Solar Energy Development in the Western Mojave Desert: Identifying Areas of Least Environmental Conflict for Siting and a Framework for Compensatory Mitigation of Impacts

July 2012

The Nature Conservancy
201 Mission Street, 4th Floor
San Francisco, CA 94105

Planning Team:

Dick Cameron
Sophie Parker
Brian Cohen
John Randall
Bill Christian
Jim Moore
Laura Crane
Scott Morrison

The Nature Conservancy
Protecting nature. Preserving life.™

Recommended Citation:

Cameron, D., S. Parker, B. Cohen, J. Randall, B. Christian, J. Moore, L. Crane, and S. A. Morrison. 2012. Solar Energy Development in the Western Mojave Desert: Identifying Areas of Least Environmental Conflict for Siting, and a Framework for Compensatory Mitigation of Impacts. Unpublished Report. The Nature Conservancy, San Francisco, California. 77 pages.

Table of Contents

List of Figures

List of Tables

Acknowledgements

This project was informed and enhanced by expert input from many individuals representing a variety of organizations, agencies, and institutions. We thank them for sharing their time and expertise, and we hope that this document will be useful to them and their partners in their efforts to protect desert species and ecosystems.

We thank the external reviewers who provided critical review and insightful comments on earlier drafts of part one of this report, the Assessment of Least Environmental Conflict for Solar Development: Jill Bays, Catherine Darst, Wayne Spencer, David Stoms, and Greg Suba and to Todd Keeler-Wolf who reviewed part two of the report. Several representatives from partner conservation and environmental NGOs also provided very helpful feedback, which also greatly improved this analysis and report.

Finally, this assessment would not have been possible without the spatial data collected and processed by scores of individuals, and in the work of various agencies, institutions, and organizations that house the data and make them available to the public. We thank Audubon California, Kern, Los Angeles and San Bernardino counties, California Native Plant Society, the US Fish and Wildlife Service, the United States Geological Survey, the Bureau of Land Management, the California Department of Fish and Game, California Energy Commission, GreenInfo Network and SC Wildlands, for generously providing GIS and other data used in this assessment.

Executive Summary

Scores of utility-scale solar electric generation facilities have been proposed for California's deserts. Minimizing the adverse impacts of these facilities can be accomplished by steering development towards defined areas of low resource conflict and diminished ecological value (e.g. previously disturbed areas), and away from areas that support important natural communities, habitats, and resources[1]. In an effort to identify and assess conservation values across the entire Mojave Desert, The Nature Conservancy released the *Mojave Desert Ecoregional Assessment* (Randall et al. 2010). Here, we narrow our focus to the western subregion of the Mojave Desert in California. Covering 3.4 million acres, the western Mojave has very high solar resource potential, is in close proximity to the largest energy market in California, and is, in general, more ecologically degraded than the rest of the ecoregion. The western Mojave also contains important ecological values, including some species that exist nowhere else on Earth.

In **Section 1** of this document, *An Assessment to Identify Areas of Least Environmental Conflict for Solar Energy Development in the Western Mojave Desert*, we present the methodology and results of an effort to assemble, categorize, and map a wide range of existing information about the western Mojave subregion. This assessment serves as a *first filter* to more fully probe what environmental constraints on utility-scale solar energy development, including ecological values, may exist throughout the western Mojave subregion.

We began with a set of Consensus Criteria identified by conservation organizations that proposes characteristics of lands that may be more or less appropriate for development of solar facilities based on ecological and other factors. We categorized these Criteria as either "avoidance" or "attractor" factors for solar development, and then assembled existing spatial data from a number of sources to represent the Criteria. We divided the data sources into groups based on the scale and the degree of certainty employed in mapping them. Giving precedence to high-resolution data, we created a composite map that displays categories of disturbance across the western Mojave subregion.

---

[1] Low conflict areas may include, for example, fallowed agricultural fields, industrial and mining sites, and other areas that have been previously disturbed by human activity. See footnote 3 for more details on relevant siting criteria.

Using this criteria-based planning method, we identified areas within the subregion that ***might***, after more comprehensive site-level investigation, prove to be acceptable, lower impact locations for utility-scale solar plants. Generally, these are areas where past or current land uses have degraded the area's conservation value, and in the western Mojave subregion those areas are primarily in private ownership. These areas include 1) lands to the south and west of Victorville in San Bernardino County, 2) the Antelope Valley, and 3) areas around the towns of Mojave and California City in Kern County that contain degraded lands with relatively high road densities that are also in close proximity to developed areas.

The subregion contains extensive areas that are degraded or fragmented by roads that contain none of the mapped "avoidance" factors that would create a conflict for development. These areas total almost half a million acres of private land and nearly 25,000 acres of undesignated BLM land. Many of these areas might be suitable for solar development, but before they are considered as candidates for development, further field investigation is needed to evaluate site-level resources.

The Antelope Valley offers a number of potential options for solar development that are identified as low conflict, mostly associated with lands in current or former agricultural production. However, recent vegetation mapping suggests that some natural communities of the Antelope Valley are adapted to disturbance, including from fire, ungulate grazing, and periodic drought, and that important native biodiversity may persist within disturbed land uses. Previously disturbed lands within the Antelope Valley may thus have higher ecological value than previously disturbed lands elsewhere in the ecoregion. This must be taken into consideration in siting decisions there.

In addition to mapping areas of low and least conflict, we identified focal areas that we suggest should be avoided or subjected to further study because of their known or suspected resource values. These include identified conservation areas for the desert tortoise (*Gopherus agassizii)* and Mohave ground squirrel (*Spermophilus mohavensis)*. Many areas of the desert have not been surveyed for occurrences or suitable habitat for a number of sensitive plant and animals. Although large areas may have indicators that suggest reduced ecological value due to fragmentation or current and past land uses, further study is needed to assess their suitability for least environmental conflict development.

The assessment also examined how the degree of parcelization of private properties and distance to transmission lines may affect desirability for siting. High degrees of parcelization exist in lands that otherwise have lower conflict. Developing incentives to facilitate the aggregation of parcels to create areas of sufficient size to develop energy projects may help alleviate pressure to develop on public lands that are more ecologically intact.

In **Section 2**, *A Framework for Aligning Compensatory Mitigation with Landscape Conservation in the Western Mojave Desert,* we describe a comprehensive mitigation program that would avoid, minimize, and offset harm to resources, with the aim of producing a net improvement to the conservation status of species and habitats in affected areas. The program would integrate requirements of traditional mitigation with broader conservation goals to maintain biodiversity and sustain landscape-scale ecological values across the western Mojave Desert. The framework invokes the mitigation hierarchy, builds on systematic landscape-level planning, and provides guidance on the prioritization of mitigation actions.

This section includes recommendations for agencies involved in mitigation planning, and concludes with an illustration of general mitigation options for the desert tortoise within the western Mojave subregion. With the focus on regional mitigation, our recommended program elements may be particularly useful as the regulatory community moves to implement the forthcoming final Solar Programmatic Environmental Impact Statement, based on BLM's recently released *Draft Framework for Developing Regional Mitigation Plans for the BLM's Solar Energy Program.*

1. An Assessment to Identify Areas of Least Environmental Conflict for Solar Energy Development in the Western Mojave Desert

1.1 Introduction

In this assessment, we assemble and map a wide range of existing information about the western portion of the Mojave Desert in California using criteria designed to minimize harm to ecological resources and to guide development of utility-scale solar energy development to previously-disturbed areas.[2] Our assessment characterizes the relative importance of lands for the conservation of species and natural communities, using available data on species and community distributions and human land use impacts.

Ranking areas according to their conservation value is admittedly challenging because of gaps in and other limitations of scientific data, the complexity of ecological systems, and the broad extent of the study area. Despite these limitations, criteria-based planning can be helpful in identifying lands that should not be developed, as well as areas that are more difficult to characterize and should be prioritized for finer-scale study. Conversely, this analytical method can identify areas that may be of lower conservation value ("least conflict areas") which in turn may enable some projects to proceed with greater assurance of their "conservation-compatibility" – and so, perhaps, with broader stakeholder support.

To this end, a number of conservation organizations[3] have proposed criteria for ecological factors that would constitute "areas of least conflict[4]" for siting of facilities (hereafter referred to as the "Consensus Criteria"). These Consensus Criteria were described in a June 2009 memo entitled "Renewable Siting

---

[2] This analysis focuses on ecological values associated with siting decisions; we recognize that cultural, social, economic and other issues are important to the siting process; these matters are largely beyond the scope of this analysis.

[3] Audubon California, California Native Plant Society, California Wilderness Coalition, Center for Biological Diversity, Defenders of Wildlife, Desert Protective Council, Mojave Desert Land Trust, National Parks Conservation Association, Natural Resources Defense Council, Sierra Club, The Nature Conservancy, The Wilderness Society, The Wildlands Conservancy.

[4] *Least-conflict areas* are places that have high renewable energy resource values and low conservation and ecological values. Identification of least-conflict areas is done within the context of a landscape-scale assessment, but may provide a rapid assessment of limited areas where renewable energy development could avoid substantial ecological impacts and associated regulatory delays. To facilitate development, least-conflict areas should also avoid areas that would result in a significant conflict with other stakeholder uses or values (e.g., cultural values, Department of Defense uses, recreational values).

Criteria for California Desert Conservation Area." In this assessment, we separate these Consensus Criteria into ***avoidance factors*** and ***attractor factors***, and then use an analytical framework to combine spatial data related to these factors using a process described in detail below.

This information may be particularly useful to local, state and federal agencies that make decisions on the siting and mitigation of renewable energy development in the western Mojave Desert. For example, this work could assist in implementing recommendations made by the Desert Renewable Energy Conservation Plan (DRECP) Independent Science Advisors (2010). The Science Advisors recommended that previously disturbed lands with low conservation value should be high priorities for siting of renewable energy projects pending completion of a comprehensive reserve system—the keystone of the DRECP's regional Habitat/Natural Communities Conservation Plan.

We focused this study on the western Mojave Desert because it has very high solar resource potential, is close to the largest energy market in California, and is generally more ecologically degraded than the rest of the Mojave Desert Ecoregion (Randall et al. 2010). Much of the study area is privately owned, and so governed by local land use authority. We are hopeful that this study will provide counties, landowners, and other entities information that will help in their land use planning, so that energy development does not adversely affect the broader conservation values of the desert.

Although our analysis does not specifically address constraints for wind power development, we note that this assessment could also be used to inform wind power development planning with regard to potential impacts on *land-based* resources. Yet, wind power impacts to volant species were not addressed by this study and should be a priority for future research.

Because parcelization[5] is often cited as an impediment to utility-scale development on private lands, we include an analysis of private land ownership patterns in the region. However, we do not investigate the planning and zoning designations for private lands in the region. This aspect of development feasibility should be investigated by stakeholders including the cities and counties within the study area.

---

[5] Parcelization is the division of large tracts of private land into smaller parcels owned by different people and organizations.

1.2 Study Area

The study area for this assessment is the western Mojave subregion, as defined in The Nature Conservancy's Mojave Desert Ecoregional Assessment (hereafter, the MDEA; Randall et al 2010; Figure 1). The subregions in the MDEA were based on dominant physiographic and vegetation patterns as well as desert tortoise recovery units as proposed by Dr. Peter Rowlands. This ecoregional subdivision was also supported by Webb et al. (2009), and recommended by the DRECP Independent Science Advisors (2010) as both ecologically relevant and potentially useful for dealing with the likely clustering of renewable energy developments in the Mojave Desert.

The western Mojave subregion covers 3.4 million acres, with elevations ranging from 1,600 feet to over 5,900 feet. Although most of the non-mountainous area is quite arid, annual precipitation within the subregion ranges from 4 to 32 inches per year, mostly as winter rainfall. The subregion includes portions of four counties: Kern, Los Angeles, San Bernardino, and a small portion of Inyo. The subregion differs from that used as the Bureau of Land Management (BLM) West Mojave Planning area and from the boundary for the Desert Renewable Energy Conservation Plan (DRECP). The BLM WEMO area extends further to the east and the DRECP area includes much of the Tehachapi Mountains in the Sierra Nevada Ecoregion outside of this study area. Wind is the predominant energy source being developed in the Tehachapi Mountains. Solar energy is the focus of this assessment, so we excluded this area.

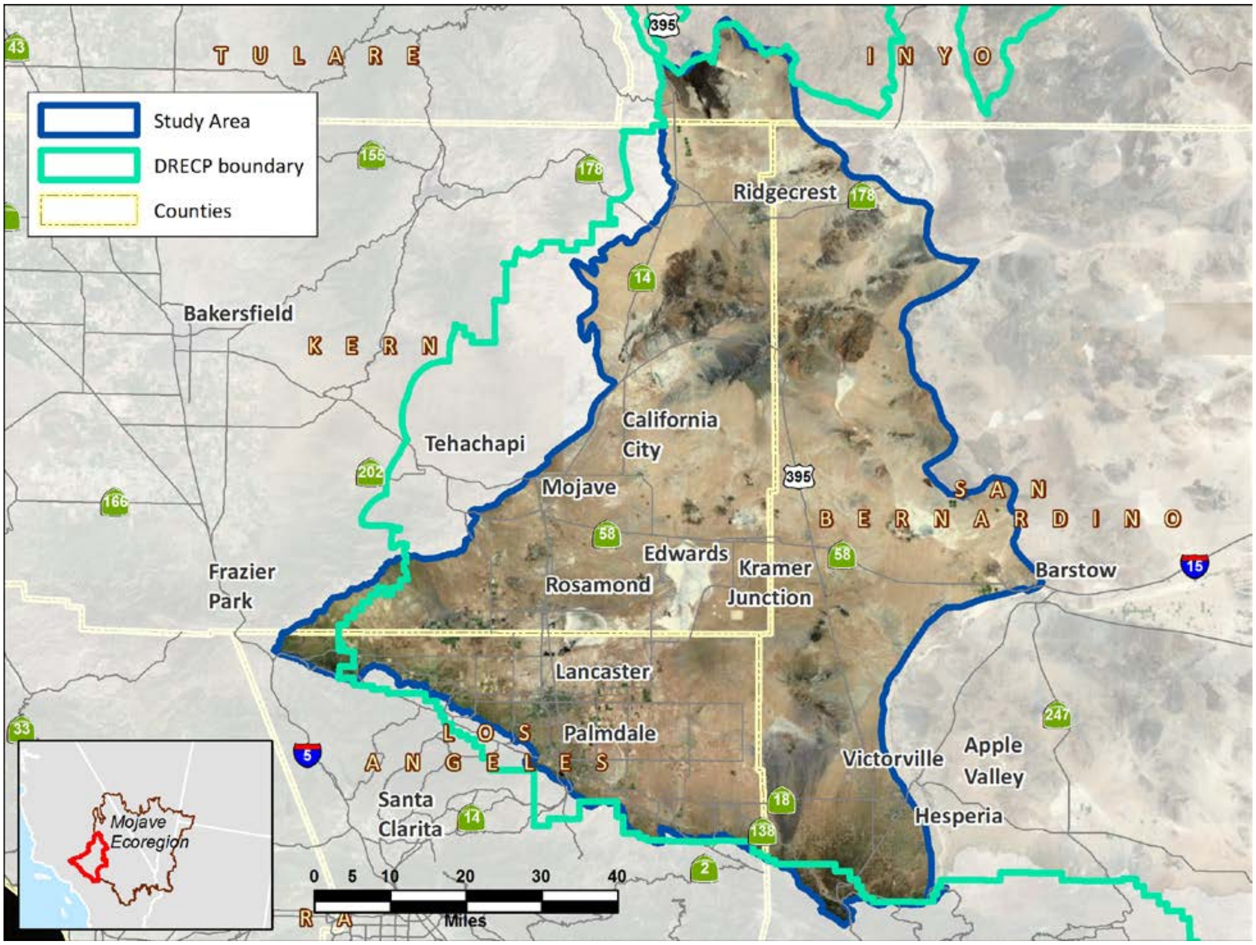


Figure 1. Study Area: Western Mojave Subregion

The land ownership in the study area is primarily a mix of private land (1.75 million acres, or 52% of the subregion), federal lands administered by the BLM (927,000 acres, or 27% of the subregion) and the Department of Defense (624,000 acres, 18% of the subregion; Figure 2). Of the BLM land in the study area, 60% is designated within Areas of Critical Environmental Concern (ACEC)—primarily as Desert Wildlife Management Areas comprising desert tortoise critical habitat.

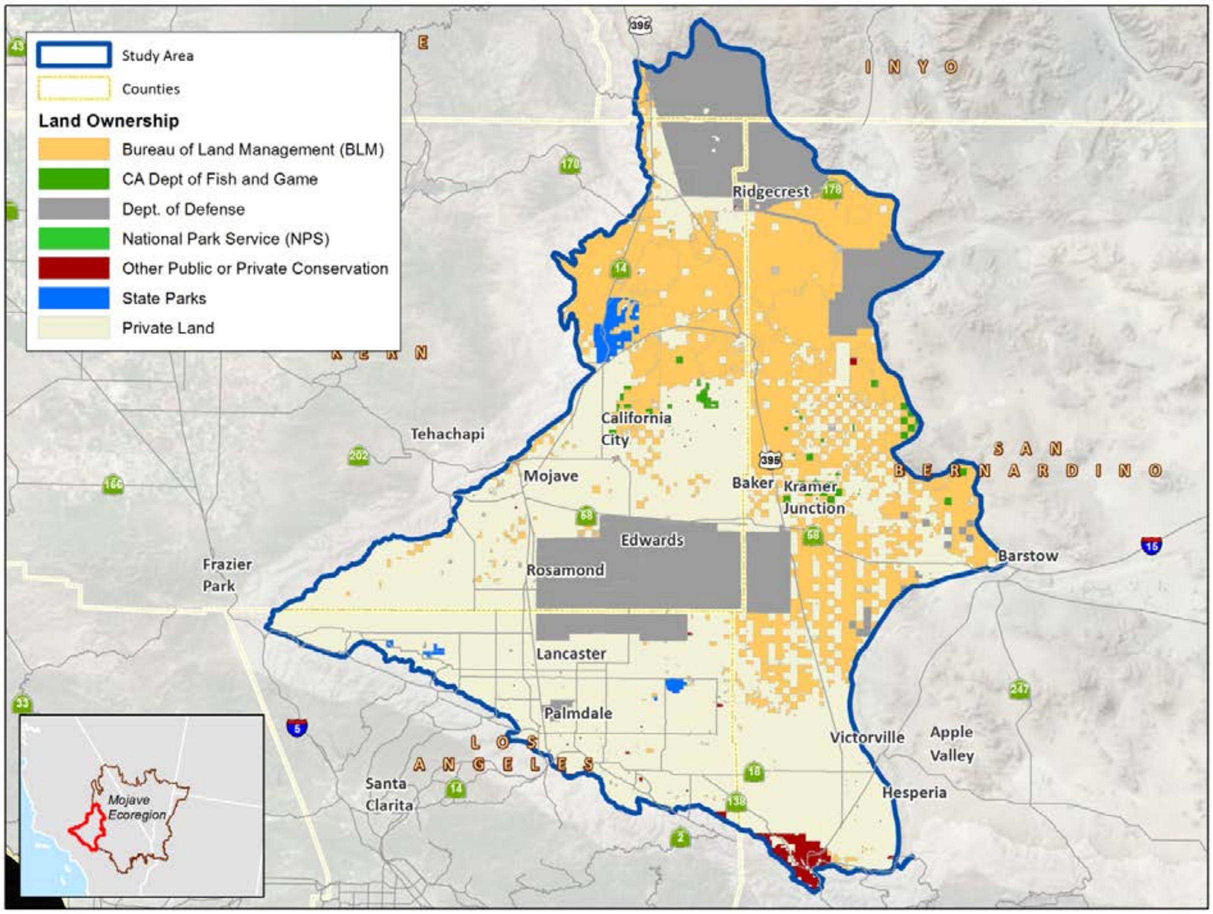


Figure 2. Land Ownership of the Western Mojave Subregion

1.3 Criteria for Least Conflict Solar Energy Development

The initial step in this analysis classified the June 2009 Consensus Criteria into two categories: factors that describe resources to be avoided (“avoidance factors”), and factors that serve as least conflict “attractors” for development because of the increased level of ecological degradation[6]. The categories are described below, grouped according to whether they describe avoidance or attractor factors:

---

[6] We classified factors to better organize the criteria for the analysis and describe to stakeholders how and why each individual factor was included. While some factors are included in multiple categories, for this document we assigned each factor into a single category which in our judgment best matched the primary purpose.

1.3.1 Avoidance Categories

A. **Administrative or legal designation** – This criterion includes ownership, conservation management or administrative status that protects land for ecological purposes, including, for example, wilderness and BLM Areas of Critical Environmental Concern.

B. **Landscape context** – This includes sites with critical roles in maintaining ecological connections or functions across the landscape, for movement of water, sand, wildlife, or other resources. Examples in this category include wildlife linkages, sand source and transport zones, intact, unfragmented areas and others factors that describe the broader context of individual sites or connections between existing protected areas. This category captures the subregion's environmental gradients and ecological processes, as recommended by the DRECP Independent Science Advisors (2010). One key data gap for this assessment is areas important for groundwater recharge that are separate from but sustain riparian vegetation or surface water expressions.

C. **Biodiversity attributes** – Lands and waters identified as occupied or potential habitat for focal, rare, unique or other special status species and communities, with consideration for the relative importance of species and habitats in terms of their rarity, uniqueness, and sensitivity or critical ecological role.

1.3.2 Attractor Categories

A. **Land use degradation** – This criterion includes lands in various states of degradation due to current or historic land uses or disturbance history[7]. Given the importance and complexity associated with this factor we discuss it in more detail below.

B. **Infrastructure proximity** – This category expresses the availability and proximity of infrastructure and markets such as distance to load centers, transmission lines with unused capacity, water, roads, substations, and human communities that could house workers without further development. In general, the ecological rationale for this attractor is to limit new fragmentation of the landscape and to take advantage of indirect benefits such as reduced loss of energy during transmission and reduced commute times for facility workers.

---

[7] We were not able to model or characterize the relative habitat quality of different natural and semi-natural habitats. The forthcoming California Department of Fish and Game vegetation mapping for this region will help address this important data gap.

Once we categorized the Consensus Criteria, we assembled spatial data to represent the avoidance and attractor factors (Table 1). The listed avoidance factors do not include, and are thus additions to, those lands that already prohibit energy development for legal or administrative reasons[8]. The avoidance factors used in this assessment are based partly on past analyses, including lands categorized as "Ecologically Core" and "Ecologically Intact" from The Nature Conservancy's Mojave Desert Ecoregional Assessment (Randall et al. 2010) and conservation areas designated through the BLM's West Mojave Plan. We developed a list of target species by using occurrence records from the California Natural Diversity Database (CNDDB), from species covered under the BLM West Mojave (WEMO) plan, from "dropped" species from the WEMO plan, and from the conservation target list included in The Nature Conservancy's 2000 and 2010 Mojave Desert Ecoregional Assessments (Appendix 1). Occurrence data from the California Natural Diversity database is an important source of information for many projects in California, yet because the sampling for species in the database is uneven especially in remote areas like the California deserts, we decided to overlay it with the final map, rather than build it into the analyses as a data source for this avoidance factor.

The sources of data for the criteria are varied and some of the factors are not well mapped. In particular, areas that are degraded or mechanically disturbed are especially difficult to accurately map across the whole region. Therefore, we used proxies for levels of degradation based on mapped land uses or features that usually indicate degradation, such as roads. See Section 1.5 below, entitled "Mapping Land Use Disturbance," for more details on methods and data sources.

---

[8] National Park Service units; designated Wilderness Areas; Wilderness Study Areas; BLM National Conservation Areas; National Recreation Areas; National Monuments; private preserves and reserves; Inventoried Roadless Areas on USFS lands; National Historic and National Scenic Trails; National Wild, Scenic and Recreational Rivers; Conservation mitigation banks under conservation easements approved by the state Department of Fish and Game, U.S. Fish and Wildlife Service or Army Corps of Engineers California State Parks; Department of Fish and Game Wildlife Areas and Ecological Reserves; Department of Defense lands

Table 1. Avoidance and Attractor Factors for Solar Energy Development

Includes lands that are not otherwise legally excluded from renewable energy development. The Consensus Criteria were designated by a group of environmental organizations in the June 2009 memo entitled “Renewable Siting Criteria for California Desert Conservation Area.”

Factor category	Avoidance factors	Data sources
Administrative or legal designation	1.1. Lands within two miles of National or State parks	USGS Protected Areas Database (PAD) v. 1.1
Administrative or legal designation	1.2. Proposed Wilderness or proposed National Monument	N/A in this region
Biodiversity attributes	1.3. Areas with rejected ROW application(s) for ecological reasons	N/A in this region (based on CA BLM personal communication)
Administrative or legal designation	1.4. Lands transferred to BLM for conservation purposes	The Wildlands Conservancy
Administrative or legal designation	1.5. Lands transferred to BLM for project mitigation	N/A in this region
Administrative or legal designation	1.6. Inventoried potential Wilderness areas	California Wilderness Coalition Citizen’s Inventory (2007)
Administrative or legal designation	1.7. Lands proposed for protection in ACEC, recovery plan or as critical habitat	USFWS Critical Habitat Units 2011, USFWS Tortoise Conservation Areas 2011, BLM WEMO plan 2005
Biodiversity attributes	1.8. Unusual plant assemblages	BLM 2011
Landscape context	1.9. Linkage areas	SC Wildlands 2003, 2012, USFWS modeled desert tortoise linkages 2011, DRECP Vegetation transition linkages 2011
Landscape context	1.10. Wetland, riparian, associated recharge areas & groundwater recharge areas, including playas and washes	DRECP Playas and Washes 2011
Administrative or legal designation	1.11. Historic Register	National Historic Register 2011
Landscape context	1.12. Dunes and sand transport areas	Muhs et al 2003., DRECP 2011
Landscape context/ Biodiversity attributes	1.13. TNC Ecologically Core or Ecologically Intact lands	Randall et al. 2010
Administrative or legal designation	1.14. Lands currently designated as ACEC or other conservation areas	USGS PAD 1.1 (2010), BLM WEMO plan 2005
Biodiversity attributes	1.15. Known habitat or occurrences of unique and/or rare species	Los Angeles County Draft Significant Ecological Areas 2002, DRECP Bighorn Sheep occupied ranges (2011), Transition Habitat Conservancy project areas (2012)

Factor category	Least conflict “attractor” factors	Data sources
Land use degradation	2.1. Mechanically disturbed lands	SCAG 2005, Department of Conservation FMMP 2008, Historically Farmed areas (FMMP processed by UCSB 2011), U.S. Census Bureau TIGER 2000 roads, Kern county parcel land use 2011, Kern county agriculture 2009, Randall et al. 2010, Gap Analysis program 1998, 2008
Land use degradation	2.2. Brownfields	No data available
Infrastructure proximity	2.3. Close to developed areas	Qualitatively assessed
Infrastructure proximity	2.4 Close to transmission with capacity	Analyzed post-hoc- Ventyx transmission line data, 2011
Land use degradation	2.5 Public lands adjacent to degraded private land	Qualitatively assessed
Land use degradation	2.6 Frequently burned places	Not incorporated

1.4 Spatial Scale of Avoidance Factors

The spatial scale of existing GIS data for the avoidance factors is highly variable. In some cases, the mapping depicts the known distribution of the resource to a high degree of certainty. Since some resources are naturally restricted they can be accurately mapped to a high level of spatial precision. In other cases, the mapping reflects a lower degree of certainty associated with the location of the resources. Some data sources, for example, use large polygons to depict the extent of a resource that may be distributed within a mosaic of non-target resources.

To account for these different methods and data qualities, we divided the data sources into *fine* and *broad* scale groups that we suggest reflect the relative level of “flexibility of avoidance.” Flexibility of avoidance refers to either the geographic scale of the spatial data *or* the degree to which a factor can be definitively mapped. Areas with higher flexibility of avoidance (broad scale factors) likely present more opportunity to avoid impacts to targeted resources due to their dispersed distribution within a mosaic of other vegetation.

Categorizing data sources based upon their geographic scale is somewhat arbitrary, but for each source we assessed whether the spatial data contained a high density of the features of interest (fine scale) or was mapped as general areas important for the feature (broad scale). It is easier to determine whether a feature can be definitively mapped. Lands that have legally designated boundaries can be definitively mapped, such as designated critical habitat and BLM conservation areas. We assigned such factors to the fine scale group, even though the actual density of the resources of interest might be quite low in the designated areas.

We classified all linkage data as *broad scale*, under the assumption that these areas typically include a variety of land uses and values, some of which might be suitable for energy development without acting as a barrier to movement (Table 2). It is important to emphasize, however, that linkages constitute avoidance factors because they represent the value of the landscape as a connected mosaic of habitats – some intact, others degraded, but not fully converted to the extent that the ecological linkage is nullified . Development in linkage areas, in particular, needs to be closely clustered and adjacent to lands that are already degraded so that the connectivity value that these areas provide is maintained.

1.5 Attractor Factors: Mapping Land Use Disturbance

Mapping least conflict areas for siting requires an assessment of the degree to which land is "mechanically disturbed" or more generally degraded by current or past land uses that are incompatible with ecologically important functions or values. This task poses challenges reconciling various sources of vegetation and land use data, and especially characterizing low density development, a dominant land use for private lands in the region. The study area contains many parcels developed at low density (i.e. greater than 5 acres per housing unit) that are often subject to extensive off-highway vehicle use. Other low density areas are formerly farmed areas that are now fallow or are in transition to more intensively developed land classes.

Table 2. Spatial Scale of Avoidance Factors. See Table 1 and Appendix 3 for full citations.

Fine scale factors
Lands within two miles of National or State parks
Proposed Wilderness or proposed National Monument
Lands transferred to BLM for conservation purposes
Lands transferred to BLM for project mitigation
Inventoried potential Wilderness areas
Lands proposed for protection in ACEC, recovery plan or as designated as critical habitat
Wetlands, playas, washes
Historic Register
Sand dunes (DRECP)
Transition Habitat Conservancy Puzzle Canyon and Pinon Hills project areas
Lands currently designated as ACEC or other conservation areas
Known habitat or occurrences of unique and/or rare species
Broad scale factors
Unusual plant assemblages
Sand dunes (Muhs et al. 2003)
TNC ecologically core lands
TNC ecologically intact lands
Wildlife linkages (SC Missing Linkages (2003) and SC Wildlands Desert Linkages (2012)
DRECP Vegetation transition linkages
Desert tortoise linkages (USFWS)

To capture the differing intensities and spatial distribution of land use disturbance, we created a composite map with several categories of disturbance based on a variety of input data. We gave precedence to high resolution data sources (Table 3). The goal of this mapping exercise was to find areas that are disturbed or fragmented—but not so densely developed that there would likely be conflicts with nearby residential areas. The sources used to map disturbance categories included a variety of original sources including aerial photos, satellite imagery, and derived analyses based on proxies for disturbance (e.g., road density).

We assigned the highest priority for solar energy development to land that was formerly farmed or industrial brownfields (though we have been unable to find spatial data to represent brownfields beyond inventory points from EPA as part of Re-powering America's Land)[9]. The second siting priority is land that is currently intensively used for agriculture (i.e., non-rangeland, based on 2008 data).

Distinguishing between the two categories (former and current) of agricultural land can be difficult, since fallow fields may come back into production after years of non-use. To make this determination, we used the California Department of Conservation Farmlands Mapping and Monitoring Program (FMMP) data from 2008 for each county (except Inyo where it is not available) that depict currently irrigated farmlands. Lands that were not classified as irrigated farmland by FMMP, but were classified as current or former agriculture by another source, were assigned to the "former agriculture" class (i.e. the highest siting priority). This is an example of how we gave higher resolution and more recent data (FMMP) precedence in determining land uses.

We recognize that sources were used to designate former agricultural lands are internally variable in terms of their original spatial scale and classification methods. In particular, the California Gap Analysis Project land cover data that we used was published in 1998, based on satellite and aerial imagery from the early 1990s. Because of the large minimum mapping unit used in this project and the vintage of the data, we qualitatively assessed this source after concerns from reviewers that this source overestimates the amount of former agricultural land. Using recent aerial photos, we found that the vast majority of the areas classified as agriculture by the Gap Analysis project in fact showed striations indicative of past plowing. We therefore concluded that use of this data source was warranted.

The decision to prioritize former agricultural land over land currently in production was made in recognition of the value that current farmland provides to the local economy of the western Mojave and the concern that displacing currently farmed lands with energy development might cause a shift of the

---

[9] http://www.epa.gov/oswercpa/docs/handbook_siting_repowering_projects.pdf

farmlands to other areas, leading to more land conversion of habitat. Currently farmed lands also provide foraging habitat for key species such as Swainson's hawk (*Buteo swainsoni*), a state threatened species. Ultimately the balance of land uses on private land is determined by land owners and local land use entities.

Once land is plowed, we assume that disturbance of the soil ordinarily leads to changes in vegetation composition and possible secondary effects that reduce the ecological value of the land (through, e.g., proliferation of invasive species or changed disturbance regimes). However, recent vegetation mapping and field surveys suggest that the Antelope Valley may be more disturbance-adapted than is conventionally thought and that native biota may be more adapted to frequent natural and human-induced disturbance regimes[10].

The third land use category includes two data sources for disturbed lands. First, we included rural, low density developed lands in the region with road access. For this category, we adapted the approach to "rural lands" mapping used by the DRECP, selecting those private lands where the size of patches bounded by any class of road was smaller than 500 acres. This approach is a proxy for a rural residential land use pattern and, as such, may include relatively large areas of high quality habitat. This uncertainty is reflected in the way that we combine the land use disturbance priority categories with the avoidance factors and will be discussed in the next section.

Second, we included land (outside areas already assigned to one of the above categories) characterized as "Moderately Degraded" or "Highly Converted" in The Nature Conservancy's Mojave Desert Ecoregional Assessment (Randall et al. 2010; Table 3). These are lands with at least 25% of their area noticeably disturbed from conversion or linear features such as roads or OHV trails, evaluated at the scale of one square mile hexagons[11].

Lands that were not classified as disturbed under one of the above categories were assigned to the fourth category for siting. The inputs described above were assembled into one land use disturbance

---

[10] Todd Keeler-Wolf, California Department of Fish and Game Vegetation Mapping program, personal communication 2012.

[11] "These are lands fragmented by roads or OHV trails, or are in close proximity to urban, agricultural and other developments. Moderately Degraded lands are partially to moderately compromised by fragmentation and other human impacts such as rural development, agriculture, OHV use, and military use. They often maintain ecological functionality (e.g., maintain groundwater infiltration and flow, serve as sand sources, provide connectivity), provide habitat for native species, or are known to have conservation target occurrences. The potential for Moderately Degraded lands to provide long-term conservation value and to be restored is greater where they are located adjacent to Ecologically Intact lands rather than Highly Converted lands. Without protection and perhaps restoration, the ability of Moderately Degraded lands to maintain functionality and sustain conservation targets will be reduced" (Randall et al. 2010).

layer classified by the priority level. The extent of different priority levels is shown in Figure 3, with the two sources for level 3 broken out.

Highly developed areas such as cities and active mines are masked in this process and are not considered as priority areas for utility-scale solar energy facility siting. Additionally, military lands and areas that are designated open areas for off-highway vehicles on BLM land are excluded from the analysis.

Table 3. Disturbance Levels for Solar Energy Facility Siting
Priority levels for siting on different categories of lands that have been mechanically disturbed, with highest priority as level 1 and lowest (not a priority) as level 4. The precedence of overlay was based on judgment of the relative accuracy and source date of the data sources contributing to each category.

Level for siting	Land Use	Data sources	Precedence in overlay
1	Former agriculture or Commercial/industrial brownfields	California Gap Analysis Program 1998 (CRP value as primary land cover); Kern county parcel land use ("Irrigated land"), SCAG land use layer (Abandoned Orchards and Vineyards, Irrigated Cropland and Improved Pasture Land, Non-Irrigated Cropland and Improved Pasture Land, Orchards and Vineyards, Other Agriculture); FMMP historical compilation of ag land pre-2008	3
2	Current intensive agriculture	FMMP 2008 (state, prime or unique), Kern county agricultural fields layer (2009)	2
3	Rural, low-density development	Road bounded polygons less than 500 ac on private land (TIGER2000 road data)	4
3	Additional degraded lands	Moderately Degraded and highly converted lands from Mojave Desert Ecoregional Assessment (Randall et al. 2010)	5
N/A	Urban / developed	California Gap Analysis 2008 (Developed - High/Medium intensity, Quarries); FMMP 2008 (Urban)	1
4	Lands with no mappable disturbance	Areas not already assigned based on above data	6

1.6 Combining Avoidance and Attractor Factors to Assign Relative Level of Conflict

We combined data for priority levels of land use disturbance (discussed above and from Table 3) with the avoidance factors classified by flexibility of avoidance[12] (Tables 1 and 2) to assess the potential suitability for solar plant siting, using mostly independent sources of information. We present this suitability evaluation as a matrix in Table 4, below. Table 4 combines land use disturbance and conflict criteria to define our approach for determining the relative suitability of an area for least conflict siting.

---

[12] When the fine and broad scale factors overlapped, we assigned the pixel to fine scale.

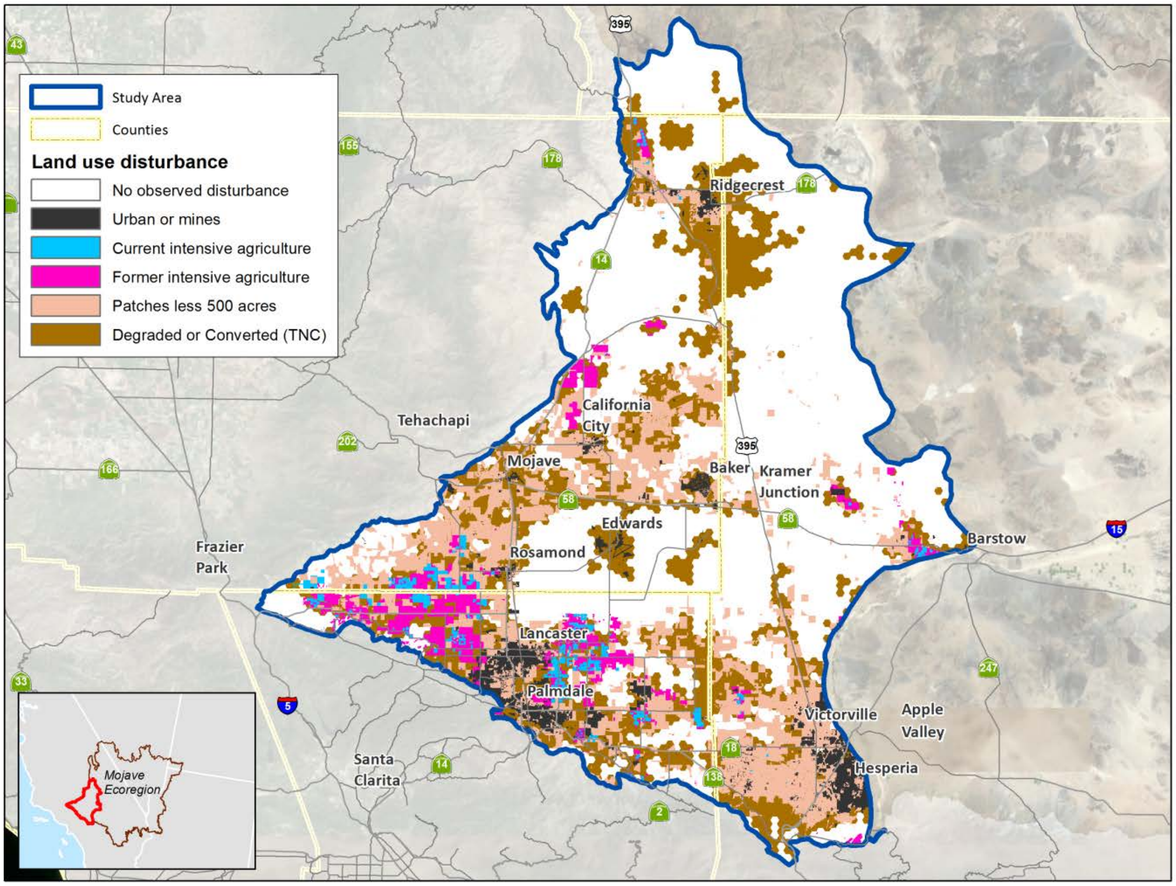


Figure 3. Land Use Disturbance
Data were assembled from a variety of input sources to reflect the potentially suitability of least conflict solar energy development. Because data on actual disturbance types and levels is not available across the study area, we relied on proxies such as evidence of ecologically degrading land uses.

We intentionally chose to recommend a conservative approach in identifying low conflict siting areas, especially in light of some of the data limitations already discussed. Utility-scale solar energy development in desert environments is an irreversible commitment of land to an industrial use. Thus, we propose classifying areas based on land use disturbance levels and Consensus Criteria that is appropriately cautious in prioritizing land for development. Only when the category of existing land use is confirmed by adequately scaled data do we present an area as potentially suitable for low conflict siting from an ecological perspective.

This approach is illustrated in the Table 4 matrix, where the upper left and lower right boxes have darker colors, representing greater certainty with respect to whether land is either appropriately considered for solar development or precluded. The colors in the matrix table are lighter where land use classification and the avoidance factors provide less certainty about whether land should *a priori* be considered or excluded from further evaluation for siting.

We assume that development proposals that overlap with ”fine scale” avoidance categories would more likely lead to encountering sensitive resources and thus, potential development conflict. Further, we assume that more overlap means likely more ecological impact for the resources of interest. As such, we use “uncertainty” to scale likely ecological impact. Yet, the nature of the impact from solar development is poorly studied especially for processes that operate at large spatial and temporal scales such as wildlife connectivity (Lovich and Ennen 2011).

Given this, we propose that this assessment underscores the importance of – and can support the implementation of – a phased approach to solar development in this region, with areas in darkest orange investigated first, and the areas in darkest green conserved first, while additional research and data can be developed to better differentiate the areas in the lighter colors. A phased approach would likely still provide sufficient land area to meet development demand in the coming decades, as long as research on ecosystem dynamics and species ecology is also advanced in the meantime.

Matrix categories 5 and 6 deserve special attention. These include lands in the rural density and other degraded category (Priority 3) with broad scale or no avoidance factors. The compatibility between energy development and conservation is especially difficult to characterize in these lands given the limits of GIS-based assessment and the spatial scale of data inputs, and many data gaps exist for priority habitats and species on these lands. Based on recent field reconnaissance of the study area, lands in these categories can be in a number of different states or conditions. Many of these areas may be open and permeable to wildlife movement, recovering from past land use disturbance, but heavily dissected by smaller (often dirt) roads. In other cases, these areas may have higher levels of degradation, possibly from past grading associated with planned development. Thus, it is especially important that careful field investigations precede development proposals for these lands. As is true of this and all categories, we intend this assessment to serve only as a *first filter* to more fully probe what constraints, including ecological values, may exist in a given area. As new information becomes available on the distribution and status of key species and habitats in these lands, they can be moved into one of the other categories in the matrix.

Table 4. Matrix of Priority Levels for Least Conflict Solar Energy Facility Siting
Integrating the spatial scale of conflict factors with land use categories. Shades of green are conservation priorities and should not be considered for energy siting, with dark green being the most important to avoid. Shades of orange are the areas that should be investigated first for energy infrastructure siting. The blue boxes represent land uses where the combination avoidance factors and land use disturbance makes it especially difficult to say whether a site will be potentially suitable for development. These may be areas where there are current or past degrading land uses, but also ecological resources distributed throughout often at a fine scale. The number in each cell in the matrix are for reference only and correspond to the categories referred to in the text and in later figures.

	Spatial scale of high conflict factors (flexibility of avoidance)		
Land use	Fine	Broad	No Conflict factors
Level 4. (No evidence of disturbance)	"Very High Conflict: Avoid" (1)	2	3
Level 3. (Rural road density and other degraded lands)	4	5	6
Level 2. (Active agriculture)	7	8	9
Level 1. (Former agriculture)	10	11	"Very Low Conflict, Investigate for Development" (12)

The matrix classification and color scheme shown in Table 4 is used in several following maps and charts. For example, the colors in the matrix are used to distinguish areas on the map in Figure 4.

1.7 Results

- **Exclusion Areas:** The Desert tortoise conservation areas (Fremont-Kramer and Superior-Cronese Desert Wildlife Management Areas) and the Mohave ground squirrel conservation area account for the vast majority of the darkest green (Categories 1 and 4 in Table 4) to the east and north of Edwards Air Force Base (Figure 4). Because these areas are designated to maintain habitat for listed species, they have been proposed as exclusion areas by a wide variety of organizations and agencies in past and current planning processes. As ongoing and future research yields new information about the area needed to maintain such species, these designated areas may change and this analysis will need to be updated.
- **Potential Siting Areas in the Antelope Valley:** The Antelope Valley offers a number of potential options for least conflict solar development, mostly associated with lands in current or former agricultural production. However, recent vegetation mapping suggests that much of the western Mojave may have been subject to human and natural disturbance over historical time periods and that some natural communities of the Antelope Valley may be adapted to disturbance, including from fire, ungulate grazing and periodic drought[13]. This observation should be assessed in future research and be taken into consideration as siting decisions are made. The connectivity value that is provided by the open land on the Valley floor farther west in Valley between the Transverse Ranges and Tehachapi Mountains also needs to be factored into future siting decisions. Also, some reviewers stated that the area between Ripley's Woodlands State Park and the Poppy Preserve is higher quality habitat than our categorization suggests, with potential opportunities for conservation or mitigation in this area.
- **Potential Siting Areas near Development:** The areas south and west of Victorville in San Bernardino County and other areas around the towns of Mojave and California City in Kern County contain lands with relatively high road densities and land degradation in close proximity to developed areas. (Figure 4). Many of these areas are apparently already under active consideration for solar energy development siting (TNC, *unpublished analysis*). The landscape context of these areas should be factored into further assessments of development suitability. For example, if a number of sites are adjacent to existing commercial or residential development

---

[13] Todd Keeler-Wolf, California Department of Fish and Game Vegetation Mapping program, personal communication 2012.

then they may represent much lower "effective" impact than the same footprint in the Antelope Valley, because of the relatively high intactness in parts of the Antelope Valley, especially farther west in the Valley. Additionally, developing land close to cities and towns presents an opportunity for economic benefits to accrue to cities and towns in construction, operation and maintenance jobs.

- **Private versus Public Lands:** Opportunities to advance solar energy development on (Table 4 matrix) Priority 1 or Priority 2 land uses are exclusively on private lands, totaling over 150,000 acres (Categories 8-12, Table 4) with over a third of that area in the category most likely suitable for development (Category 12) (mapped on Figure 5, below). By contrast, nearly 900,000 acres—nearly 40%—of the land in private ownership or managed by BLM as ACECs or in undesignated categories (land with no legal or administrative protective status) is intact with no evidence of land use disturbance, suggesting that much of the study area maintains important habitat and connectivity values (Figure 5), and should not be considered for siting facilities.
- **Degraded Lands with no Avoidance Factors:** Areas with rural road density or otherwise degraded but with no apparently associated avoidance factors (that is, Category 6 in Table 4) are extensive, totaling almost a half million acres of private land and over 20,000 acres of undesignated BLM land (Figure 5). Many of these areas might be suitable for solar development, but, before they are considered as site candidates, even on a preliminary basis, further field investigation is needed to evaluate site-level resources[14]. It is likely that there are areas of mixed private and public ownership that could be aggregated into larger project areas, but given challenges of assessing the suitability of this land use pattern with GIS data, further investigation with aerial photos and field reconnaissance is needed.

---

[14] These may be areas where avoidance and minimization actions could circumvent the need for extensive compensatory mitigation.

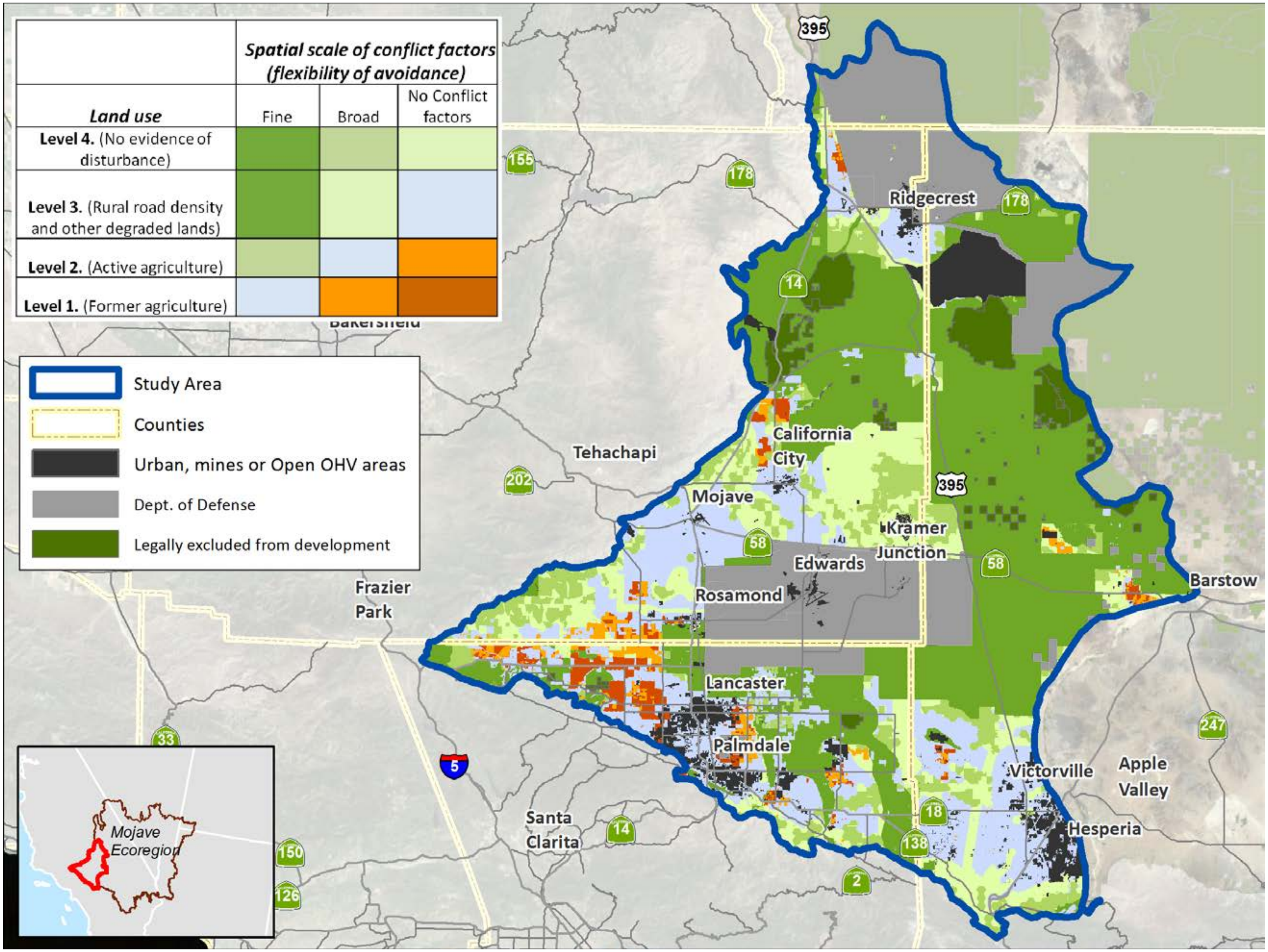
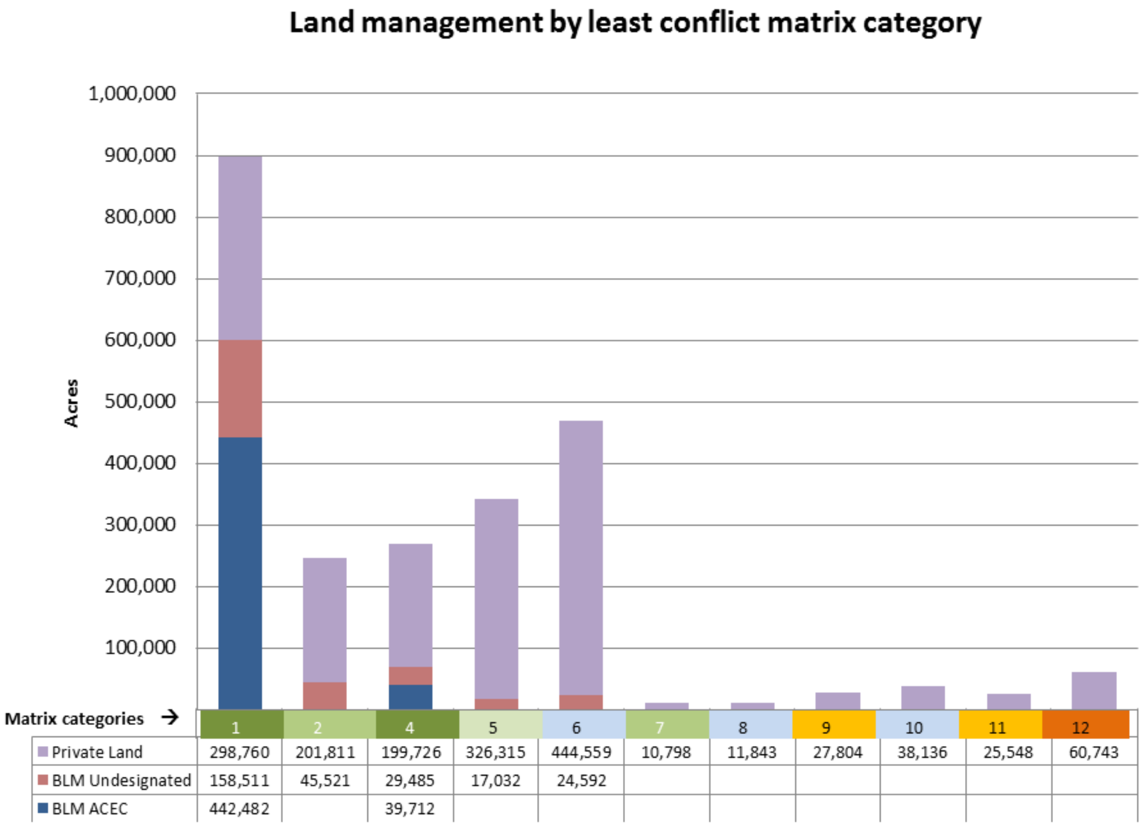


Figure 4. Least Conflict Criteria Matrix Applied to Study Area



Matrix categories →	1	2	4	5	6	7	8	9	10	11	12
▨ Private Land	298,760	201,811	199,726	326,315	444,559	10,798	11,843	27,804	38,136	25,548	60,743
▨ BLM Undesignated	158,511	45,521	29,485	17,032	24,592						
■ BLM ACEC	442,482		39,712								

Figure 5. Acres by Land Ownership in Each Least Conflict Matrix Category
The Mohave ground squirrel conservation area is considered BLM Undesignated land in this chart. Approximately 172,000 acres of Mohave ground squirrel conservation area are included in category 1 and 4 as BLM Undesignated land. Combinations of ownerships smaller than 2470 acres (1000 ha) are not shown, which includes all of category 3.

Areas with lower potential conflict represent an opportunity to align conservation objectives and renewable energy development, but some significant constraints remain. One of the most challenging issues of developing on private lands can be the number of parcels that need to be acquired in an area to make a large and contiguous property suitable to site an industrial-scale energy plant. For wind projects, leases may minimize this challenge, but solar energy often requires that land be acquired in fee title. There are tens of thousands of parcels of private land in categories 8-12 in the Kern County, Los Angeles County, and San Bernardino County portions of the western Mojave (Figures 6 and 7). The median size of these parcels is 2.5 acres. Surprisingly, the average size of privately owned parcels in categories 8-12 (shown in orange colors in Table 4), is slightly larger (8.1 acres) than the average size of parcels in categories 1-7 as a group (6.7 acres) for all counties but Inyo (Figures 6 and 7). This is likely due to the fact that many of the areas in categories 8-12 are, or were recently, in active agriculture and are in the larger ownerships needed to support this activity. There are many fewer parcels in categories 8-12 in Kern and San Bernardino counties with more mixed results for the other two counties. Yet, the average size for all matrix categories for all private (non-masked—excluded) parcels is very small, at 6.9 acres. This highlights the disincentive of implementing utility scale solar projects on private lands. See Appendix 2 for larger scale maps of the least conflict categories with parcels.

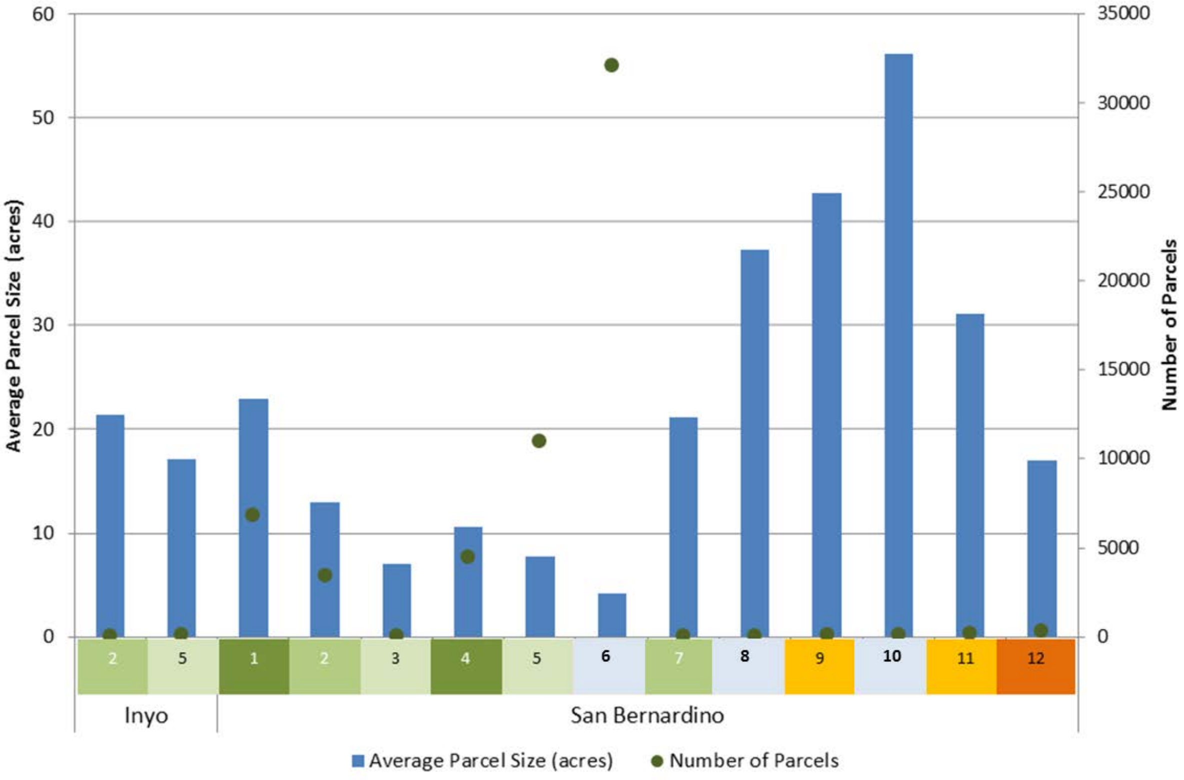


Figure 6. Privately Owned Parcels of Inyo and San Bernardino Counties
Number and average size of parcels by least conflict category in each county within the study area.

Combing the matrix classification for lower conflict categories (5, 6, 8-12) with larger parcels suggests that there are possible areas to investigate for private land utility-scale projects with fewer ecological constraints (Figure 8). Additional analyses to investigate the local land use planning classification and distribution of property owners within the least conflict areas will further extend the value of this analysis of environmental constraints.

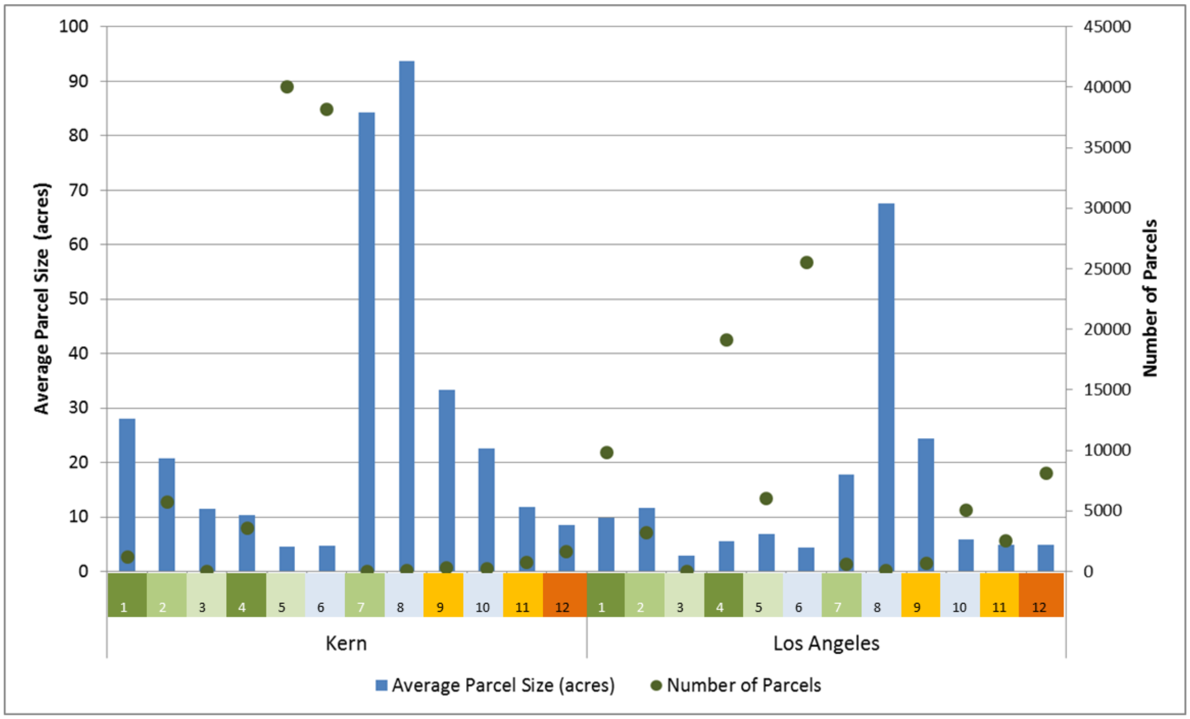


Figure 7. Privately Owned Parcels for Kern and Los Angeles Counties
Number and average size of parcels by least conflict category in each county in the study area.

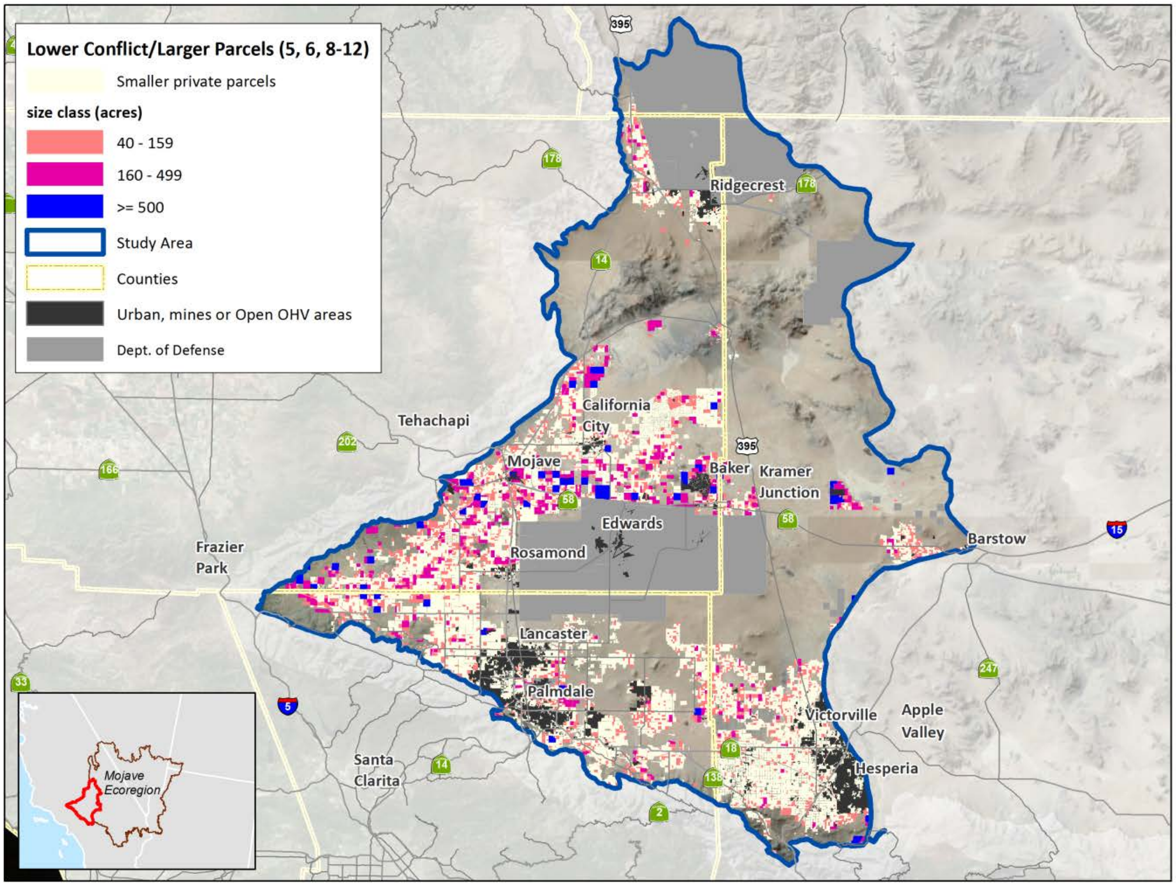


Figure 8. Privately Owned Parcels in Lower Conflict Matrix Categories
Parcels of at least 40 acres in size in lower conflict matrix categories 5, 6, and 8-12 are shown. Additional analyses can be performed to assess the distribution of parcels with the same owner.

1.8 Transmission Issues

Proximity to substations and transmission lines with capacity to accept additional power is often a key factor in determining economically viable locations for renewable energy development. The capacity available on specific transmission lines is a critical issue, but it is quite difficult to analyze because the information is largely proprietary, buried deep in agency reports or subject to complex regulatory rules. To address this issue, we included a simple proxy for whether connection to existing transmission lines was feasible—an analysis of linear distance to transmission lines. We then overlaid a shaded version of the analysis results onto the least conflict map (Figure 9). This analysis suggests that most of the areas classified as candidates for least conflict siting are relatively close to transmission lines. On Figure 9, the darker areas are relatively farther from existing lines. We note that the eastern two-thirds of the study area is generally farther from existing transmission than the Antelope Valley and lands between Palmdale and Victorville that are lower conflict areas.

Because the availability of transmission is one of the drivers in siting decisions, The Nature Conservancy requested input from Southern California Edison (SCE) regarding the transmission constraints in area covered by the scope of this analysis. SCE provided an overview of the transmission constraints based on four publicly available documents that contain transmission information[15]. These documents suggest that the existing electric system within the study area is constrained, and that interconnecting new generation in this area will aggravate constraints. Various types of upgrades would be necessary to reliably and safely interconnect new generation in this area. In addition, SCE indicated that the entire DRECP planning area was similarly constrained from a transmission perspective.

While transmission constraints provide a challenge in interconnecting near-term projects, the situation also affords decision-makers a significant opportunity to enhance the overall conservation-compatibility of the overall system. Transmission upgrades will be required to bring renewable energy generated in the desert into the electrical grid. Prioritizing upgrades to those areas where siting would have lower environmental impact will provide a meaningful incentive for developers to site in these areas and will also encourage renewable energy development in a manner to protect species, habitats and ecosystem function.

---

[15] Annual California Independent System Operator Transmission Plan (http://www.caiso.com/2734/2734e3d964ec0.html); California Independent Operator Generation Interconnection Queue (http://www.caiso.com/planning/Pages/GeneratorInterconnection/Default.aspx); Southern California Edison WDAT Generation Interconnection Queue (http://www.sce.com/nrc/aboutsce/regulatory/openaccess/wdat/wdat_queue.xls); Southern California Edison Transmission Projects Webpage (http://www.sce.com/PowerandEnvironment/Transmission/ProjectsByCounty/projects-by-county.htm)

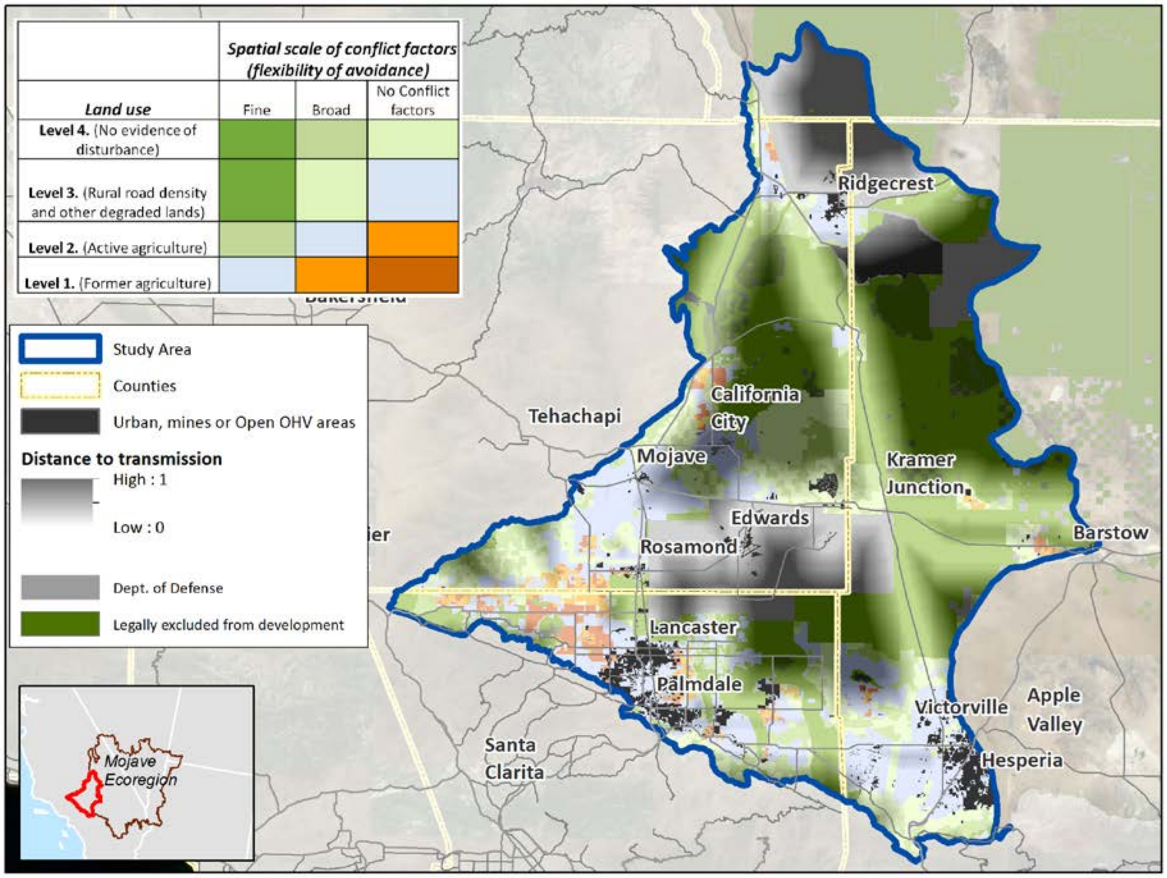


Figure 9. Relative Distance to Transmission for the Least Conflict Criteria Matrix
Darker areas may be more economically difficult to develop given the distance to existing transmission lines. Note that the colors in the least conflict matrix are lighter than the previous maps.

1.9 Uses and Limitations of this Assessment

This assessment is based on available GIS data from various sources and at a wide range of scales of resolution. As a landscape-scale, GIS-based analysis, it cannot substitute for site-based field assessment of resource values or for detailed studies of conservation priorities at the species, habitat, or landscape level. Many resources and locations are poorly surveyed, especially for rare and endemic species. These data gaps particularly limit the use this assessment to support site-level decisions for development or conservation. We provide the following guidelines for how this assessment should be used, and what purposes it should not serve, given these limitations.

1.9.1 Uses of this Assessment

This assessment can act as a “first filter” screening of locations within the western Mojave to predict the likelihood that those areas will present conservation conflicts. It is designed to help developers and other stakeholders apply the precautionary principle and proactively avoid areas likely to have a *higher* risk of conflicts, in favor of other areas likely to have *lower* risk. This approach could help reduce the up-front costs and risks of development projects. Siting projects in already degraded areas will lessen overall impacts of development, while also providing stakeholders additional time to study the more ecologically intact areas of the desert and evaluate the conservation-compatibility of development in those areas. Utilities can use this assessment to evaluate the potential risk associated with timely completion of projects, as one component of their project evaluation process.

This assessment can complement existing state and federal planning processes that seek to develop renewable energy resources while maintaining resource conservation values. It is *not* offered to replace these stakeholder-driven processes, or to supersede local land use planning and authority; public input on siting decisions is important. Rather, we present these results as a transparent analysis of available data, and offer the matrix classification schema a tool that can inform land use decision making.

1.9.2 Limitations of this Assessment

This assessment is a GIS-based analysis, and cannot substitute for site-based field assessment of resource values because many resources and locations within the study area are poorly surveyed. Although we believe the analysis can be used to presumptively rule out some areas for siting, the reverse is not true—data gaps limit the ability to use this assessment to support positive site-level decisions for development. As a filter, it should be used to sort areas into different categories of constraint from an environmental point of view, and to prioritize further investigation for conservation or development. This study is meant to aid local land use authorities such as counties in assessing the potential environmental conflict associated with different scenarios of solar energy development. We underscore that the results of the study are not meant to be interpreted as suggested zoning or designations.

Ecological processes in the desert are in many cases poorly understood, and even well-documented processes can be difficult to present spatially. For example, connections between surface water and groundwater cannot be easily measured or characterized at the landscape-scale. In the face of these difficulties, a better understanding of the effects of development on these less apparent ecosystem processes should be sought and incorporated into the process of evaluating sites for development. This will likely require an adaptive planning approach, requiring conservative siting approval conditions to model and detect possible adverse effects, combined with longer-term study and monitoring of the effects of installed facilities, with triggered mitigation if adverse effects are likely.

Maintaining landscape connectivity is imperative for sustaining biodiversity values (i.e. functionality, viability) in the desert, especially in the context of projected changes in environmental conditions due to climate change. While this assessment includes some information about important wildlife linkages (as one surrogate for features that may facilitate climate change adaptation), a more thorough, holistic understanding of landscape integrity should be incorporated into the planning process for renewable energy siting, including using projections of species distribution under various climate and land use change scenarios. Determining how the impacts of development will affect connectivity and incorporating this knowledge into planning and siting decisions is critical for protecting the long-term viability of desert plants and wildlife.

There are several known data gaps that should be addressed. High resolution vegetation data is not available yet for this study area, but should be incorporated when it becomes available. Forthcoming high resolution mapping of vegetation communities from the California Native Plant Society and the California Department of Fish and Game for the region needs to be considered for any ongoing and future conservation planning, as it fills a much needed gap in assessing the composition, structure and ecological integrity of vegetation. Vegetation type and condition data is critical for hydrologic, ecosystem and wildlife modeling and as such plays a “keystone” role in conservation planning. Data gaps for riparian and wetland resources are chronic throughout California, as is the detection of casual off-highway vehicle use routes. The Mojave Desert Ecoregional Assessment (Randall et al. 2010), which employed an exhaustive photo interpretation analysis, is still probably the best source for these types of disturbances that do not typically show up in GIS data. Additional inventory of such disturbances is important especially in addressing cumulative impacts. We also struggled with an appropriate way to assess vacant areas close to cities and towns. In many cases (based on field reconnaissance) these areas are very large, but often are more difficult to identify in a GIS-based analysis.

Additional environmental, biogeographic, and conservation planning information not included in this assessment should be considered when planning for renewable energy development in the western

Mojave Desert. For example, although lands and waters identified as Important Bird Areas (IBAs) by National Audubon Society were not incorporated into this assessment, they should be evaluated as siting decisions are made. The Antelope Valley IBA is recognized for its global importance[16] particularly as foraging habitat for raptors. See Appendix 1 for a map showing the least conflict matrix results with the Antelope Valley IBA and locations important for Swainson's hawk.

Prioritizing agricultural areas for energy development is not always appropriate, as the maintenance of productive agricultural capacity is an important element of many rural economies. However, planning decisions do need to consider the likely long-term viability of different agricultural crops in the desert, especially given scenarios of climate change and its impact on water availability and growing conditions. Carefully considered, future agricultural uses of desert lands may not be economically viable.

Conservation success requires that land use decisions be made in light of the cumulative impacts of *all* of the developments and other changes which have occurred, are underway, or are likely to occur within a given geography. This means that the potential impacts of proposed energy facilities must be comprehensively evaluated, and that cumulative impacts that emerge due to present and future siting decisions within a given region must be assessed as each facility is considered for approval. Cumulative impacts assessments predict and weigh the overall effects of development proposed for, and occurring at, multiple sites on the biodiversity and other natural resources of the region over the long term. There are limits on how much conversion and alteration a landscape can accommodate before it ceases to function in a manner that allows native species and natural community diversity to persist. It is extremely important, therefore, to ascertain *a priori*, and not as a moving target, where ecological thresholds lie to avoid crossing them and causing irreversible damage. Adherence to the precautionary principle and the mitigation hierarchy[17] in land-use decision making, as well as fostering cross-jurisdictional and cross-sector collaboration to allow for comprehensive and adaptive monitoring, management, and research, will be essential to ensure successful biodiversity conservation of the western Mojave Desert into the future.

---

[16] http://iba.audubon.org/iba/viewSiteProfile.do?siteId=270&navSite=state

[17] The Council on Environmental Quality (CEQ), empowered by presidential executive order, defines environmental review requirements for executive agencies approving projects, including most utility scale solar facilities, subject to the National Environmental Policy Act. In policy guidance issued January 14, 2011, titled "Appropriate Use of Mitigation and Monitoring and Clarifying the Appropriate Use of Mitigated Findings of No Significant Impact," the CEQ provided specific definition in following mitigation hierarchy requirements in federal agency decision-making on projects.

Finally, while the main focus of this assessment is on conservation concerns, we recognize that industrial-scale renewable energy development also has the power to transform landscapes socially and economically. We are not experts in all of the potential environmental, social, cultural, or economic impacts or constraints of renewable energy development in the desert, nor in the design, construction, or operation of renewable energy facilities. Many of these considerations are important, but beyond the scope of this assessment. As similar assessments become available for cultural, social and economic constraints of energy development, we propose developing an integrated analysis framework to weigh objectives in an attempt to reduce trade-offs.

2. A Framework for Aligning Compensatory Mitigation with Landscape Conservation in the Western Mojave Desert

2.1 Introduction

The goal of this section is to develop a framework for strategic compensatory mitigation that integrates the requirements of traditional mitigation with broader conservation goals, such as maintaining biodiversity and sustaining landscape-scale ecological values[18] within the western Mojave Desert. The first goal of mitigation should always be the prevention of harm to habitats and species through avoidance. Where that goal cannot be met, full and permanent compensation for all remaining harm—providing a net benefit for species and habitats—should be required.

Rational structuring and implementation of mitigation tools can help advance the dual societal goals of increased renewable energy development and conservation of biodiversity. Designed well, policies that guide the implementation of these tools can provide powerful *incentives* for renewable energy development in areas of "least conflict" that avoid ecologically important locations. Such policies can also help to promote a regional *framework* for aligning any offsets with broader conservation needs.

Utility-scale solar plants permanently disturb large areas of habitat wherever they are sited, and some form of permanent mitigation to offset damage to ecological values will therefore be necessary. In the western Mojave Desert, large tracts of previously disturbed lands exist where habitat values are degraded or diminished. These "low conflict" areas are often the most ecologically preferred solar development locations, and agency[19] policy should strive to give developers effective incentives to locate plants in these disturbed areas, while precluding or disincentivizing siting in ecologically valuable locations.

For a number of reasons, intact, high-quality desert habitat has been targeted by developers for utility-scale solar plant sites in the Mojave Desert, primarily on Bureau of Land Management (BLM) managed

---

[18] Landscape-scale ecological values refers to the ecological patterns (e.g. soil type, biophysical gradients) and processes (e.g. flow of disturbances, species, nutrients or water within and among different ecosystems) that influence the distribution, structure and function of ecosystems at a geographic scale of 10^4 to 10^6 acres.

[19] Agency here refers to federal, state, and county authorities: different combinations of these agencies have authority and responsibility for approving solar plants depending on location, generation technology, and size of the proposed plant; uniformity in mitigation practices given different statutory and regulatory rules has presented a real problem.

lands. If applications in these areas go forward, as some already have, significant, permanent damage will certainly persist even after application of aggressive on-site mitigation actions. Given this, strategic compensatory mitigation must be implemented to improve and secure conservation benefits to affected species and habitats commensurate with the impacts of the project, which will last beyond the operating life of the project. We recommend developing a strategic mitigation policy to encourage siting in "least conflict" areas of low ecological (and cultural) value; discourage applications in ecologically valuable locations, and to fully compensate for unavoidable damage that will result if and when plants are located in ecologically valuable sites. We further recommend that the goals of compensatory mitigation should be to accrue benefits to whole ecosystems, leveraging mitigation funds for broader conservation objectives.

Devising a program for ecologically effective, lasting compensatory mitigation for ecological harm is challenging. Existing agency practice largely determines compensatory mitigation measures case-by-case, gauging requirements by the project's projected effects on a limited set of listed and sensitive species and their habitats. We propose here a more comprehensive, regionally focused compensatory mitigation framework that would advance and inform the content and coverage of the California state-sponsored Desert Renewable Energy Conservation Plan (DRECP), which is currently under development.

We organize the framework by first discussing the importance of implementing the mitigation hierarchy, and stress the primary role of avoidance and minimization strategies as the cornerstone of protecting conservation priorities in the face of infrastructure development. The document then goes into more detail to propose guidelines for matching compensatory mitigation to conservation needs across a broader spectrum of habitats and species of interest.

2.2 Following the "Mitigation Hierarchy[20]"

A. **Avoid**— Regional planning, verified by on-the-ground surveys or validated mapping with proper attributes, is necessary to identify areas of the broader landscape with the lowest conservation resource values, and to direct development toward these areas and away from areas with higher ecological value. Equally important is to identify those areas that contain such important

---

[20] The Council on Environmental Quality (CEQ), empowered by presidential executive order, defines environmental review requirements for executive agencies approving projects, including most utility scale solar facilities, subject to the National Environmental Policy Act. In policy guidance issued January 14, 2011, titled "Appropriate Use of Mitigation and Monitoring and Clarifying the Appropriate Use of Mitigated Findings of No Significant Impact," the CEQ provided specific definition in following mitigation hierarchy requirements in federal agency decision-making on projects.

ecological values that they should not be considered in the lands available for development. These "ecologically core" areas – which are essential to meeting broader conservation goals – should be avoided completely from siting of renewable energy as well as other development. Pursuing this first step in the hierarchy (avoidance), offers the best opportunity to preserve and improve conservation values across a landscape while allowing for development of solar power plants (Figure 9). Avoidance should take precedence over minimization and offsetting strategies—the best compensatory mitigation plan is the one that is not needed.

B. **Minimize**— When complete avoidance is infeasible, additional steps must be taken to minimize impacts. At the project scale, planning verified by concurrent pre-construction surveys should designate specific areas to be avoided (e.g., unique plant populations, raptor nesting areas, animal colonies, stands of sensitive or rare vegetation), and development activities should be moved within the application's acreage envelope to avoid all sensitive areas. (Note: this implementation of avoidance measures as part of minimization is different from avoidance of siting in areas that are critical to meeting broader ecological goals.) This may be accomplished through changes in technology (e.g., shifting from concentrating solar to photovoltaic generation to minimize use of ground water), timing of activities (e.g., avoiding critical life history phases), or by choosing different construction practices.

C. **Restore**— Sites that are unavoidably harmed should be restored, where possible, through rehabilitation of the affected area, to conditions that support ecological processes, natural communities, and patterns of species distribution and abundance to levels at or above pre-disturbance levels within reasonable time limits[21]. It is important to note that ecological restoration of desert systems is costly and the probability for long-term success is often low (Lovich and Bainbridge 1999). Where avoidance, minimization, and restoration actions are not likely to be able to prevent significant adverse ecological impacts or to fully restore affected resources, serious consideration should be given to relocating the development to a different location, ideally within a "least conflict" area.

D. **Compensate**— All remaining (residual) harm should be fully and permanently offset with a goal of providing a net positive benefit to the affected ecological systems (Figure 10)[22]. There are

---

[21] "Restoration" in parts of the western Mojave subregion such as the Antelope Valley may include better managed grazing and agricultural practices compatible with maintenance of mosaics of vegetation in different seral states.

[22] If compensation is used, then a good understanding of "in-kind" is very important. At the least it should be completed within a well circumscribed area based on knowledge of ecological variation across the landscape.

many aspects to selecting sites and strategies for offsetting that are discussed in Section 2.3, entitled "Aligning Mitigation actions with Landscape-Scale Conservation Priorities."

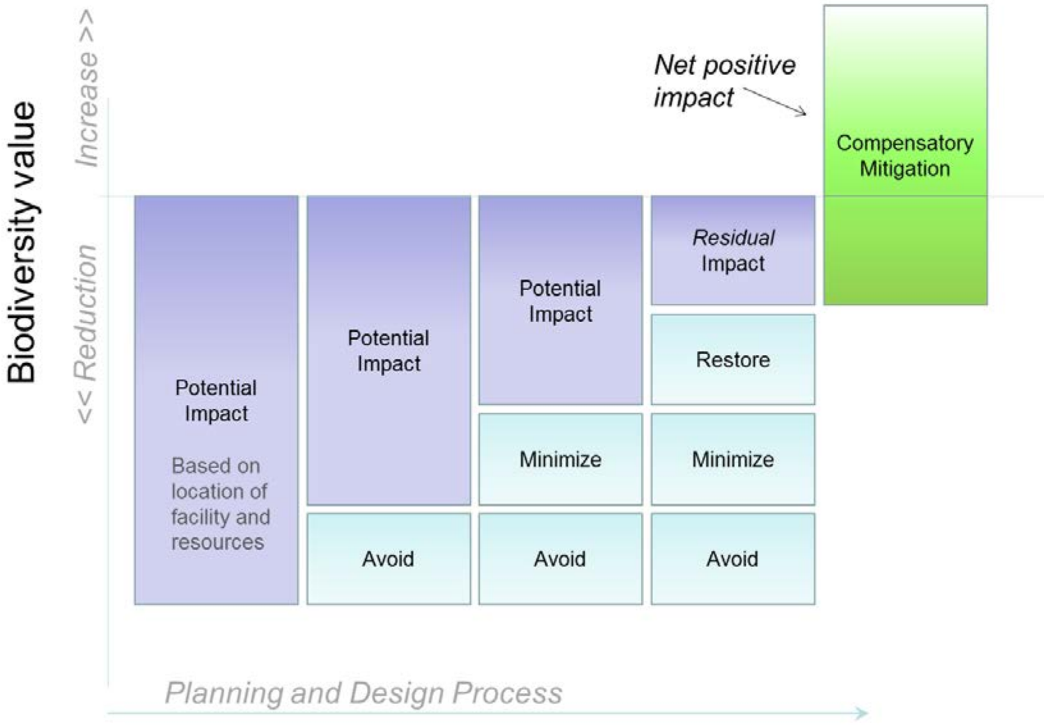


Figure 10. Visualizing the Steps of the Mitigation Hierarchy
As a project works its way through the siting, planning and design phases, it is imperative to choose locations that avoid impacts. If impacts cannot be completely avoided then the developer needs to take steps to minimize impacts such as shifting the footprint to minimize habitat and species disturbance or choosing technology that minimizes use of groundwater resources. Once impacts are minimized to the full extent, then restoration opportunities, if available, should be taken. Residual impacts that remain despite actions taken to avoid, minimize, and restore damage must be offset through compensatory mitigation, and should result in a net positive impact on biodiversity. Figure adapted from the Convention on Biological Diversity: https://www.cbd.int/images/biz/biz2010-03-03-p36.jpg.

2.2.1 The Role of Landscape Planning

Landscape or regional conservation planning is an essential tool for reducing adverse ecological effects of infrastructure development[23]. Science-based assessments provide the context and location of areas to be avoided by development activities. In their absence, development almost invariably proceeds

---

[23] As an example of this approach, in January of 2012 The Nature Conservancy provided comments on the Supplement to the Draft Solar Programmatic Impact Statement (http://solareis.anl.gov/documents/supp/index.cfm) that included an analysis of various solar development alternatives using the Mojave Desert Ecoregional Assessment (Randall et al. 2010).

haphazardly without due attention to key species, habitats and the importance of maintaining ecological processes across the landscape. Such processes – hydrological cycles, plant and animal dispersal, sand transport, for example —are critical to ecosystems and the long term viability of many native species. Habitat connectivity may be especially important for species' ability to adapt to climate change over the longer term. Landscape-level conservation plans also characterize and map the distribution of habitats and species characteristic of the biodiversity of a region within the context of existing and projected future land uses and other stressors. Other sources of information that can inform avoidance or compensatory mitigation strategies include recovery plans and other species-based assessments of distribution, population status, and threats.

The Nature Conservancy has developed a methodology for incorporating landscape-level planning into development decisions. "Development by Design[24]" considers the ecological values of a region proposed for development in order to direct development away from conservation priorities and to align compensatory mitigation with broader conservation objectives. This approach was originally developed to address impacts of oil and gas extraction (Kiesecker et al. 2010, Copeland et al. 2009), and has been applied domestically and internationally (Heiner et al. 2011) across infrastructure and ecosystem types including wind power (Kiesecker et al. 2011, Obermeyer et al. 2011). A recent application of this approach addresses the current pressure from solar development in the Mojave Desert (Cameron et al. 2012). In some cases, these assessments may also evaluate the effectiveness of potential avoidance and minimization measures[25]. We advocate the use of this or another similar method to integrate, through planning, collective regional project effects with mitigation actions to maintain or improve conservation values for key species and habitats and overall regional biodiversity. Compensatory mitigation requirements should accordingly focus on sites and strategies prioritized in such plans and assessments. Below, we present examples of the use of ecological data and conservation priorities in the mitigation hierarchy organized by the spatial scale at which the information is most useful (Table 5).

---

[24] http://www.nature.org/aboutus/developmentbydesign/index.htm

[25] Avoidance, minimization and restoration requirements are often included under the agency rubric of "best management practices (BMPs)." BMPs are applied with reasonable uniformity to similar developments, although often specific project features mandate additional or different avoidance, minimization or restoration requirements.

Table 5. The Role of Ecological Data and Conservation Priorities in the Mitigation Hierarchy
Adapted from Randall et al. (2010).

Step in the Hierarchy	Definition (40 CFR, Sec 1508.20)	Role of Ecological Data and Conservation Priorities	Scale of Information Needed
Avoid	Avoiding the impact altogether by not taking a certain action or parts of an action at a given site (action may be taken at another site with low ecological value)	Determine what areas should be avoided based on conservation value	Region[26], landscape, site
Minimize	Minimizing impacts by limiting the degree or magnitude of the action and its implementation or by designing the project to protect or leave untouched portions of the development site with higher ecological value (such as rare plant populations, bird nesting areas or unusual community assemblages).	Determining the extent of impact resulting from different options for technology type, different scales of build out, or different practices (e.g., wet vs. dry cooling), different timing of construction activities	Landscape, Site
Restore/Reduce	Rectifying the impact by repairing, rehabilitating, or restoring the affected environment	Help assess what resources may be restorable, determine the configuration and context for linking restoration with broader ecosystem flows, help define viability criteria or performance measures for "restored" function	Landscape, Site
Compensatory mitigation	Compensating for the impact by replacing or providing substitute resources or environments	Help define areas where mitigation can contribute to conservation goals, identify and define options for locations, assess landscape context for mitigation to assess viability	Region, landscape, site

2.3 Aligning Mitigation Actions with Landscape-Scale Conservation Priorities

Landscape-scale planning can identify and prioritize locations where off-site mitigation opportunities may be found, define how mitigation requirements should be structured, and identify potential compensatory actions that are most likely to be effective, as well as those that should be avoided because they are likely to be harmful or ineffective (Wilkinson et al 2009). Below we list evaluative criteria for identifying and prioritizing appropriate sites for compensatory mitigation, provide recommendations for how multiple species should be treated in compensatory mitigation programs, and outline several steps to ensure that mitigation priorities are properly reflected in decision making.

---

[26] Ecoregion or other region defined by biophysical or cultural attributes, typically with an area of 10^6 to 10^7 acres.

2.3.1 Selecting Priority Sites for Compensatory Mitigation Investments

A. Landscape Context—desirable areas exhibit one or more of the following characteristics:

  a. An area where surrounding land uses are likely to preserve and enhance mitigation benefits over time is preferred. Areas significantly impacted by trespass, areas invaded by non-native species, areas with adverse changes in water quantity or quality due to human activities, and/or areas with significant levels of anthropogenic dust, noise, or night-time light may be able to provide relatively little ecological benefit (e.g., they may support no target species or may even serve as a population "sink" for species that they do attract) and should generally be avoided.

  b. Areas with heterogeneity in biota, climate factors, or physical gradients that will facilitate adaptation and expand the available bioclimatic "space" for species to adjust to changing conditions are preferred. Adjacency or connectivity to areas with these characteristics is suitable if they are not available at a sufficient scale on the site itself.

  c. Areas that provide movement corridors between ecologically-defined and effectively protected landscape units or habitat blocks are preferred. Areas that are bounded by closed barriers between adjacent and nearby units should be avoided. Linkage protection is an example of a conservation action that can yield ecological benefits far beyond the location of an individual project.

  d. Areas featuring desert aquatic and riparian habitats supplied by perennial, protected sources of water are desirable. If protection occurs in areas with over-allocated and depleted groundwater basins, water acquisition to reverse the situation should be part of the protection strategy.

B. Biodiversity attributes

  a. Areas featuring distinct or unique assemblages of species or communities or locations that provide valuable ecosystem services (e.g., rare plant assemblages, desert washes), and extra-limital populations or occurrences of species or communities should be considered.

  b. Sites featuring high-quality habitat for, and healthy populations of, both target species (especially those that are special-status) and non-target species are desirable. Existing conservation and resource management plans often identify these areas.

C. **Administrative or Legal Designation—permanence of conservation protections**
    - **a.** Areas that offer assured long-term protection of conservation values are essential. This protection can consist of perpetual easements, other permanent legal restrictions or agency designations that cannot be easily undone through subsequent administrative action. Under current law and agency practice, tools such as Area of Critical Environmental Concern (ACEC) designations to protect ecological use of public lands at broad scales through re-designation are inadequate.
    - **b.** Areas that continue to allow uses that might prevent successful implementation of mitigation actions are not appropriate (e.g., grandfathered off-highway vehicle [OHV] events or livestock grazing allotments, including those that allow motorized access for maintenance). However, mitigation investment in these areas that also includes the permanent cessation of activities that negatively impact native species, natural communities, and/or ecosystem processes is appropriate.

D. **Proximity to Impacts**
    - **a.** Priority should be given to sites that present the best options for successful mitigation and conservation co-benefits, without regard to proximity to the impact area. The offset and impact need to be ecologically similar but the assumption that "closer is better" in mitigation siting is often not defensible ecologically, especially given the associated edge effects caused by nearby infrastructure.

2.3.2 Selecting Species and Communities in Mitigation Planning

A. Compensatory mitigation should seek to provide benefits to the full array of species, habitats, and ecological processes damaged by the development, not just to those species for which mitigation is customarily administratively mandated. Mitigation targets should be broadened beyond species that are rare, sensitive, and/or declining, or that have protected regulatory status for other reasons. Targets should include a wider array of species, habitat types, and ecological features[27]:

  - **a.** Mitigation targets should include more than just federal/state listed species and should address impacts to more common species and habitats. Every time a large amount of habitat is destroyed, formerly common species become rarer, so impacts are felt beyond endemics and highly-protected listed species. A good mitigation program should account for this.
  - **b.** Accounting systems should track the effects of compensatory mitigation actions to a range of affected habitats, in area, abundance or other functional units across a number of infrastructure projects to assess cumulative effects. Monitoring and reporting should feed into a regional monitoring system that allows for the analysis of broader impacts, cumulative impacts, and the progress of restoration over time.
  - **c.** As noted, following the Habitat Conservation Plan model would mitigate for many ecological factors at once with clear boundaries and rules for compensatory mitigation in places where development is allowed.
  - **d.** Mitigation actions should be informed by region-wide cumulative impact analyses done not just for listed and sensitive species—but also for natural communities at the habitat-type level. Cumulative impact assessments need to consider the full range of threats to a species or community, including impacts projected to be caused by climate change. Modeling and forecasting should be developed for species that are most imperiled.

- **B.** Use of ground or surface water should always be mitigated
  - **a.** State CDFG/EPA rules require mitigation for surface water in certain circumstances, but not always, and groundwater use generally has no mitigation requirements (an exception is where groundwater use interferes with other human uses, such as the Colorado River or a privately-owned well).
  - **b.** As defined in the desert, “waters” should include washes, arroyos, and other water courses that are not regularly flowing.

---

[27] Properly designed compensatory mitigation programs should address a range of species and other features of habitat conservation plans, as will California’s Desert Renewable Conservation Plan (DRECP), which is now under development. The DRECP will cover a broad range of species, habitats and actions that will trigger compensatory mitigation actions ranked regionally.

2.3.3 Prioritizing Mitigation Actions

A. Identify high-priority mitigation actions (there needs to be some measurable effectiveness attributable to these actions). Some possibilities include:

  a. Acquire privately-held lands that comprise or connect large blocks of good habitat.

    i. Inholdings within a larger protected area or that connect existing protected areas (e.g., privately-owned parcels within or abutting National Parks, ACECs, or wilderness areas) should be prioritized.

    ii. Exclude, or reduce in the priority list lands that have been developed or severely disturbed (e.g., OHV recreation areas and most agricultural lands).

  b. Control or limit OHV access.

    i. Limit non-utility maintenance access to new and existing transmission corridors as a way to limit OHV use.

    ii. Barricade or obfuscate illegal routes; close open routes used for illegal access.

    iii. Fence roads to prevent desert tortoise and other susceptible animals from wandering onto them and being killed and provide or retrofit under-road passages for tortoises and other terrestrial vertebrates.

    iv. Reroute competitive/organized OHV events to non-mitigation public lands.

  c. Improve public land management effectiveness

    i. Protectively designate mitigation areas by permanently withdrawing these lands from uses incompatible with long-term biodiversity conservation.

    ii. Close areas to mineral and materials exploration.

    iii. Permanently retire livestock grazing allotments in the Mojave Desert where grazing is driving normal vegetation states across thresholds such that severe restoration and management is needed to bring them back.

B. Identify and avoid low-priority mitigation actions—where benefits are hard to measure or measurable, but slight[28]. Some possibilities include:

  a. Increased law enforcement (e.g., adding enforcement officers especially where penalties are slight). Officers will not work weekends and holidays when violations of OHV and other use rules are most likely to threaten target species and habitats.

  b. Small-parcel private land acquisition that is not within, connected to, or near already protected areas, unless it has unique values that are not possible to replicate elsewhere. Some small reserves are effective depending on their core attributes.

  c. Public education and outreach ostensibly designed to reduce activities that threaten target species and habitats, but whose benefits to those targets are extremely difficult to detect and quantify.

Combining the suggested guidelines for selecting locations, targets, and strategies into a decision-making process can help provide transparency and structure to mitigation requirements (Figure 11). These factors can be put into a decision tree framework or a scoring scheme that can utilize a variety of data, and help to standardize compensatory mitigation site and project selection.

---

[28] These actions may be necessary and appropriate as part of an agency implementation of required species recovery actions, but they are not appropriate as a mitigation investment.

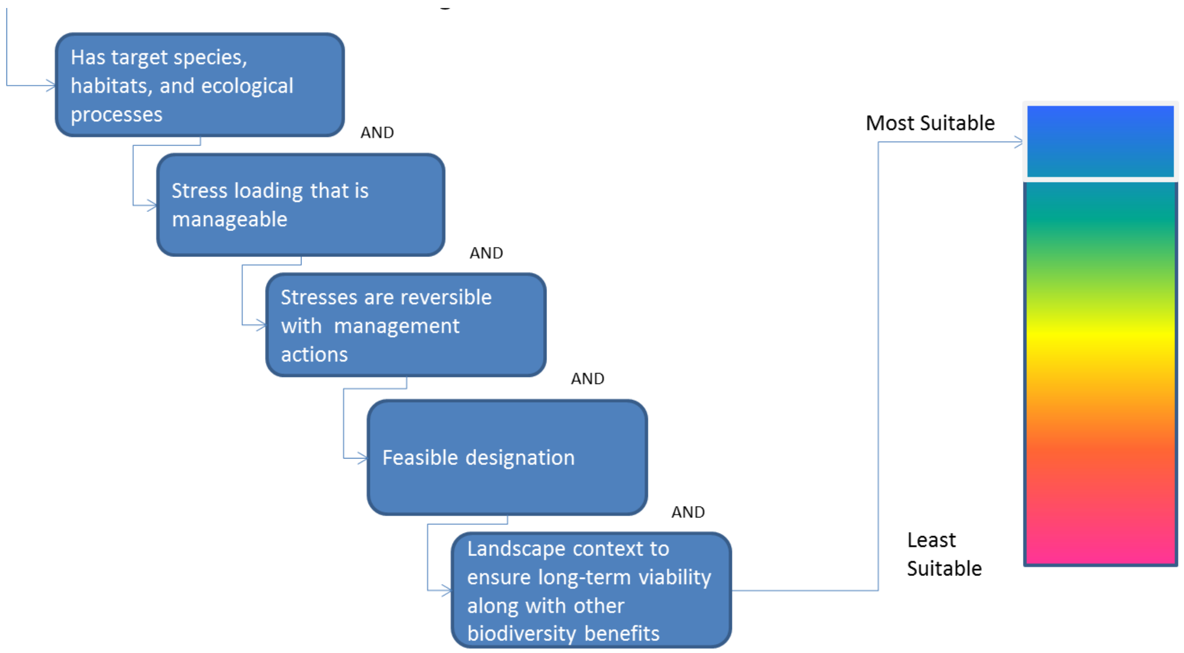


Figure 11. Key Steps and Factors to Address in the Selection of Suitable Mitigation Sites and Projects

2.4 Recommendations on Policy and Process

Successful compensatory mitigation programs require considerable attention to design and implementation details. Current agency compensatory mitigation programs could be improved by increased transparency, consistency, and consideration of cumulative impacts; monitoring of effects of actions taken; and broadening of goals to prioritize sites and actions that benefit a broad array of species, habitats, and ecological processes rather than a narrow focus on species for which mitigation is customarily administratively mandated.

Existing agency mitigation decisions have largely centered on devising case-by-case compensation for predicted adverse effects on a limited number of listed and sensitive species. By focusing on individual project mitigation, mostly near the project site, the conservation benefit of considering and planning for the impact of multiple projects to an entire suite of species and habitats is lost. This more comprehensive approach to mitigation is embodied in habitat conservation plans such as the Desert Renewable Energy Conservation Plan (DRECP), currently in development. A comprehensive approach is most effective when necessary information is available prior to decision-making.

Agency mitigation programs have suffered from a lack of consistency, transparency, and monitoring[29]. Without clear regulatory guidance on how to conduct compensatory mitigation, decisions are inconsistent. Some resource management plans (and associated biological opinions) contain guidance on aspects of compensatory mitigation, but these plans were formulated without consideration of the large habitat impacts generated by industrial scale solar development. Desert groundwater withdrawals by solar facilities have not usually triggered the imposition of compensatory mitigation unless they affect regulated sources (e.g., Colorado River) or other human uses, thus ignoring compensation for long-term effects on key riparian and aquatic ecological resources.

Federal and state compensatory mitigation approaches often differ, and these differences in approach go beyond what is required by the framework statutes of different agencies. On-the-ground and case-by-case mitigation decisions made by BLM can also differ markedly from one field office to another. Specific compensatory mitigation determinations are frequently made after project approvals are in place, and the decisional process is often not open to public comment and review. Long-term monitoring and follow up on compensatory mitigation actions—with the exception of the comprehensive monitoring programs to implement desert tortoise protection—are usually lacking as well. Critical assumptions about the success and permanence of mitigation actions must be assessed with long-term monitoring to ensure that they are not misplaced as has often been alleged, and to ensure that compensation for long-term habitat disturbance by projects is actually realized and not just asserted.

California deserts have limited tracts of privately owned lands with quality natural habitat, so the generally preferred compensatory mitigation option—acquisition and protection of private lands to replace impacted habitats — will not be adequate to compensate for the damages resulting from development of large areas for solar energy production. Consequently, mitigation options must also include actions to improve or restore the habitat qualities of existing public lands[30]. This raises the issue of additionality—that is, whether the mitigation expenditure is replacing funds for actions that the agency was or should have been doing anyway. One approach that could potentially ensure that mitigations expenditures are truly additional is to enact policies that would require expenditures to be

---

[29] For explanation and examples please see: http://www.environment.nsw.gov.au/resources/biobanking/biobankback0609.pdf

[30] In some regions of the Mojave Desert, such as the Antelope Valley, lack of public land may require that all in-kind mitigation take place on privately owned lands.

adequately justified and documented as additional in relation to an agency's pre-established, baseline activities.

2.4.1 Recommendations for Agency Compensatory Mitigation Programs

A. **Clarity:** Adopt clear and consistent compensatory mitigation programs that are based on landscape-level ecological assessments and that fully offset all residual harm to the broad suite of habitats and species after avoidance, minimization, and restoration steps are implemented.

B. **Additionality and Permanence:** Where compensatory mitigation resources are expended on public lands, this investment should be additional as well as permanent (or durable.) Specifically, the area where the investment occurs should remain an area that is designated for the protection of conservation values. Both the designation and the management of the land for the purposes of conservation must be enduring. In addition, the mitigation investment (i.e., the financial resources) must be permanently tied to meeting the mitigation obligations and need to be additive—and do not merely provide funding to or otherwise substitute for current agency programs and obligations (taking into account that many offices, regions and programs are currently understaffed).

C. **Cumulative Impacts:** Ensure that the cumulative impacts of all development in the region are taken into account; plan for and implement regional mitigation efforts that combine resources that address offsets from multiple projects, as developed under Regional Advance Mitigation Planning[31] (RAMP). Developing a regional information and monitoring system that can forecast potential impacts from a broad range of projects and other threats in a spatially-explicit modeling environment can improve the speed, transparency, and rigor of cumulative impacts analyses. The system should include multiple scales of ecosystem impact on individuals, populations, and natural communities, and the interaction of all of these on the landscape. Such a system can measure the contribution of a number of different conservation and mitigation actions to regional conservation goals. It can also serve as a credit and debit system where the units of transaction are in functional units related to the species and habitats in question. Funding for such a system should be sufficient to enable effective data stewardship and stakeholder outreach, including updates

---

[31] https://rampcalifornia.water.ca.gov/documents/18/1299110/RA+Summary+for+CSV.doc?targetExtension=pdf

or additional functionality as new data become available. The Desert Tortoise Recovery Spatial Decision Support System[32] is an excellent example of this type of tool.

D. **Public Input:** Establish mitigation rules openly, and select strategies with public participation and review prior to making decisions.

E. **Adequate Funding:** Ensure that mitigation requirements are adequately funded, enforceable, and fully described in the Environmental Impact Statement Record of Decision as well as in other decisional documents and facility permits.

F. **Monitoring, Enforcement, and Adaptive Management:** Ensure that mitigation actions include monitoring, enforcement, and mandatory adaptive management provisions requiring modification in mitigation actions in the event of failure.

G. **Federal-State Consistency:** Federal and state compensatory mitigation programs should be made internally consistent, congruent where possible, and compatible where statutory provisions require differences. This enables mitigation to be consistent and predictable, and allows agencies to permit cross-boundary compensatory mitigation where landscape-level ecological assessments justify such actions (i.e., between ecologically linked portions of counties, regions, and states).

H. **Incentives for Good Siting:** Design incentives in all mitigation programs, including compensatory mitigation features, which encourage developers to locate facilities on degraded and other low conflict sites, in part by requiring significantly greater off-site compensation for lands that have higher ecological value. In this regard, current compensatory mitigation requirements that provide for multiple habitat replacement acreages for listed species should be expanded to include other species and habitats, and the multiples increased.

I. **Mitigate Impacts to Water:** Compensatory mitigation should be required for all uses of desert groundwater resources. Mandatory mitigation elements include acquisition of a full understanding of the hydrology of the basin where pumping will occur, as well as that of linked basins. Long-term modeling and monitoring designed to predict adverse effects well before they impact protected groundwater dependent resources, and, where impacts are likely, the obligation to reduce or cease groundwater use. Plants should be located outside

---

[32] http://www.spatial.redlands.edu/sds/ontology/?n=SDSSTool:DTRO_SDSS_V3

of groundwater basins where existing and projected uses are likely to exceed sustainable yield, or, at the very least, retirement of existing active senior water rights or uses in multiples of the projected solar plant pumping should be required.

2.5 Mitigation Options for Desert Tortoise in the Western Mojave Desert: an Illustration

Below, we present a series of maps that begin to illustrate the potential set of options for mitigation sites and actions in the western Mojave using the Desert tortoise as an example. While we recognize that this illustration leaves out much of the nuance and complexity associated with implementing mitigation projects, we want to provide some sense of the breadth of mitigation options for this species in this area.

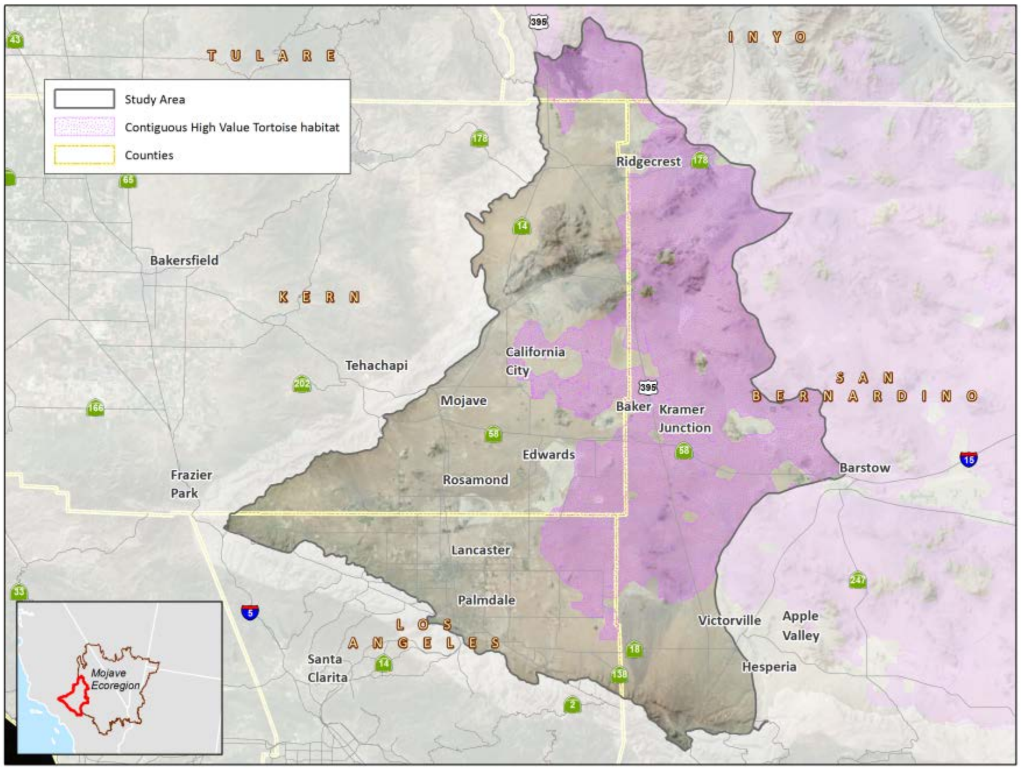


Figure 12. Modeled High-Value Contiguous Tortoise Habitat

By combining a tortoise habitat model[33] (Figure 12) with land ownership and administrative status (Figure 13), we can begin to get at these options and start to illustrate where in the study area primary mitigation strategies might be implemented (Figure 14 and 15). In the region, much of the suitable habitat is already on BLM land, designated as an ACEC or in undesignated status (Figure 16). Additionally, 60% of the private land in high quality habitat is within the designated boundary of an ACEC suggesting that consolidation of ownership within these areas may be a viable mitigation strategy. These maps and pie chart are meant to be illustrative of broader mitigation options in the study areas. Linking the selection of mitigation sites to the sites selected for avoidance in the least conflict matrix companion analysis may present a logical way to link development opportunities with mitigation options.

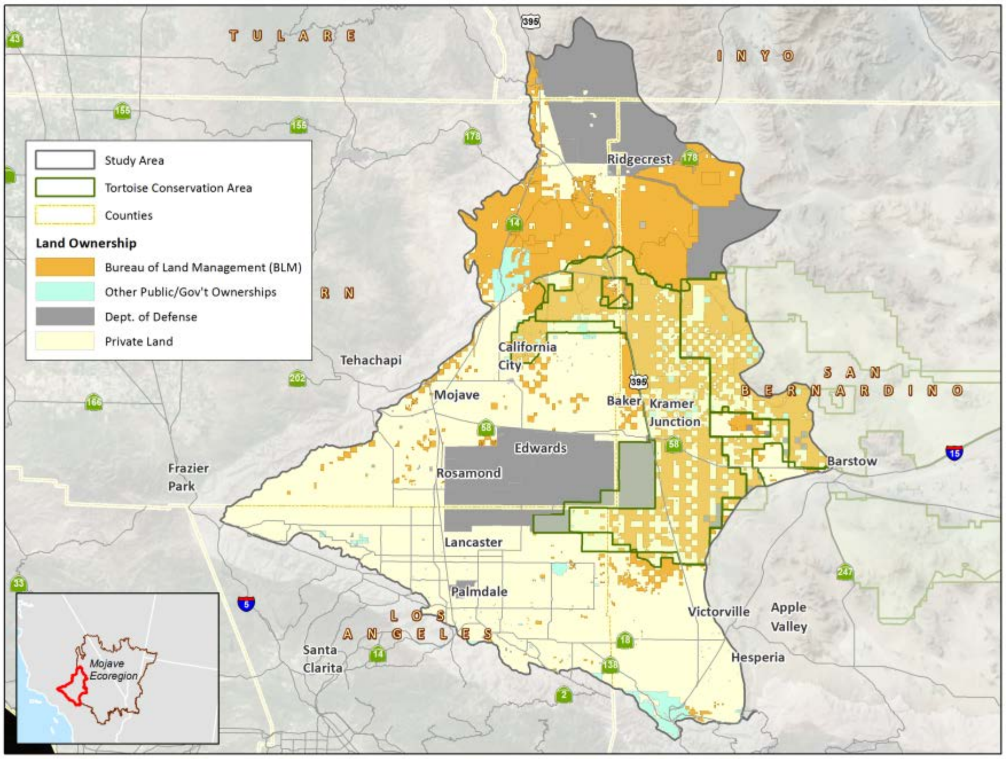


Figure 13. Land Ownership and Administrative Status

---

[33] "Contiguous Highest Value Habitat" developed by U.S. Fish and Wildlife Service, Desert Tortoise Recovery Office, released January 2012.

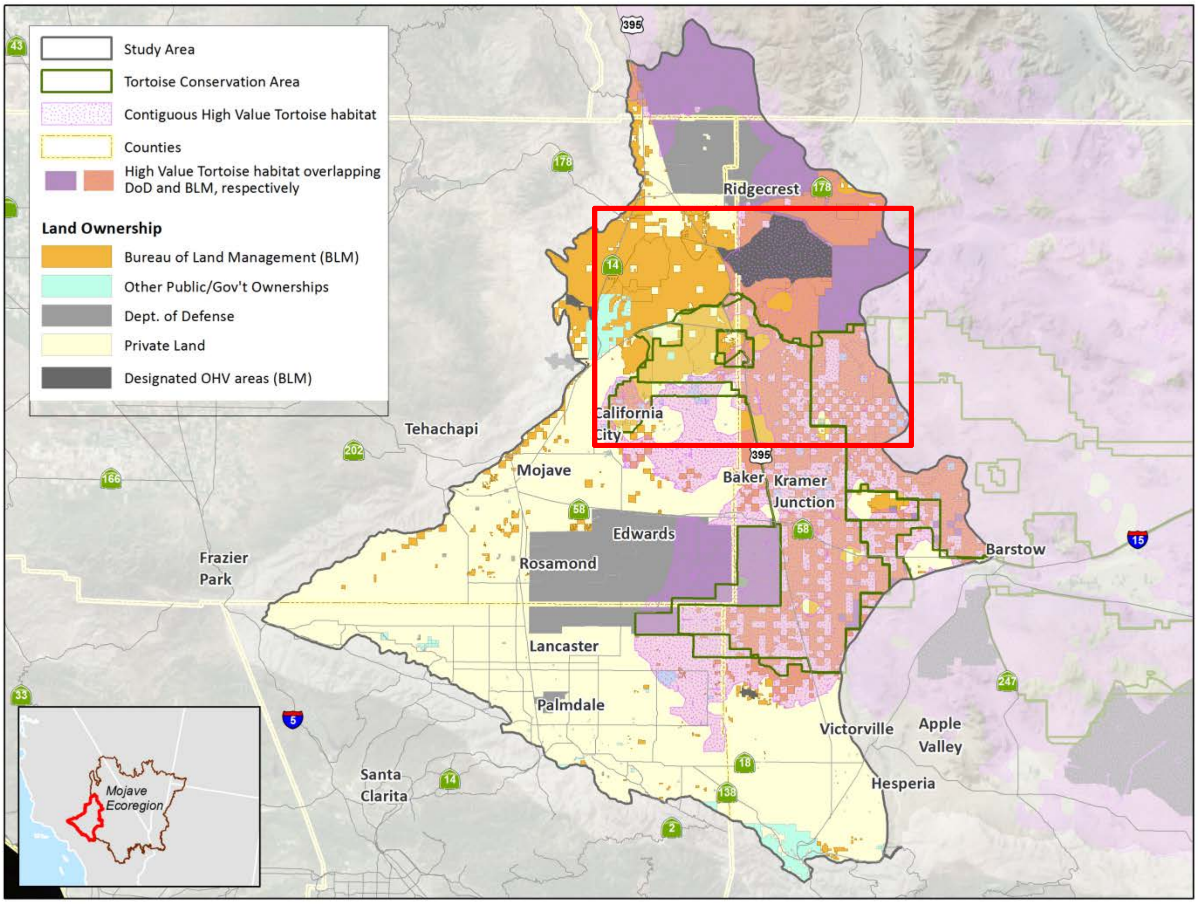
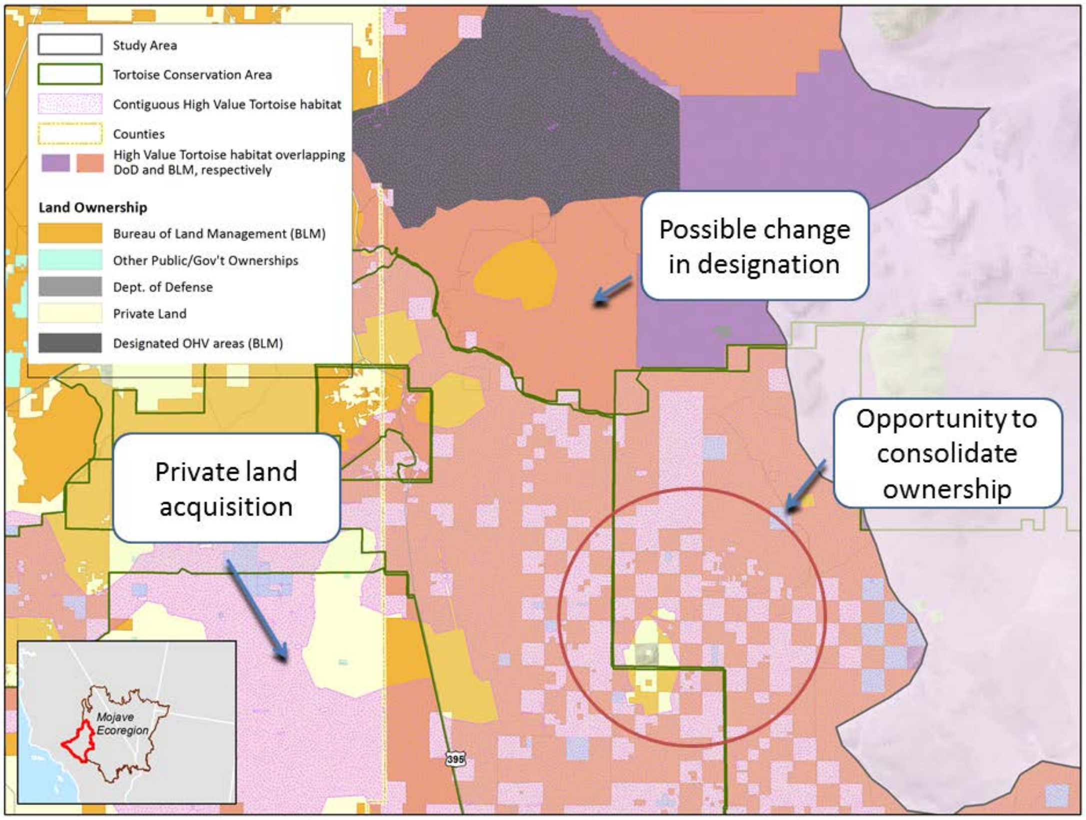


Figure 14. Combination of Tortoise Habitat with Land Ownership and Administrative Status. The focal area in Figure 15 is shown in the red outline.



Possible change in designation

Opportunity to consolidate ownership

Private land acquisition

Figure 15. Examples of Actions that Can Be Integrated through Regional Mitigation Planning

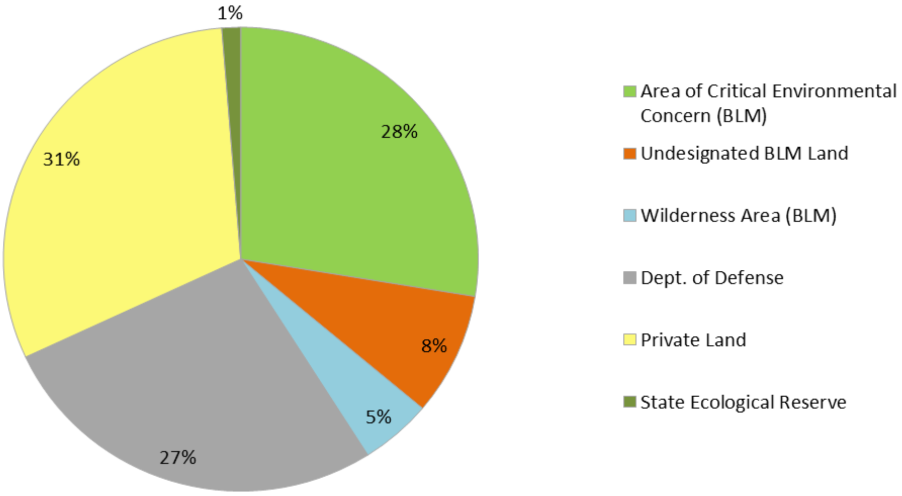


Figure 16. Ownership and Status of Contiguous High Value Desert Tortoise Habitat in the Study Area

3. References

Cameron, D.R., B.S. Cohen, S.A. Morrison. 2012. An approach to enhance the conservation-compatibility of solar energy development. PLoS ONE 7(6):e38437. doi:10.1371/journal.pone.0038437

Copeland, H.E., K.E. Doherty, D.E. Naugle, A. Pocewicz, J.M. Kiesecker. 2009. Mapping oil and gas development potential in the US intermountain west and estimating impacts to species. PLoS ONE 4(10): e7400. doi:10.1371/journal.pone.0007400

DRECP ISA [Desert Renewable Energy Conservation Plan Independent Science Advisors]. 2010. Recommendations of Independent Science Advisors for The California Desert Renewable Energy Conservation Plan (DRECP), DRECP-1000-2010-008-F. Report prepared for the Renewable Energy Action Team: California Department of Fish and Game, U.S. Fish and Wildlife Service, U.S. Bureau of Land Management, and California Energy Commission. 115 pages + appendices. Available at: http://static.consbio.org/media/reports/files/SA_Desert_Renewables.pdf

Heiner, M., G. Davaa, J. Kiesecker, B. McKenney, J. Evans, et al. 2011. Identifying Conservation Priorities in the Face of Future Development: Applying Development by Design in the Grasslands of Mongolia. Unpublished Report. The Nature Conservancy, Arlington, Virginia. 46 pages + appendices. Available at: http://50.18.62.210/DevByDesign/

Kiesecker J.M., H. Copeland, A. Pocewicz, B. McKenney. 2010. Development by design: Blending landscape-level planning with the mitigation hierarchy. Frontiers in Ecology and the Environment 8:261–266.

Kiesecker, J.M., J.S. Evans, J. Fargione, K. Doherty, K.R. Foresman, et al. 2011. Win-win for wind and wildlife: A vision to facilitate sustainable development. PLoS ONE 6(4): e17566. doi:10.1371/journal.pone.0017566

Lovich J.E., D. Bainbridge. 1999. Anthropogenic degradation of the southern California desert ecosystem and prospects for natural recovery and restoration. Environmental Management 24:309–326.

Lovich J.E., J.R. Ennen. 2011. Wildlife conservation and solar energy development in the desert Southwest. BioScience 61: 982-992

Muhs, D. R., R. L. Reynolds, J. Been, G. Skip. 2003. Eolian sand transport pathways in the southwestern United States: importance of the Colorado River and local sources. Quaternary International 104:3–18.

Obermeyer, B., R. Manes, J. Kiesecker, J. Fargione, K. Sochi. 2011. Development by design: Mitigating wind development's impacts on wildlife in Kansas. PLoS ONE 6(10): e26698. doi:10.1371/journal.pone.0026698

Penrod, K., C. Cabañero, C. Luke, P. Beier, W. Spencer, E. Rubin. 2003 South Coast Missing Linkages: A Linkage Design for the Tehachapi Connection. Unpublished report. South Coast Wildlands Project, Monrovia, CA. 48 pages.

Penrod, K., P. Beier, E. Garding, C. Cabañero. 2012. A Linkage Network for the California Deserts. Produced for the Bureau of Land Management and The Wildlands Conservancy. Produced by Science and Collaboration for Connected Wildlands, Fair Oaks, CA www.scwildlands.org and Northern Arizona University, Flagstaff, Arizona. 286 pages. Available at: http://oak.ucc.nau.edu/pb1/.

Randall, J. M., S.S. Parker, J. Moore, B. Cohen, L. Crane, B. Christian, D. Cameron, J. MacKenzie, K. Klausmeyer, S. Morrison. 2010. Mojave Desert Ecoregional Assessment. Unpublished Report. The Nature Conservancy, San Francisco, California. 106 pages + appendices. Available at: http://conserveonline.org/workspaces/mojave/documents/mojave-desert-ecoregional-2010/@@view.html.

Stoms, D.M., S.L. Dashiell, F.W. Davis. 2011. Mapping Compatibility to Minimize Biodiversity Impacts of Solar Energy Development in the California Deserts. UC Santa Barbara Biogeography Lab. Unpublished Report. University of California, Santa Barbara, California. 31 pages.

Webb, R.H., J.S. Heaton, M.L. Brooks, D.M. Miller. 2009. Introduction. pp 1 – 6. *In* R.H. Webb, L Fenstermaker, J. Heaton, D. Hughson, E. McDonald and D. Miller, *editors*. The Mojave Desert: Ecosystem Processes and Sustainability. University of Nevada Press. Reno, Nevada.

Wilkinson, J. B., J.M. McElfish, Jr., R. Kihslinger, R. Bendick, B. McKenney. 2009. The Next Generation of Mitigation: Linking Current and Future Mitigation Programs with State Wildlife Action Plans and Other State and Regional Plans. Arlington, VA. 65 pages. Available at: http://www.elistore.org/reports_detail.asp?ID=11359

4. Appendices

Appendix 1. Species Conservation Targets and Important Avian Values Added to Supplement Avoidance Criteria

Table A1.1. Species Conservation Targets Added to Supplement Avoidance Criteria

Reptiles	**Scientific Name**	**In CNDDB in study area**	**Other sources**
Desert tortoise	*Gopherus agassizii*	N	USFWS tortoise conservation areas
Birds			
Burrowing owl	*Athene cunicularia*	Y	
Prairie falcon	*Falco mexicanus*	Y	
Brown-crested flycatcher	*Myiarchus tyrannulus*	N	
Gray vireo	*Vireo vicinior*	Y	
Inyo California towhee	*Pipilo crissalis eremophilus*	N	
LeConte's thrasher	*Toxostoma lecontei*	Y	
Bendire's thrasher	*Toxostoma bendirei*	N	
Golden eagle	*Aquila chrysaetos*	Y	
Mammals			
Bighorn sheep	*Ovis canadensis*	N (need to evaluate inclusion)	DRECP
Argus Mountains kangaroo rat	*Dipodomys panamintinus argusensus*	N	
Mohave ground squirrel	*Spermophilus mohavensis*	Y	BLM conservation area
Yellow-eared pocket mouse	*Perognathus xanthonotus*	N	
Plants			
Alkali mariposa lily	*Calochortus striatus*	Y	BLM conservation area
Barstow woolly sunflower	*Eriophyllum mohavense*	Y	BLM conservation area
Charlotte's phacelia	*Phacelia nashiana*	Y	
Desert cymopterus	*Cymopterus deserticola*	Y	
Kern buckwheat	*Eriogonum kennedyi* var. *pinicola*	N	
Mojave monkeyflower	*Mimulus mojavensis*	Y	BLM conservation area

Mojave tarplant	*Deinandra [Hemizonia] mohavensis*	N	
Parish's phacelia	*Phacelia parishii*	Y	BLM conservation area
Parish's popcorn flower	*Plagiobothrys parishii*	*presumed extirpated*	
Red Rock poppy	*Eschscholtzia minutiflora* ssp. *Twisselmannii*	Y	
Red Rock tarplant	*Deinandra* [*Hemizonia*] *arida*	Y	
Short-joint beavertail cactus	*Opuntia basilaris* var. *brachyclada*	Y	
Spanish needle onion	*Allium shevockii*	N	
Cream layia	*Layia heterotricha*	N	
Palmer's jackass clover	*Wizlizenia refracta* ssp.*palmeri*	N	
Lancaster milkvetch	*Astragalus preussii* var. *laxiflorus*	Y	
Piute Mountains jewelflower	*Streptanthus cordatus* var. *piutensis*	N	
Sagebrush loeflingea	*Loeflingea squarrosa* var. *artemisiarum*	Y	
Flax-like monardella	*Monardella linoides* ssp. *oblonga*	N	
Pygmy poppy	*Canbya candida*	N	
Kelso Creek monkeyflower	*Mimulus shevockii*	N	
Clokey's cryptantha	*Cryptantha clokeyi*	Y	

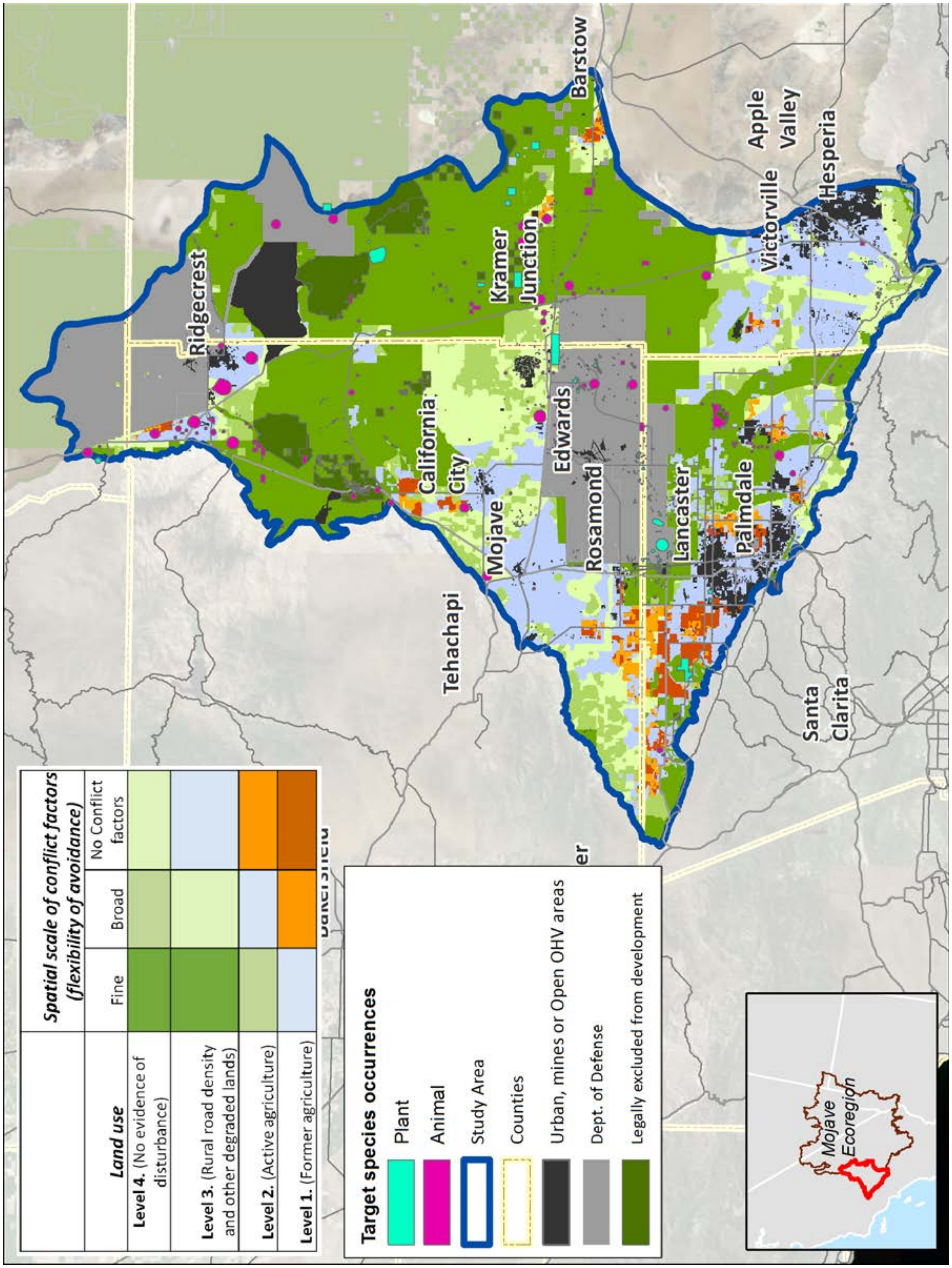


Figure A1.1. Least Conflict Criteria Matrix and CNDDB Occurrences of Species Added to Supplement Avoidance Criteria

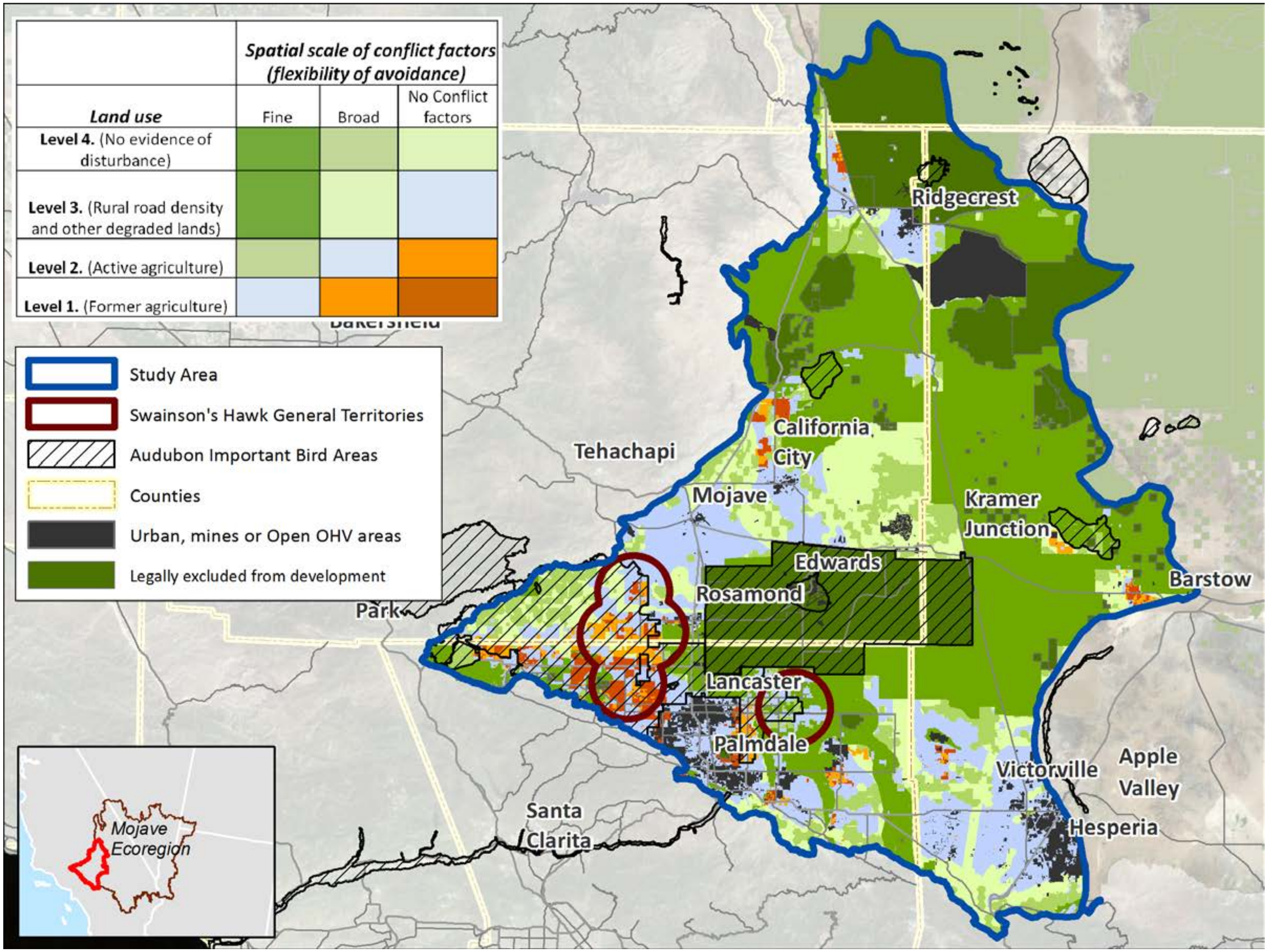
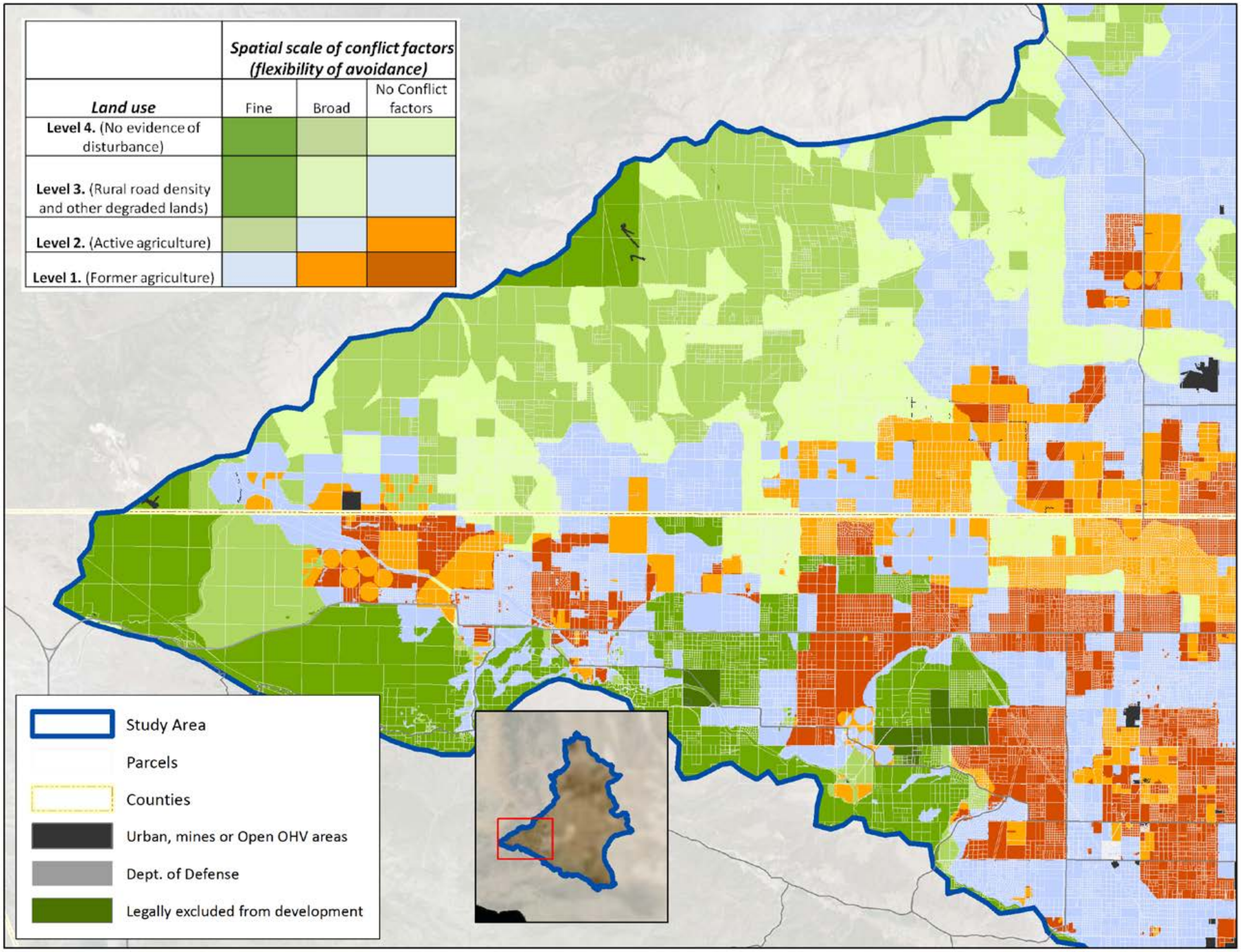
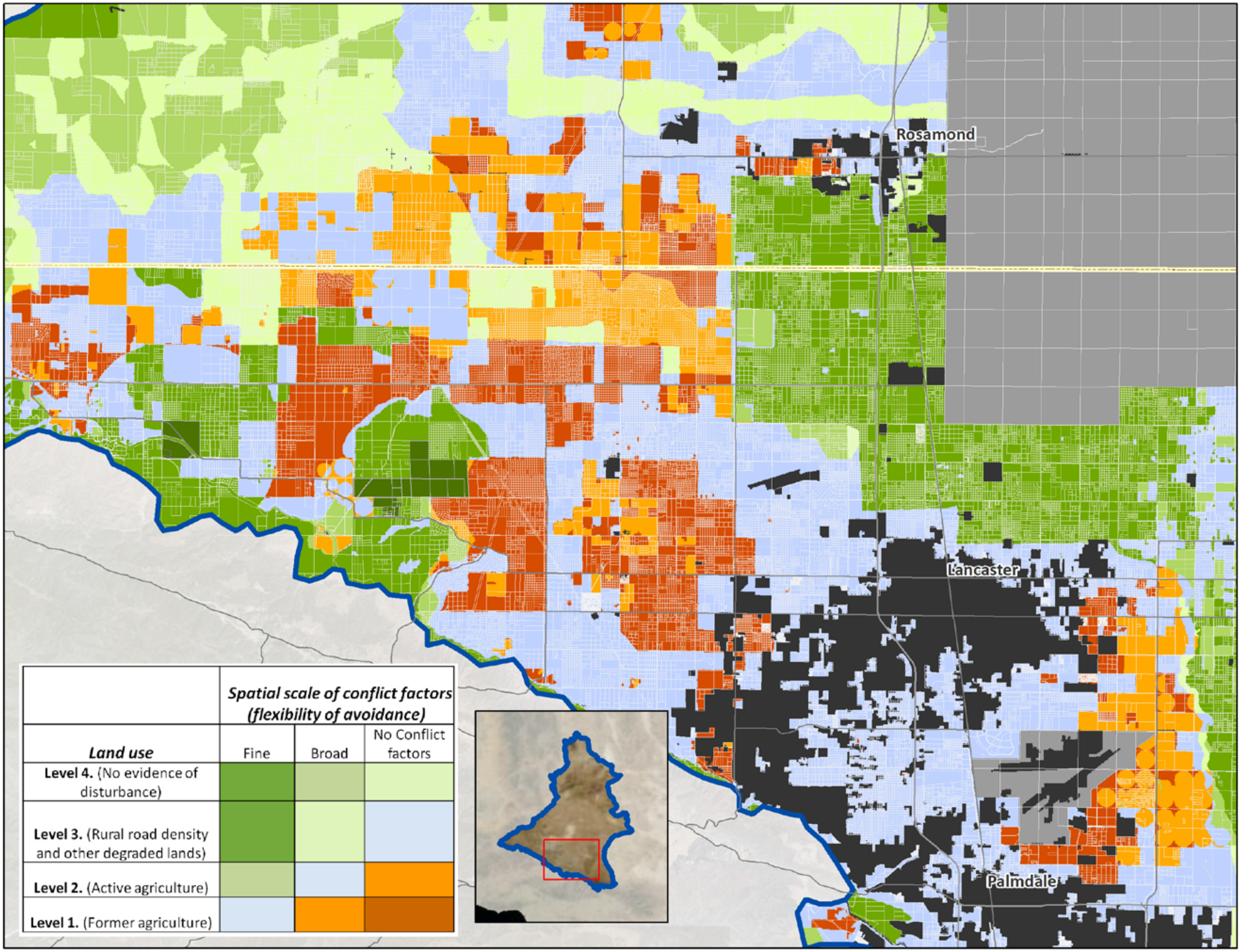
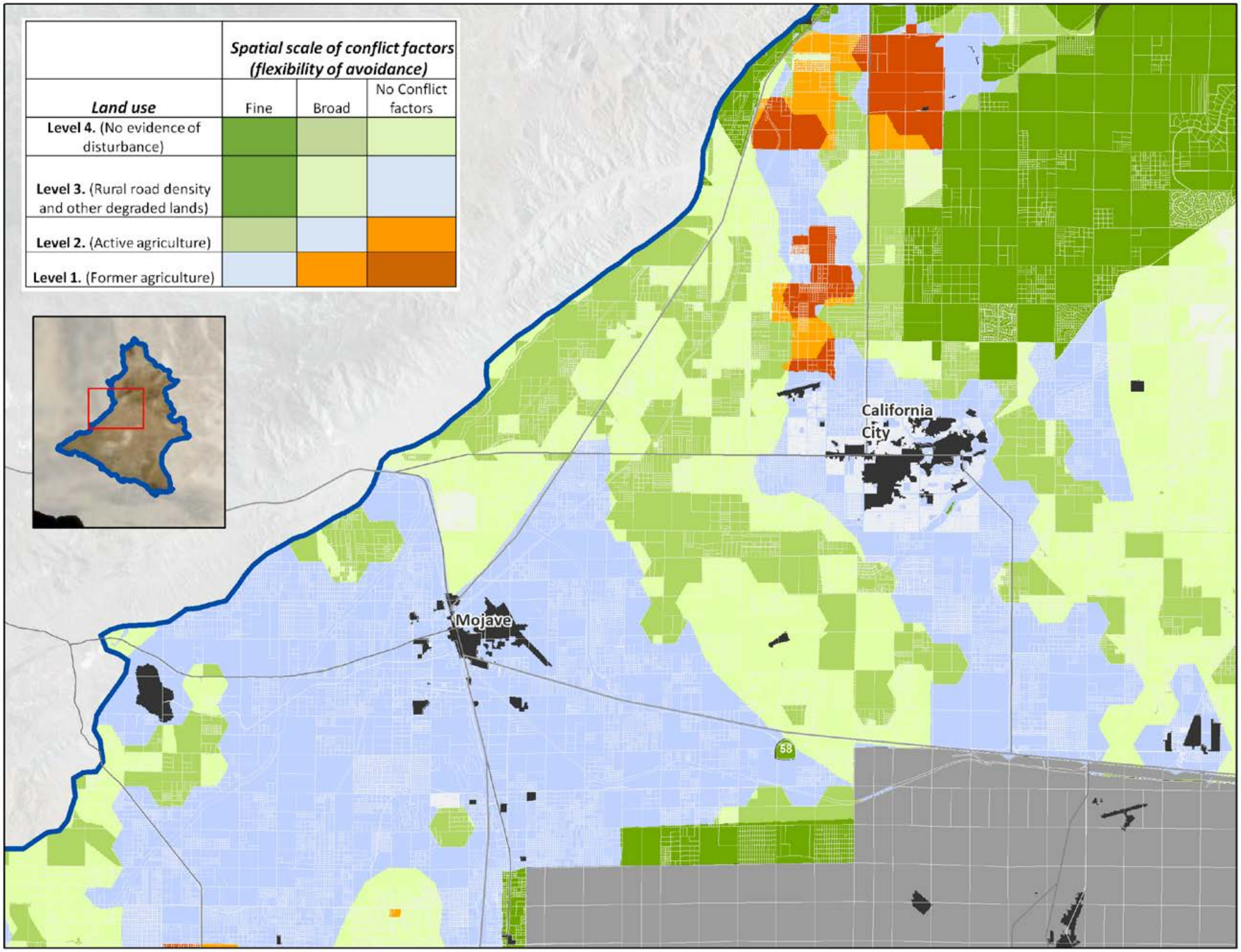


Figure A1.2. Least Conflict Criteria Matrix and Avian Resources

Appendix 2. Least Conflict Matrix Classification with Parcels




Rosamond
Lancaster
Palmdale
Spatial scale of conflict factors (flexibility of avoidance)
Land use
Fine
Broad
No Conflict factors
Level 4. (No evidence of disturbance)
Level 3. (Rural road density and other degraded lands)
Level 2. (Active agriculture)
Level 1. (Former agriculture)


Spatial scale of conflict factors (flexibility of avoidance)
Land use
Fine
Broad
No Conflict factors
Level 4. (No evidence of disturbance)
Level 3. (Rural road density and other degraded lands)
Level 2. (Active agriculture)
Level 1. (Former agriculture)
California City
Mojave
58

Appendix 3. GIS Data Sources

Audubon California. 2010. Important Bird Areas GIS data set

BLM. (2011 digitized). Unusual Plant Assemblages

BLM. 2005. West Mojave plan GIS data (Includes Mohave ground squirrel, Barstow wooly sunflower conservation areas (CAs)) other CAs reviewed but were not in study area

Bloom Biological. 2010. Swainson's Hawk General Territories (digitized by TNC from map)

CA Department of Fish and Game. 2011. Natural Diversity Database.

CA Department of Conservation. 2008. Farmlands Mapping and Monitoring Program. Prime, statewide importance and unique categories.

CA Energy Commission. 2011. Renewable Energy Action Team projects. From September 2011

California Wilderness Coalition. 2007. Citizen Wilderness Inventory

DRECP. 2011. Bighorn Sheep occupied ranges

DRECP. 2011. Merged Dunes layer

DRECP. 2011. Playas and Washes

DRECP. 2011. Vegetation transition linkages (includes Central_Antelope_Joshua_Tree_Poppy_Reserve1_20111001, North_Rosamond_Tehachapi_Reserve1_20111001, Rosamond_Tehachapi_Ecological_Corridor1_20111001, South_of_Edwards_Linkages_20111001, West_Antelope_Woodland_Grassland_Reserve1_20111001, West_Central_Antelope_Valley_Joshua_Tree_Wildflower_Field_Reserve1_20111001, WMoj_variousSp_W14_20111001)

Kern County. 2009. Agricultural fields. Permitted Crop boundaries.

Kern County. 2011. Land use linked to parcel data. For mapping "irrigated lands" as part of former agricultural land composite.

Los Angeles County. 2002. Draft Significant Ecological Areas

Muhs, D.R., R.L. Reynolds, J. Been, G. Skipp. 2003. Eolian sand transport pathways in the southwestern United States: importance of the Colorado River and local sources. Quaternary International 3-18

National Historic Register. 2011. Inventory of National Historic Register sites

Randall et al. 2010. Mojave Desert Ecoregional Assessment. The Nature Conservancy. San Francisco, CA.

SC Wildlands. 2003. South Coast Missing Linkages: A Linkage Design for the Tehachapi Connection

SC Wildlands. 2012. A Linkage Network for the California Deserts

Southern California Area Governments. 2005. Existing Land use.

The Wildlands Conservancy. 2008. Acquisitions in the California deserts

Transition Habitat Conservancy. 2012. CAPP Project areas

U.C. Santa Barbara. 1998. California Gap Analysis program vegetation data

U.C. Santa Barbara. 2011. Historically Farmed areas (FMMP data as developed in Stoms, D.M., S.L. Dashiell, F.W. Davis. Mapping compatibility to minimize biodiversity impacts of solar energy development in the California Deserts.

U.S. Census Bureau. 2000. TIGER roads data

USFWS. 2011. Critical Habitat Units, http://criticalhabitat.fws.gov/crithab/

USFWS. 2011. Desert tortoise modeled linkages

USFWS. 2011. Tortoise Conservation Areas

USGS. 2008. California Gap Analysis land cover. Available at: http://gap.uidaho.edu/index.php/california-land-cover/

USGS. 2010. Protected Areas Database (PAD-US) v. 1.1

Ventyx. 2011. Transmission line and substation data licensed to the Nature Conservancy

Appendix 4. Assessment of Land Use Disturbance Mapping Accuracy

To assess the degree to which the land use disturbance classification corresponded with patterns on disturbance from aerial photos, we conducted an accuracy assessment. This Appendix describes the methods and results of that assessment.

We evaluated the degree of land disturbance at 100 sites across the study area by looking at aerial photos and estimating the percent of land disturbance within a 90m radius circle (an area of approximately 6 acres). The locations of the random points were generated using the ArcGIS *Create random points* tool. These points were then buffered by 90 meters. We excluded lands that prohibit energy development (defined above), urban areas, Desert Tortoise Conservation Areas, BLM designated off-highway vehicle areas, and Mohave ground squirrel conservation areas. Each location was visually examined by three reviewers, separately, using the following scale:

0 - No apparent disturbance
1 - Slight land cover disturbance (< 25% impacted)
2 - Substantial land cover disturbance (25% - 75% impacted)
3 - Complete transformation of land (> 75% impacted)

Discrepancies between the ratings were evaluated jointly by the three reviewers, with a final assignment being mutually agreed upon.

We assessed the locations using the *Imagery* basemap map service available via ArcGIS, viewed at a scale of 1:800.

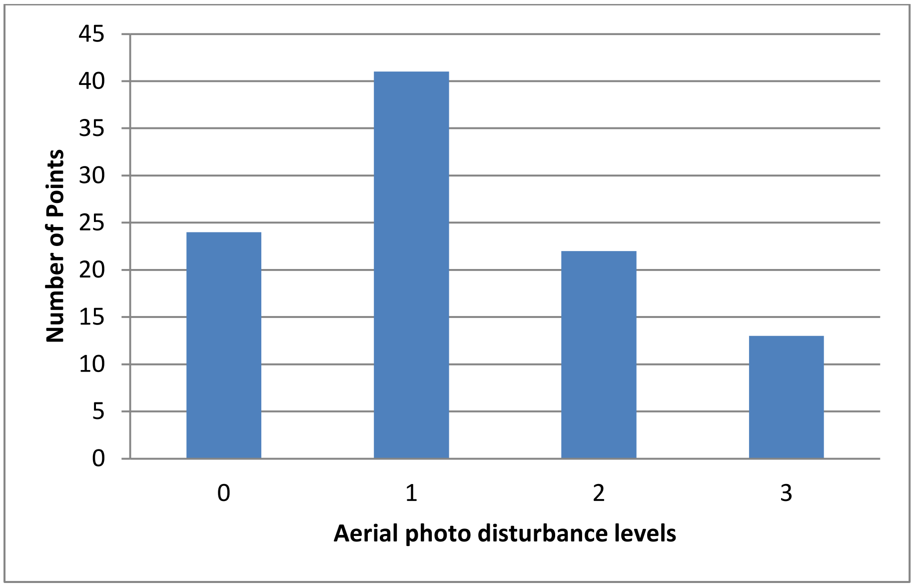
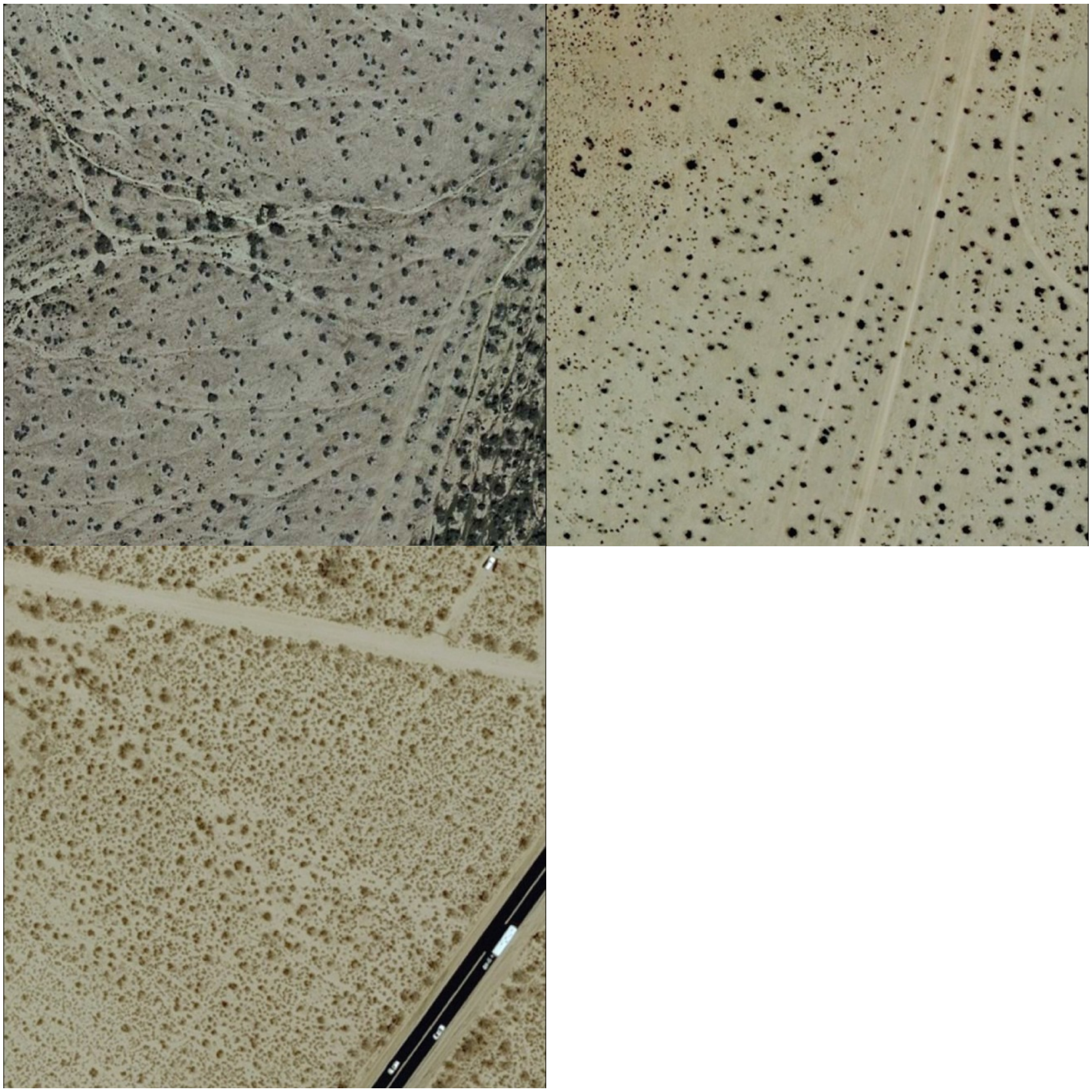


Figure A4.1. Distribution of Land Use Disturbance Ratings of 100 Random Locations.

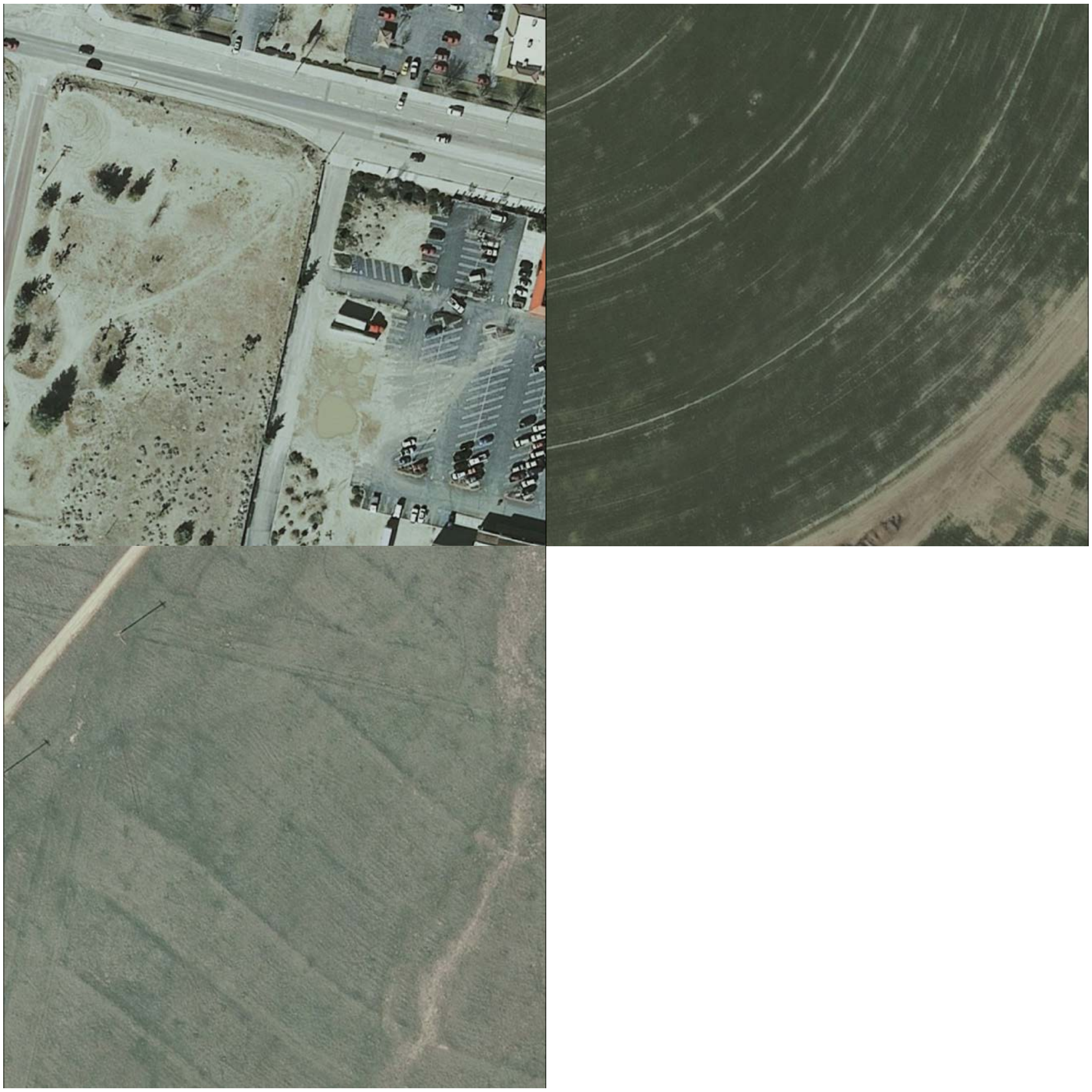
The following are examples of the locations assessed of the four categories of land disturbance:

Category 0: No apparent Disturbance



Category 1: Slight land cover disturbance (< 25% impacted)

Category 2: Substantial land cover disturbance (25% - 75% impacted)



Category 3: Complete transformation of land (> 75% impacted)

To qualitatively assess the accuracy of the composite land use disturbance layer (described in Section 1.5), we compared the disturbance levels assigned via photo interpretation at the random sample points with the mapped land use category. Because there is not a 1:1 match between the disturbance level photo classification and the land use disturbance GIS data, the results require interpretation, especially for Priority Level 3 (Rural road density and other degraded/converted lands). This category grouped the Moderately Degraded and Highly Converted Land from the Mojave Desert Ecoregional Assessment with the model of rural road density defined by road-bounded polygons less than 500 acres in size. Consequently, this is a potentially broad set of actual land uses, from open rangelands with dirt roads, to more fragmented OHV areas or mosaics of farmland and residential or commercial development. The wide range in observed disturbance levels shown in Table A 4.1 supports this observation. There are twice as many points falling in the Slight Disturbance category as there are in either the Undisturbed or Substantial Disturbance categories which provides rationale for our interpretation of these areas as having generally low levels of high intensity land use. Yet, at the scale of individual 6 acre sample points, there are a roughly equal number of points showing no disturbance as showing substantial disturbance. The results for the current and former agriculture categories provides evidence that these areas have been type converted and may possibly be recovering, but the few number of points in these areas limits our ability to extrapolate the results. For areas mapped as having “No evidence of disturbance,” about 40% of the points showed no disturbance while 50% showed slight disturbance (which in many cases was fewer than three dirt roads going through the circle). These results should give confidence to the users of this study as to its utility as a first filter for siting decisions, and also re-iterate that as you get to the lower priority land uses (Level 3 and 4), the ability to accurately characterize actual ecological condition and land use disturbance at a fine spatial scale is challenging using GIS-based proxies.

Table A4.1. Comparison of Land Use Disturbance Composite GIS Layer with Observed Disturbance Levels from Aerial Photo Interpretation.

	Observed Disturbance Level			
	Undisturbed	Slight Disturbance	Substantial Disturbance	Completely Transformed
Mapped Disturbance Level				
Former agriculture	0	0	2	3
Current agriculture	0	0	1	5
Rural road density and other degraded/converted	13	27	16	5
No evidence of disturbance	11	14	3	0

Appendix 5. Comparison of Least Conflict Siting Analysis with UCSB Solar Compatibility Model

To improve the interpretation and usability of this study, we assessed the level of agreement between our results and the report: “Mapping compatibility to minimize biodiversity impacts of solar energy development in the California Deserts” by Stoms et al. (2011) at UC Santa Barbara. The goals of the two assessments were very similar, but the methods were slightly different. Stoms et. al used a more structured approach to look at the potential indirect effects of siting locations in terms of road and transmission infrastructure needed to support development. Most notably for this section, their study proposed that areas in current agricultural land use were more compatible for solar development, than areas that were formerly irrigated but now transitioning to other vegetation. In terms of the on-site degradation, we agree that current agricultural areas are more degraded than former agricultural land, but for the reasons discussed in section 1.5 we prioritized lands that we classified as formerly agriculture. The mean and standard deviation of the UCSB on-site degradation scores (higher = more degraded, range 0-100) by land use category is shown in Figure A 5.1. This chart shows that the distinction between our Priority 1 land use (former agriculture) and Priority 3 use (Rural road density and other degraded areas) could not be attained using the UCSB approach for on-site degradation. The scoring shows the strong preference in the UCSB modeling for urbanized and irrigated farmland for utility-scale solar development, and the strong level of agreement between the two approaches for these categories is largely due to the same data being used. The models agree also on areas with no observable disturbance.

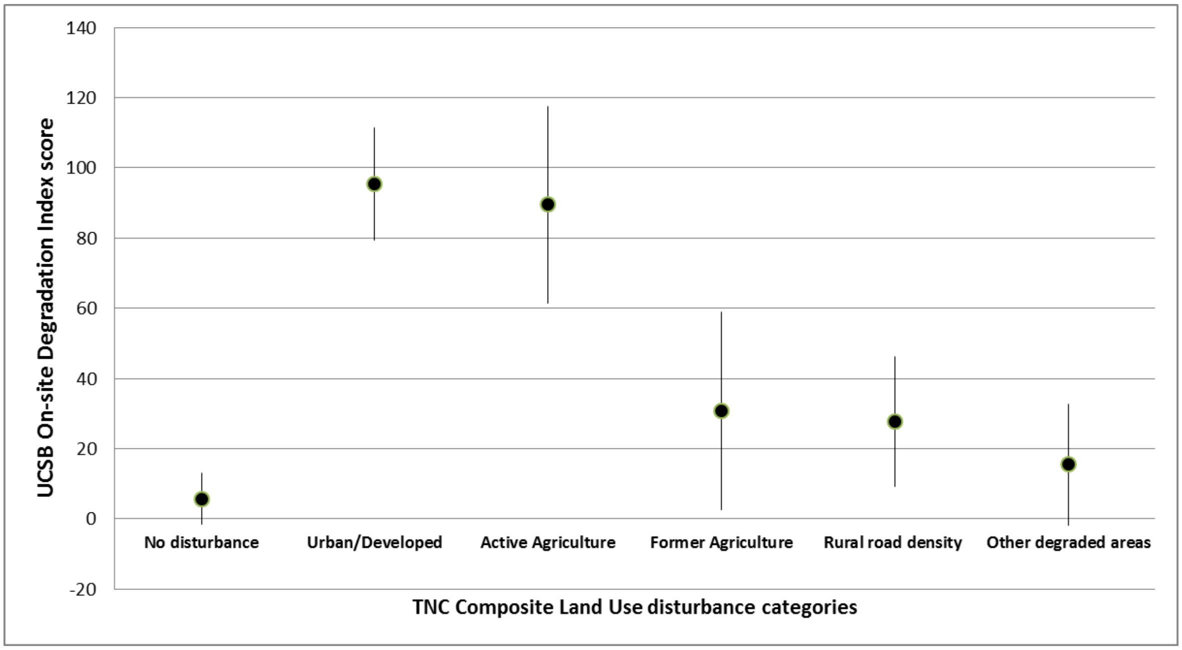


Figure A5.1. Comparison of UCSB On-Site Degradation Model with TNC Land Use Disturbance Categories

Comparing the final output for each study is also helpful and provides a solid basis for comparison (Figure A 5.2). Not surprisingly Matrix categories 7-9 which we had mapped as Current agriculture have consistently the highest scores for compatibility from the UCSB model. Aside from a strong agreement between Matrix category 1 and the UCSB model, their approach does not distinguish much between categories 2-7, except slightly higher averages for categories 5 and 6. This is not surprising because of the relatively similar land use patterns in much of the lands in our Priority 3 and 4 (Rural/Other degraded and No disturbance, respectively). One significant difference between the two approaches is the lack of distinction in compatibility between Matrix categories 10-12 (where land use is former agriculture), and Matrix categories 2-6 which have no disturbance or low density disturbance. This is largely because this study assumed a lower ecological condition for lands that had been in agriculture compared to lands that have low density road and development patterns. The UCSB study assumed former agricultural land could recover to former condition given enough time to recover. Additionally a number of other factors used in the UCSB study may also be contributing to the lack of distinction between many of the Matrix categories. Our use of avoidance criteria assigned to the two scales also may explain some of the variation (e.g. between Matrix category 1 and 3, and 4 and 6) in compatibility likely due to the fact that the two studies used designated lands such as Critical habitat and other protected areas (ours as fine-scale avoidance or masked, and UCSB, in the off-site impact model.)

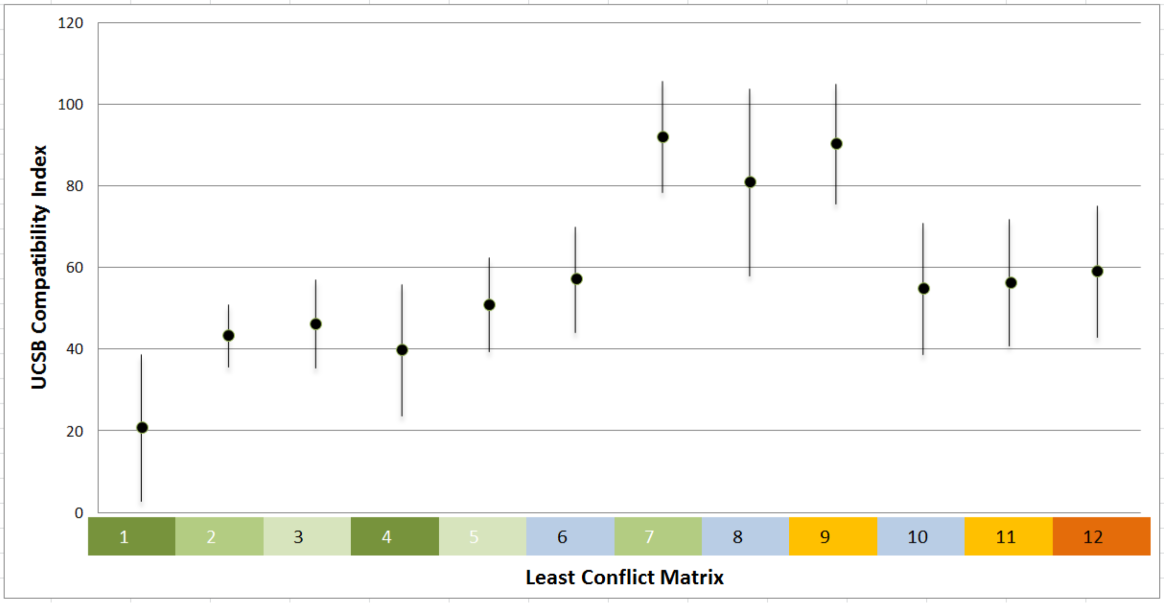


Figure A5.2. Comparison of UCSB Solar Development Compatibility Model and TNC Least Conflict Matrix

Comparing the locational agreement between the two models is more difficult but still instructive (Figure A5.3). We classified the UCSB compatibility model into four categories using a natural breaks classification. Combining the resultant grid with our least conflict matrix grid allows us to identify where the two models agree and where they disagree. The agreement is primarily in the Antelope Valley in terms of a higher compatibility for potential development, and in areas protected for Desert Tortoise in the eastern and northern part of the area. The areas where there is disagreement is primarily due to the use of avoidance factors used in this study with the Los Angeles Draft Significant Ecological Areas and BLM conservation areas accounting for the vast majority of the areas in dark orange. The areas where TNC characterized it being more compatible for solar development are imperceptible at this scale.

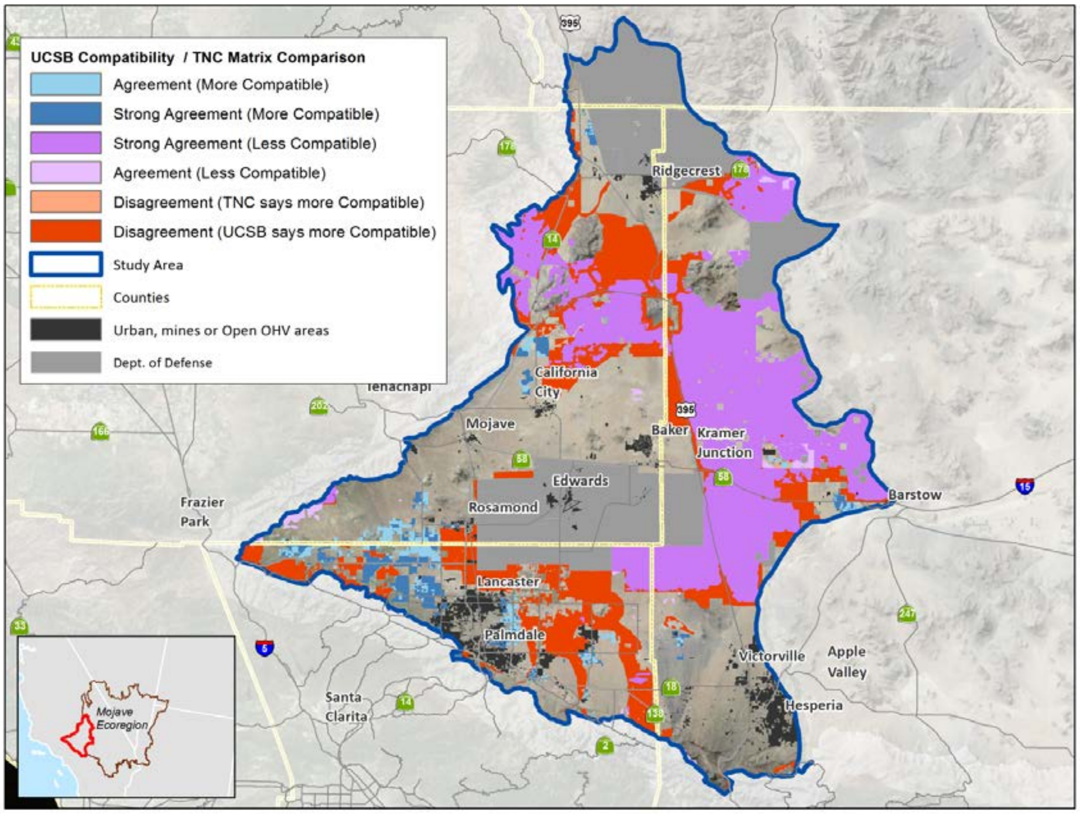


Figure A5.3. Geographic Comparison of UCSB Solar Development Compatibility Model and TNC Least Conflict Matrix