorne et al. 2016). Additionally, Serra-Diaz et al. (2014) project that blue oak and valley oak are likely to experience climate exposure at a rate of 0.28 and 0.29 km per year, respectively, by mid-century (2041-2070); by late century (2071-2100), blue oak exposure accelerates slightly to 0.3 km per year, while valley oak exposure slows minimally to 0.28 km per year. For blue oak, habitat suitability gains at the leading distribution edge occur slightly faster than habitat suitability losses at trailing edges of its distribution, while for valley oak, rates of change are fairly equal at both the leading and trailing edges of current species distribution (Serra-Diaz et al. 2014).

Bioclimate species distribution modeling for valley oak and blue oak indicates that young tree sensitivity may further limit habitat climate suitability and dispersal patterns (McLaughlin & Zavaleta 2012; McLaughlin et al. 2014). Under a warmer and drier future, McLaughlin & Zavaleta (2012) project that valley oak saplings will cluster around available water bodies (i.e., drought refugia) rather than exhibit uniform northerly and upward dispersal. Similarly, in habitat areas projected to contract under warmer and drier conditions, blue oak recruits are projected to utilize moisture microrefugia, including areas near available surface and groundwater and topographical refugia such as north-facing slopes and riparian corridors (McLaughlin et al. 2014). Comparatively, in newly suitable oak habitat areas (e.g., northerly locations), blue oak recruit distribution is not projected to be as limited by moisture availability (McLaughlin et al. 2014).

Precipitation (amount)

> ***Sensitivity:*** *Moderate-high (high confidence)*
> ***Future exposure:*** *Moderate-high (moderate confidence)*

Although precipitation models for California are highly uncertain, some projections suggest that annual precipitation will remain quite variable over the next century, and may increase slightly in the Sacramento River Basin and decrease slightly in the San Joaquin River Basin by 2050 (Bureau of Reclamation 2015), and precipitation extremes may increase (Toreti et al. 2013).

Oak woodlands in the Central Valley region generally receive 51-102 cm (20-40 in) of annual precipitation (California Department of Fish and Game 2016a, 2016b, 2016c). Precipitation volume and soil moisture influence oak woodland type, species composition, and landscape distribution (Swiecki & Bernhardt 1998; Jimerson & Carothers 2002; California Department of Fish and Game 2016a, 2016b, 2016c). For example, valley oaks often require access to permanent groundwater or occur along riparian areas, while blue oak woodlands and blue oak-foothill pine woodlands can persist on drier sites (California Department of Fish and Game 2016a, 2016b, 2016c), although they are more abundant on mesic microsites within these harsher areas (Swiecki & Bernhardt 1998).

Low annual precipitation may impede acorn production, seedling emergence and persistence, oak establishment (Tyler et al. 2006 and citations therein), and oak growth and distribution (Swiecki & Bernhardt 2006). For example, low rainfall years often trigger early defoliation and leaf browning in blue oaks, and consecutive low rainfall years can contribute to blue oak decline and reduced regeneration (Swiecki & Bernhardt 2006).

Precipitation (timing)

> ***Sensitivity:*** *Moderate-high (high confidence)*
> ***Future exposure:*** *Moderate-high (moderate confidence)*

The timing of early season rainfall can impact acorn germination, particularly for acorns that have not been cached (Tyler et al. 2006). Although oaks are adapted to seasonal summer drought, declines in growing season precipitation (April-August) could contribute to reduced climatic suitability for oak species in the Central Valley region. Alternatively, increases in growing season precipitation could expand oak habitat suitability (Kueppers et al. 2005).

Drought

Sensitivity: *Moderate (moderate confidence)*
Future exposure: *Moderate-high (high confidence)*

The frequency and severity of drought is expected to increase over the next century due to climate change (Hayhoe et al. 2004; Cook et al. 2015; Diffenbaugh et al. 2015; Williams et al. 2015), as warming temperatures exacerbate dry conditions in years with low precipitation, causing more severe droughts than have previously been observed (Cook et al. 2015; Diffenbaugh et al. 2015). Recent studies have found that anthropogenic warming has substantially increased the overall likelihood of extreme California droughts, including decadal and multi-decadal events (Cook et al. 2015; Diffenbaugh et al. 2015; Williams et al. 2015). Enhanced, hotter drought conditions are likely to stress trees, making them more vulnerable to mega-disturbances involving wildfire, insects, disease, and invasive species (Millar & Stephenson 2015).

Air temperature

Workshop participants did not further discuss this and the following climate factors beyond assigning a sensitivity and/or exposure score.

Sensitivity: *Moderate (moderate confidence)*
Future exposure: *Moderate (moderate confidence)*

Soil moisture

Sensitivity: *Moderate (moderate confidence)*

Regardless of changes in precipitation, warmer temperatures are expected to increase evapotranspiration and cause drier conditions (Cook et al. 2015). For example, Thorne et al. (2015) project that climatic water deficit is expected to increase by 131 mm in the Central Valley (compared to 140 mm statewide) by 2070-2099 under a drier scenario and 44 mm (compared to 61 mm statewide) under a wetter scenario, although some areas in the northern Central Valley may experience less stressful conditions because deep soils will allow storage of excess precipitation.

Snowpack amount

Future exposure: *Moderate (low confidence)*

Potential refugia: *Upper elevations and moister areas (e.g., north-facing slopes).*

Climatic changes that may benefit the habitat:

- Warmer air temperature can open up colder areas to oak expansion.

Non-Climate Factors

Workshop participants scored the resource's sensitivity and current exposure to non-climate factors, and these scores were then used to assess their impact on climate change sensitivity.

Overall impact of non-climate factors: Moderate-high (high confidence).

Non-Climate Factor	Sensitivity	Current Exposure
Agriculture & rangeland practices	High	High
Dams, levees, & water diversions	Low-moderate	Low
Groundwater overdraft	Moderate	Moderate
Invasive & other problematic species	High	High
Nutrient loading	Moderate	Low
Pollution & poisons	Moderate	Moderate
Urban/suburban development	High	High
Overall Scores	**Moderate-high**	**Moderate**

Urban/suburban development

Sensitivity: *High (high confidence)*
Current exposure: *High (high confidence)*
Pattern of exposure: *Localized to areas of urban expansion - Sacramento suburbs and Placer and El Dorado Counties. Fresno, Tulare and Kern Counties are affected to a lesser degree because the slope of mountains somewhat excludes development. Approximately 10% of Tejon Ranch is zoned for development, which could occur on the Los Angeles side rather than the Central Valley side. The west side of the valley is not developed as much due to low water availability (i.e., for people to dig wells).*

Development has contributed to historical oak woodland habitat loss and fragmentation in the Central Valley, particularly amongst valley oak woodlands (Bolsinger 1988). Continued development pressure in the foothills surrounding the Central Valley threatens oak woodland persistence and habitat continuity, which can undermine habitat quality and availability for wildlife (Spero 2002; Grivet et al. 2008).

Invasive & other problematic species

Sensitivity: *High (high confidence)*
Current exposure: *High (high confidence)*
Pattern of exposure: *Widespread; blue oaks in non-native annual grassland may be most vulnerable to invasive species-mediated shifts in fire regimes.*

Invasive annual grasses and forbs increase moisture competition with native understory species and oak seedlings (Jimerson & Carothers 2002; Tyler et al. 2006), inhibiting acorn germination, reducing seedling emergence, growth, and survival (Gordon & Rice 1993), and reducing oak woodland biodiversity (Jimerson & Carothers 2002). Invasive annuals also perpetuate more frequent fire regimes (Jimerson & Carothers 2002). Common invaders include cheatgrass (*Bromus tectorum*), medusahead (*Taeniatherum caput-medusae*), and yellow starthistle (*Centaurea solstitialis*). A common introduction pathway is cattle-mediated dispersal from adjacent annual grasslands. In the future, invasive pressure may increase in areas with lower oak canopy cover, which allows shade-intolerant invasives to thrive (Jimerson & Carothers 2002).

Agricultural & rangeland practices

> ***Sensitivity:*** *High (high confidence)*
> ***Current exposure:*** *High (high confidence)*
> ***Pattern of exposure:*** *Widespread among areas with cattle ranching because, until the 1970s, there was active state policy to cut down oaks for rangeland improvements. Many oak stands have already been lost to agricultural conversion (the loss of lowland woodlands is thought to be almost complete) and rangeland practices continue to be an issue. Conversion to vineyard or orchard is a threat for upland oak woodlands in the northern and central regions of the study area.*

A large portion of historical Central Valley oak woodland habitat was lost to agricultural and rangeland conversion from 1850 through the mid-20th century (Bolsinger 1988; Swiecki & Bernhardt 1998). For example, it is believed that almost 98% of historical valley oak woodland habitat has been lost in the San Joaquin Valley, with cascading impacts on biodiversity and wildlife (Kelly et al. 2005). Continued agricultural conversion of oak woodlands is possible, particularly conversion for vineyards in foothill areas (Grivet et al. 2008).

Pollution & poisons

> ***Sensitivity:*** *Moderate (high confidence)*
> ***Current exposure:*** *Moderate (moderate confidence)*
> ***Pattern of exposure:*** *Widespread; ozone and pesticide/herbicide pollution issues are tied to urbanization.*

Aerosol deposition may affect photosynthetic activity. Ozone exposure slows stomatal responses (Paoletti & Grulke 2010) and may increase foliar water loss (Grulke et al. 2007). Ozone can also damage leaf structure, cause cell death, and reduce plant carbohydrate production[1].

Pesticide or herbicide impacts on oak woodlands are unknown, but no evidence of special sensitivity has been observed in the field. Oak communities are not as impacted by pesticides as other habitats such as wetlands, since pesticide application is lower[1].

Groundwater overdraft

> ***Sensitivity:*** *Moderate (low confidence)*

Current exposure: *Moderate (high confidence)*
Pattern of exposure: *Localized due to complex hydrogeology of valley and foothills; well documented in the Consumes Preserve. Groundwater development related to urban development is an issue for blue oaks. Agricultural overdraft occurs in areas where blue oaks are not found.*

Nutrient loading

Sensitivity: *Moderate (high confidence)*
Current exposure: *Low (moderate confidence)*
Pattern of exposure: *Localized; similar to pollution exposure.*

Nitrogen loading could be problematic for oak woodlands (e.g., by increasing vulnerability to insect damage; Bernhardt & Swiecki 2001).

Dams, levees, & water diversions

Sensitivity: *Low-moderate (moderate confidence)*
Current exposure: *Low (high confidence)*
Pattern of exposure: *Localized; Sites Dam and other large dams.*

Oak woodland habitat is typically upslope of where water diversions are occurring. Large dams, like the proposed Sites Dam, could flood out upland oak woodlands and have a limited impact[1].

Disturbance Regimes

Workshop participants scored the resource's sensitivity to disturbance regimes, and these scores were used to calculate climate change sensitivity.

Overall sensitivity to disturbance regimes: *Moderate (moderate confidence).*

Wildfire

Future exposure: *Moderate-high (high confidence)*

Large fire occurrence and total area burned in California are projected to continue increasing over the next century with total area burned projected to increase by up to 74% by 2085 (Westerling et al. 2011).

Mature oaks are fairly resilient to fire. Oak seedlings and saplings occasionally experience complete mortality during fire, but more frequently experience topkill followed by resprouting (Swiecki & Bernhardt 1998; Holmes et al. 2008). Fire severity, frequency, seasonality and species burned all likely influence oak woodland response, but a synthesis of all California studies found no significant trends, and at times conflicting results, in these factors (Holmes et al. 2008). For example, more frequent fire may inhibit oak regeneration and increase mortality (Swiecki & Bernhardt 1998), but may also promote lower fire severity by maintaining lower fuel loads (Holmes et al. 2008). In general, smaller trees, higher fuel loads, and hotter fires undermine oak woodland resilience to fire (Holmes et al. 2008).

Disease

Oak species in the Central Valley are vulnerable to several fungi and pathogens, which can lead to a variety of impacts including, but not limited to, leaf spotting, blisters, and lesions, twig dieback, root and trunk decay, or branch or trunk failure (Swiecki & Bernhardt 2006).

Oak woodlands in the Central Valley are less vulnerable to sudden oak death, caused by the pathogen *Phytophthora ramorum*, than coastal areas of the state due to a lack of pathogen host plants (Meentemeyer et al. 2004). Canopy dominants blue oak (*Quercus douglasii*) and valley oak (*Quercus lobata*) are not thought to be susceptible to sudden oak death, but some other oak woodland affiliate species are, such as California buckeye (*Aesculus californica*) (Rizzo et al. 2002). Although current risk is thought to be low in the northern end of the Central Valley and very low in the southern end of the Central Valley (Meentemeyer et al. 2004), *P. ramorum* has been shown to infect a variety of plant families, so unknown pathogen hosts may exist (Rizzo et al. 2002), and climate suitability for this pathogen could increase in the region if wetter conditions prevail (Meentemeyer et al. 2004).

Insects

Acorns, particularly those on the ground, are vulnerable to insect damage, including ovipositing and boring. Insects can also cause severe oak defoliation (Swiecki & Bernhardt 2006).

Grazing

Many oak woodlands are used as rangeland in the Central Valley and surrounding foothills. Cattle grazing can negatively impact oak recruitment and growth when cattle browse acorns, seedlings, and saplings. Grazing can also degrade recruitment microsites by compacting soil and reducing leaf litter. Grazing impacts may be most severe on driest sites, in areas with low canopy cover (Swiecki & Bernhardt 1998), with higher stocking densities, and in spring and summer when overall soil moisture is lower and available grass forage declines (Hall et al. 1992). Grazing by native ungulates (e.g., deer) and rodents can also have a significant impact on oak regeneration (Swiecki & Bernhardt 1998; Tyler et al. 2006). Additionally, acorn harvesting by wild turkeys (*Meleagris gallopavo*) has been reported as locally important (Gardner 2004). Wild turkeys have become well established in oak woodlands since first being introduced in the 1870s (Gardner 2004). Oak acorns are utilized by turkeys in the winter and fall (Gardner 2004), which may have localized impacts on oak recruitment.

Adaptive Capacity

Workshop participants scored the resource's adaptive capacity and the overall score was used to calculate climate change vulnerability.

Adaptive Capacity Component	Score
Extent, Integrity, & Continuity	Moderate
Landscape Permeability	Low-moderate
Resistance & Recovery	Low-moderate
Habitat Diversity	High
Overall Score	**Moderate**

Extent, integrity, and continuity

Overall degree of habitat extent, integrity, and continuity: *Moderate (high confidence)*
Geographic extent of habitat: *Occurs across state (high confidence)*
Structural and functional integrity of habitat: *Altered but not degraded (high confidence)*
Continuity of habitat: *Patches with connectivity between them (high confidence)*

Oak woodlands occur across the state of California. Blue oak woodlands and blue oak-foothill pine woodlands encircle the Central Valley, while valley oak woodlands occur more on the valley floor. Oak woodland habitat continuity is higher amongst the foothills, particularly on the eastern side of the valley in the Sierra Nevada foothills; continuity is patchy in the western foothills along the flanks of the Coast Ranges, particularly from Mendocino to Ventura Counties. Habitat continuity declines as elevation decreases, with valley oak woodlands occurring primarily in remnant patches in the Sacramento Valley and San Joaquin Valley (California Department of Fish and Game 2016a, 2016b, 2016c) due to agricultural and urban conversion (Swiecki & Bernhardt 1998). Habitat fragmentation is believed to reduce pollination opportunities, genetic exchange (Sork et al. 2002), and acorn production (Knapp et al. 2001), undermining the resilience of this habitat in the face of climate change.

Landscape permeability

Overall landscape permeability: *Low-moderate (high confidence)*
Impact of various factors on landscape permeability:
- ***Agricultural & rangeland practices:*** *High (high confidence)*
- ***Urban/suburban development:*** *Moderate-high (high confidence)*
- ***Energy production & mining:*** *Moderate (moderate confidence)*
- ***Roads, highways, & trails:*** *Low-moderate (moderate confidence)*

Low pollen exchange in fragmented habitats (Knapp et al. 2001; Sork et al. 2002) and low acorn dispersal distances (Bernhardt & Swiecki 2001) indicate that oaks may have limited ability to migrate in response to climate change (Kueppers et al. 2005).

Resistance and recovery

> ***Overall ability to resist and recover from stresses:*** *Low-moderate (high confidence)*
> ***Resistance to stresses/maladaptive human responses:*** *Moderate (moderate confidence)*
> ***Ability to recover from stresses/maladaptive human response impacts:*** *Low-moderate (high confidence)*

Oak habitat resilience to human and climate disturbance may be undermined by slow recruitment and regeneration trends in the region. In general, mature oaks are more resilient than young oak life stages (Holmes et al. 2008; McLaughlin & Zavaleta 2012; McLaughlin et al. 2014). Oak woodlands lack a persistent seedbank because acorns do not survive multiple years, but small oak seedlings can persist below the canopy for many years, waiting for canopy disturbance to allow growth (Swiecki & Bernhardt 1998). In general, variable inter-annual acorn production and survival contributes to highly variable recruitment patterns amongst oak woodland locations and species (Tyler et al. 2006). Due to long generation times, a high average age of reproductive maturity (Bernhardt & Swiecki 2001; Tyler et al. 2006), and limited genetic exchange across currently fragmented landscapes (Sork et al. 2002), oaks may not be able to rapidly adapt or migrate in response to climate change (Kueppers et al. 2005).

Habitat diversity

> ***Overall habitat diversity:*** *High (high confidence)*
> ***Physical and topographical diversity of the habitat:*** *High (high confidence)*
> ***Diversity of component species within the habitat:*** *High (high confidence)*
> ***Diversity of functional groups within the habitat:*** *High (high confidence)*

Component species or functional groups particularly sensitive to climate change:

- Oaks (not listed as endangered)

Keystone or foundational species within the habitat:

- Oaks

Oak woodlands harbor high biodiversity, typically higher than adjacent habitats (Rice et al. 1993). Blue and valley oaks are typically dominant in the canopy, but these habitats also support other oak species, shrubs, and perennial and annual understory species. Oak woodlands also support a variety of wildlife species, providing habitat for breeding, foraging, and shelter (California Department of Fish and Game 2016a, 2016b, 2016c). Oaks are keystone species in this system; loss of dominant oak canopy species would not only affect oak diversity, but have cascading impacts on understory vegetation, mammalian, bird, and insect diversity (Rice et al. 1993).

Management potential

Workshop participants scored the resource's management potential.

Management Potential Component	Score
Habitat value	High
Societal support	High
Agriculture & rangeland practices	High
Extreme events	Moderate-high
Converting retired land	Moderate
Managing climate change impacts	Moderate-high
Overall Score	**Moderate-high**

Value to people

Value of habitat to people: *High (high confidence)*

Support for conservation

Degree of societal support for managing and conserving habitat: *Moderate-high (high confidence)*

Degree to which agriculture and/or rangelands can benefit/support/increase the resilience of this habitat: *High (high confidence)*

Degree to which extreme events (e.g., flooding, drought) influence societal support for taking action: *Moderate-high (moderate confidence)*
Description of events: *Fire-related type conversion and sudden oak death.*

Likelihood of converting land to habitat

Likelihood of (or support for) converting retired agriculture land to habitat: *Moderate (moderate confidence)*

Likelihood of managing or alleviating climate change impacts on habitat: *Moderate-high (moderate confidence)*
Description of likelihood: *Oaks with possible limited ranges currently (Q. john-tuckeri) may be good to look at for assisted migration due to drought adaptations. Currently these species are in southwestern valleys on hillside slopes in rain shadows facing desert. May want to target migration to areas that are not considered refugia for blue oaks.*

Cattle grazing can be managed to minimize impacts on oak woodlands (Hall et al. 1992; Swiecki & Bernhardt 1998), but will likely need to be paired with restoration plantings to bolster regeneration (Swiecki & Bernhardt 1998). Protecting and maintaining available groundwater and surface water, riparian areas, and areas with topographical diversity may help maintain drought refugia for oak species (McLaughlin & Zavaleta 2012; McLaughlin et al. 2014). Many remnant oaks along the valley floor occur adjacent to agricultural areas, and some higher quality restoration sites occur along riparian floodplains removed from agricultural production. Across much of the study region, however, poor site quality and seedbed condition may reduce restoration success in agricultural and rangeland areas (Bernhardt & Swiecki 2001). There have been regional efforts by state agencies and non-profit groups to protect remnant oak habitats in order to mitigate agricultural and development pressure and protect genetic and evolutionary hotspots in order to foster oak woodland habitat persistence and adaptive potential in the face of climate change (e.g., see Grivet et al. 2008).

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[1] Expert opinion, Central Valley Landscape Conservation Project Vulnerability Assessment

* Workshop participants did not further discuss this and the following climate factors beyond assigning a sensitivity and/or exposure score.