Identification of potentially suitable habitat for strategic land retirement and restoration in the San Joaquin Desert

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Scope of Assessment

The San Joaquin Desert, an area that historically encompassed 28,493 km^2 including about two thirds of the San Joaquin Valley, has experienced a near-complete biome conversion due primarily to agricultural, urban, and industrial land uses (Germano et al. 2011). As a result, this region has one of the highest concentrations of threatened and endangered species in the continental United States (Williams et al. 1998). These species primarily exist in remnant strongholds on the western side of the San Joaquin Desert in protected areas at the Carrizo Plain National Monument, Ciervo-Panoche Natural Area, and in smaller blocks within western Kern County. Historically, recovery of these species has focused on protecting additional existing habitat to expand core recovery sites, and the satellite and linkage sites that connect them, and supporting research and management that fosters stable populations (Williams et al. 1998). The historic drought in California (Griffin and Anchukaitis 2014) from 2011-2015 led to a near doubling in agricultural land fallowing in this region (Melton et al. 2015). Together with passage of the Sustainable Groundwater Management Act of 2014 (SGMA), which is projected to lead to more than 500,000 acres of agricultural land retirement in the region over the next 10-20 years (Hanak et al. 2017), there may be an opportunity to expand the focus of recovery efforts to include restoration of retired agricultural lands (Hanbury-Brown et al. 2016, Stewart et al., in review).

Without strategic planning by conservation, agricultural, governmental, and industry interests, land retirement, like the fallowing that occurred during the drought (Melton et al. 2015, Hanbury-Brown et al. 2016), is likely to be haphazard and driven largely by a landowner’s access to surface water and groundwater rights, without consideration of habitat restoration value. Strategic land retirement, on the other hand, seeks to identify larger contiguous blocks of habitat that can support populations of species, including those listed as threatened and endangered. Key to demonstrating the value of strategic planning is meeting multiple goals through strategic retirement (e.g., recovery of species, groundwater sustainability, viable agriculture industry, clean energy). The focus of this assessment is to present the methodology and analysis for meeting one of those goals: recovery of species.

An important first step in understanding the suitability of lands for strategic land retirement is to identify which agricultural lands, if retired and restored, would contribute the most to biodiversity conservation goals, including recovery of 30+ threatened and endangered species in the San Joaquin Desert. The Nature Conservancy, in collaboration with the University of California-Berkeley, began exploring this issue in 2016, producing a report “*Strategic Fallowing: Drivers, restoration potential, and co-benefits of fallowing in California’s Central Valley*” (Hanbury-Brown et al. 2016), and have more recently completed an analysis, in collaboration with researchers from the University of California-Santa Cruz, Bureau of Land Management, California Department of Fish and Wildlife, and California State University-Bakersfield, evaluating the efficacy of habitat restoration on retired agricultural lands to help recover the endangered blunt-nosed leopard lizard (*Gambelia sila*) (Stewart et al., in review).

Building from these two studies, this assessment more specifically identifies current agricultural lands within the San Joaquin Desert that have high potential for restoration to support species recovery for focal threatened, endangered, and sensitive species. This approach identifies current irrigated agricultural lands that are potentially suitable for San Joaquin Desert species, then identifies which lands, if restored, would contribute to the existing network of protected lands, and finally identifies where favorable enabling conditions may coincide with potentially suitable habitat.

The primary goal of this habitat assessment is to identify areas within the region that may be suitable for land retirement and restoration using regionally consistent data. These areas could then be further evaluated with more comprehensive site-level investigations. This assessment does not attempt to prioritize retirement on a parcel-by-parcel basis. The results of this assessment will directly feed into a larger study on the habitat and groundwater sustainability benefits of alternative restoration scenarios currently being done by The Nature Conservancy with collaborators from the Natural Capital Project at Stanford University. Other applications of this assessment may emerge as strategic planning progresses, both within The Nature Conservancy, and among interested stakeholders.

This report summarizes the overall purpose and need for this assessment, presents a detailed description of the methods and provides a summary of the results.

1. Introduction

The San Joaquin Desert is an area of high conservation value that has been significantly changed by land conversion and degradation (Williams et al. 1998, Germano et al. 2011). The San Joaquin Desert represents the last remaining habitat for a suite of threatened, endangered, and sensitive species, including kit fox (*Vulpes macrotis mutica*) (Federally endangered (FE), State threatened (ST)), giant kangaroo rat (*Dipodomys ingens*) (FE, State endangered (SE)), blunt-nosed leopard lizard (*Gambelia sila*) (FE, SE and California Fully Protected Species under Fish and Game Code 5050), and woolly-thread (*Monolopia congdonii*) (FE). Their recovery depends on the protection and restoration of their remaining habitats (Williams et al. 1998). For that reason, the United States Fish and Wildlife Service (FWS) has designated large portions of the San Joaquin Desert as core, satellite, and linkage recovery areas (Williams et al. 1998). Historically, recovery has focused on protecting these areas from further land conversion and degradation, including from incompatible solar energy development. To that end, The Nature Conservancy produced a Western San Joaquin Valley least conflict solar energy assessment, which identified areas where solar may be sited without negatively impacting these habitats and species (Butterfield et al. 2013), and later collaborated with environmental, agricultural, and industry partners to expand the analysis to the entire San Joaquin Valley (Pearce et al. 2016).

While the drought of 2011-2015 was historically severe (Griffin and Anchukaitis 2014) and had negative near-term consequences on populations of San Joaquin Desert threatened and endangered species (Westphal et al. 2016, Stafford et al. 2015, Bean 2013, 2014, 2016, O'Dell 2016, Prugh et al. 2016), it also resulted in a near doubling of agricultural land fallowing in the region (Melton et al. 2015). Given the possibility that droughts like these could become more regular (Swain et al. 2016) combined with the implementation of the Sustainable Groundwater Management Act of 2014 (SGMA), which is projected to lead to more than 500,000 acres of agricultural land retirement in the region over the next 10-20 years (Hanak et al. 2017), there may be an opportunity to expand the focus of recovery efforts to include restoration of retired agricultural lands (Hanbury-Brown et al. 2016, Stewart et al., in review).

There is currently no comprehensive assessment that identifies the lands that, if retired and restored, would contribute most to recovery of the full suite of threatened and endangered species in the San Joaquin Desert (although, see Hanbury-Brown et al. 2016 and Stewart et al., in review). Given the current potential opportunity for species recovery through land use change presented by SGMA (Hanak et al. 2017), an assessment is needed to identify agricultural areas in the San Joaquin Desert that if retired and restored have potential for high conservation value.

We focused this assessment on the San Joaquin Desert given its high concentration of threatened and endangered species and the likely impact of SGMA in this region. Additionally, landowners in this region have expressed interest in working with The Nature Conservancy to determine whether there are strategies for retirement that would benefit both conservation and the sustainability of their agricultural land practices. The methods used in this assessment could serve as a model for evaluating potential conservation outcomes on retired agricultural lands in relevant regions of the world.

1.1 Study Area

The study area for this assessment is the San Joaquin Desert (Germano et al. 2011). This study area represents a subset of the San Joaquin Valley, California's largest agricultural region and an important contributor to the nation's food supply. The San Joaquin Desert is 7.1 million acres. Germano et al. (2011) distinguished the San Joaquin Desert from the larger San Joaquin Valley based on a precipitation threshold of 229-279 mm, and the presence of aridic soils, desert vegetation communities, and animal species only found in desert communities. We chose to focus on this study area because it contains some of the highest concentrations of threatened and endangered species in the continental Unites States (Williams et al. 1998). The Nature Conservancy has invested heavily over the past 30+ years in the protection of these species, including at places like the Carrizo Plain National Monument, where the Conservancy is a Managing Partner along with the Bureau of Land Management and California Department of Fish and Wildlife (United States Department of Interior 2010, Butterfield and O'Donoghue 2011). The eastern and western portions of the San Joaquin Desert have very different dominant land uses. Both sides are influenced heavily by agriculture and have seen recent increases in the acreage of perennial crops, but the eastern side of the study area is dominated by intensive irrigated agriculture, while the western side is dominated by more natural, open rangeland used for livestock grazing (Butterfield et al. 2013).

2. Methods

2.1 Overview and assumptions

We conducted this assessment using a three-part approach. First, we identified which irrigated agricultural lands were potentially suitable for San Joaquin Desert species based on bioclimatic models. Second, we evaluated which of these lands, if restored, would contribute to the existing network of protected lands; and then finally we determined where favorable enabling conditions coincide with potentially suitable habitats.

For this assessment, we made certain assumptions, including: 1) lands identified by the analysis are restorable, 2) species will find, occupy, and populate restored lands, 3) the potential exists to attract or move species to new sites in the future, and 4) restored lands can become part of a larger protected lands network.

2.2 Potential habitat suitability

We first determined which agricultural lands are potentially suitable for San Joaquin Desert species using models developed by Stewart et al. (in review) (Table 1). Based on our project goals and expert review at a National Center for Ecological Analysis and Synthesis (NCEAS) working group convened by The Nature Conservancy in January 2016, we decided to use potential habitat suitability models for blunt-nosed leopard lizard, giant kangaroo rat, San Joaquin kit fox, and San Joaquin woolly-thread. We used the analyses of Stewart et al. (in review) to examine how these four species together can be used to represent the full suite of 30+ San Joaquin Desert threatened, endangered, and sensitive species. These Maxent-based potential habitat suitability models evaluated a large group of predictor variables known or hypothesized to be important to the natural history, demography, and distribution of these species. These variables included mean annual precipitation, climatic water deficit, thermal physiology, vegetation productivity, actual evapotranspiration, soil pH, soil electrical conductivity, and soil composition. Stewart et al. (in review) found that for blunt-nosed leopard lizard six environmental variables: mean annual precipitation, actual evapotranspiration, slope, percentage of clay in the soil, electrical conductivity, and soil pH, created the best performing temporally-transferable habitat suitability model. The Stewart et al. (in review) approach, unlike those developed previously for San Joaquin kit fox (Cypher et al. 2013), giant kangaroo rat (Bean et al. 2014), and blunt-nosed leopard lizard (Pearce et al. 2015), resulted in habitat suitability models that allowed us to estimate historical distribution and habitat quality on both *intact* and *converted*, including irrigated agricultural, lands.

We classified the potential habitat suitability within irrigated agricultural lands in two ways as part of this assessment: 1) for one or more target species, and 2) for two or more target species. This allowed us to evaluate a larger range of strategies, from less to more restrictive, for habitat protection and restoration. We determined that there was no additional benefit to including three or more species, or four or more species in the assessment based on little additionality of acres beyond suitability for 2 species. We used Cropscape data from 2015 to clip the potential habitat suitability layers to only those lands mapped as irrigated agriculture (Table 1).

We did not use landscape permeability and/or connectivity data, including for specific target species (e.g. Cypher et al. 2013), to further refine our identification of potential habitat suitability. These datasets largely treat irrigated agricultural land cover as impermeable for wildlife movement and therefore, could not help us determine the potential suitability of current agricultural lands for increasing landscape connectivity.

2.3 Contribution to existing network of protected lands

To assess the contribution of potentially suitable habitats to the existing network of protected lands, we first combined data from the California Protected Areas Database (CPAD) and California Conservation Easement Database (CCED) (Table 1) to create a single protected lands data layer. Based on expert review of target species dispersal distances (Koopman et al. 2000, Cooper and Randall 2007, Germano and Rathbun 2016, Westphal et al., in review) and our project goal to facilitate movement between restored, retired lands and already occupied and/or protected lands, we created a 5-km buffer around each protected area. Within this 5-km distance, we believe our target species can move from already occupied lands to restored lands. We then conducted an analysis to identify all the potentially suitable habitat, both for one or more target species and two or more target species, within irrigated agricultural land that was within 5-km of a protected area. Finally, to better refine the quality of the habitat within each protected area for our target species, we classified each protected area into one of three categories based on the dominant type of habitat present: 1) San Joaquin Desert habitat only, 2) Wetland habitat only, and 3) both San Joaquin Desert and Wetland habitat.

2.4 Enabling conditions evaluation

The main objective of this assessment is to identify lands with the highest conservation value for restoration to support species recovery. We did not attempt to prioritize where we should engage with landowners. However, we included a basic overlay analysis in this assessment that evaluates the potential habitat suitability areas against a variety of "enabling conditions" that we felt would influence which agricultural lands may be retired in the San Joaquin Desert, including 1) agricultural lands frequently fallowed during the drought between 2011-2015 (Melton et al. 2015), 2) lands identified as least conflict for solar photovoltaic (PV) energy development (Pearce et al. 2016) and 3) lands with the lowest groundwater recharge potential (Table 1). We determined through outreach with agricultural partners that annual crops were not necessarily more likely to be retired as part of SGMA, so all our maps treat irrigated agricultural land as a single cover class versus, for example, as annual or perennial cropland.

2.4.1 Agricultural land fallowing data

We reasoned that frequent fallowing during the drought might help identify those parcels that are more likely candidates for permanent retirement because of the SGMA regulations. We used annual fallowing data from 2011, 2013, 2014, 2015, and 2016 developed by Melton et al. (2015). We did not use the 2012 annual fallowing data based on feedback about poor data quality (F. Melton, personal communication, September 2017). We organized the annual fallowing data into two categories: fallowed once and fallowed more than once during the 2011-2016-time period. We ran an overlay analysis with our potential habitat suitability data layers to show where fallowing was coincident with:

1) potentially suitable habitat for one or more target species within irrigated agricultural land;
2) potentially suitable habitat for two or more target species within irrigated agricultural land;

3) potentially suitable habitat for one or more target species within irrigated agricultural land and within 5-km of a protected area; and
4) potentially suitable habitat for two or more target species within irrigated agricultural land and within 5-km of a protected area.

2.4.2 Solar energy least conflict and groundwater recharge potential

The solar energy dataset that we used from Pearce et al. (2016) represented areas of potential least conflict identified in consensus between environmental, agricultural, and solar energy industry groups. A large portion of the acreage that was identified as least conflict was on agricultural land with drainage problems and high salt content (Butterfield et al. 2013). While these issues reduce the viability of the land for irrigated agriculture, there is evidence that at least some of the San Joaquin Desert threatened and endangered species may be able to use these lands as habitat (Stewart et al, in review). For that reason, we were interested in identifying where there was overlap between least conflict areas for solar energy development and areas of potential suitable habitat. Because Pearce et al. (2016) classified most irrigated agricultural land, especially that land with higher productivity (e.g. prime farmland), as higher conflict for solar energy development, we hypothesized that there may be limited overlap between least conflict solar energy areas and the agricultural areas we identified as potentially suitable for retirement and restoration. However, we recognized that even if overlap was minimal, low-impact solar energy development and strategic land retirement could complement each other, providing multiple options for landowners in determining how to manage their lands in less intensive ways.

We assumed that areas of high groundwater recharge potential would be less suitable for these target species because most have evolved under dry climatological regimes and prefer sparse vegetation, and many live under ground in burrows. We used the Soil and Agricultural Groundwater Banking Index (SAGBI) data available from the California Soil Resource Lab at the University of California-Davis and University of California-Division of Agriculture and Natural Resources (https://casoilresource.lawr.ucdavis.edu/sagbi/; O'Green 2015). SAGBI is a suitability index for groundwater recharge on agricultural land. SAGBI scores are based on five major factors that are critical to successful agricultural groundwater banking: deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition.

3. Results and Discussion

3.1 Potential habitat suitability

There are 2.5 million acres of land that are potentially suitable to be retired and restored for at least one target species within the extent of irrigated agricultural land (Figure 1; Table 2). For two or more target species, the suitable area drops to 2.1 million acres (Figure 2; Table 2). There are 1 million acres and 840,000 acres, within 5-km of protected areas, for one or more and two or more species, respectively (Figure 3 and 4; Table 2).

In the San Joaquin Desert, there is currently just over 1 million acres of protected areas, a large portion of which provides habitat for San Joaquin Desert threatened and endangered species (Figures 3 and 4; Table 2). The recovery of most of these species depends on protecting additional currently occupied, but unprotected, acreage, including specific places like the 10,000+ acre Silver Creek Ranch in San Benito County (Williams et al. 1998), which was recently protected as part of mitigation for the Panoche Valley Solar Farm. None of the places that we identify in this assessment are in the recovery plan, since agricultural land retirement was not considered in the development of the plan. However, the recovery plan does give us an idea of how much acreage each species needs (e.g. from no additional acreage for the San Joaquin woolly-thread (Williams et al. 1998) to more than 50,000 acres for the giant kangaroo rat (U.S. Fish and Wildlife 2010)) to support species recovery. In addition, more recent research has refined our understanding of the size habitat patches need to be to support populations of different species, including values as small as 1,000 acres for blunt-nosed leopard lizard (Bailey and Germano 2015) to values as large as 10,000-15,000 acres for San Joaquin kit fox (Cypher et al. 2011). No matter what method we used in this assessment to determine potential habitat suitability, the opportunity exists to significantly contribute to the down- or de-listing of this suite of species with a successful agricultural land retirement and restoration project (Figures 1-4; Table 2). It is important to note that this assessment, unlike the recovery plan, did not include an objective to prioritize specific geographic locations for species recovery, even though we know factors like climate change (Westphal et al. 2016, Stewart et al., in review) and population structure (O'Dell 2016, Statham et al. 2016, Richmond et al. 2017, Statham et al. in review) will be important to consider in future analyses.

3.2 Impact of enabling conditions on potential habitat suitability

Overall, a significant proportion of land fallowed from 2011-2016 was also identified as being potentially suitable habitat for our San Joaquin Desert target species (Table 3). Using the least restrictive methodology for determining potential habitat suitability (i.e. at least one species), we determined that of the 2.5 M acres of habitat, 350,000 acres was fallowed once and 260,000 acres was fallowed more than once (Figure 5; Table 3). Adjusting the habitat suitability methodology from one or more target species to two or more target species reduced the amount of overlap with fallowing, to 300,000 acres that was fallowed once and 225,000 acres that was fallowed more than once (Figure 6; Table 3). Finally, as we restricted the analysis to areas within 5-km of protected areas, we reduced overlap with fallowing to 130,000 acres fallowed once and 120,000 fallowed more than once for one or more species (Figure 7; Table 3), and 115,000 and 105,000 acres, respectively, for two or more species (Figure 8; Table 3). Even using the most restrictive methodology, which focuses on two or more target species within 5-km of a protected area, we still found more than 100,000 acres of land where there was an overlap between frequent fallowing and potentially suitable habitat. If frequent fallowing does indeed highlight portions of the landscape that are more likely to be permanently retired, then this finding is important because it shows that there are enough acres that are important biologically but potentially of lower agricultural value and/or with lower-value water rights to create meaningfully large areas for species recovery.

There is significant development pressure from solar PV energy development in the San Joaquin Desert (Pearce et al. 2016). As of 2016, there were 120 solar energy facilities, averaging 500 acres and producing 67 megawatts worth of energy in the San Joaquin Valley (Pearce et al. 2016). There is an additional ~500,000 acres (Butterfield et al. 2013, Pearce et al. 2016) of land that has been identified, by consensus between environmental, agricultural, agency, and industry partners, as being potentially suitable for additional solar PV energy development in this region. This assessment was not meant to directly evaluate the compatibility between species recovery and solar energy development on retired agricultural lands, but rather to identify where there was overlap between the two. We hypothesized that low-impact solar PV development and strategic retirement could complement each other, providing multiple options for landowners in determining how to manage their lands in less water-intensive ways. We found that there was more than 230,000 acres that was both potentially suitable habitat for San Joaquin Desert species and least-conflict for solar energy development (Figure 9; Table 4).

We found that there were over 1 million acres of potentially suitable habitat for San Joaquin Desert species that were classified as having either very poor, poor, or moderately poor groundwater recharge potential.

4. Conclusions

4.1 Uses of this Assessment

This assessment can act as a “first filter” of locations within the San Joaquin Desert that could be suitable for strategic land retirement. The Nature Conservancy is using the results of this assessment, together with previous analyses evaluating the role of climate change in future potential habitat suitability (Westphal et al. 2016, Stewart et all, in review) and population genetics in how, when, and where to consider species translocation (O’Dell 2016, Statham et al. 2016, Richmond et al. 2017, Statham et al. in review), to inform a larger strategic land retirement planning analysis currently being done with collaborators from the Natural Capital Project at Stanford University. This multi-benefit assessment of strategic land retirement for the entire San Joaquin Valley will develop and evaluate alternative scenarios that seek to meet multiple objectives including renewable energy development, groundwater sustainability, agricultural sustainability, and species recovery.

This assessment can complement proposed or future local, state and federal planning processes that seek to develop strategies for land retirement. It is not meant to replace these stakeholder-driven processes, or to supersede local land use planning and authority; public input in land retirement decisions is important.

4.2 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. This assessment does not seek to prioritize specific potentially suitable habitat parcels for retirement and restoration across the landscape. And it is not a conservation plan that details how or whether specific parcels should be restored to support populations of threatened and endangered species. As stated above, there are many additional biological considerations, not to mention socio-economic ones, that need to be added to inform a strategic plan for the landscape. Although we believe the analysis can be used to presumptively rule out some areas for retirement and restoration, the reverse is not true—data gaps limit the ability to use this assessment to support positive site-level decisions for retirement. As a filter, it should be used to sort areas into different categories of suitability from an environmental point of view, and to prioritize further investigation with potential landowner partners for retirement and restoration—strategic retirement should seek to maximize social, economic and environmental considerations and is best suited to happen as part of a collaborative stakeholder dialogue. This assessment is also limited in that it assumes all lands identified by the analysis are restorable. The Nature Conservancy is currently working with partners on a synthesis aimed at reviewing and summarizing existing research on the restoration potential of irrigated agricultural land in the San Joaquin Valley for the recovery of threatened and endangered species. This synthesis will help determine restoration potential, costs, and trade-offs associated with different retirement and restoration strategies.

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Table 1. Data sources used.

Name	Source
Habitat Suitability Models: San Joaquin kit fox, giant kangaroo rat, blunt-nosed leopard lizard, San Joaquin woolly-thread	Stewart et al. in review
Irrigated agricultural land	Cropscape 2015
Protected areas and easements	CPAD 2014; CCED 2016
Fallowed area mapping	NASA 2015; Melton et al. 2015
Least conflict solar energy mapping	CBI 2015; Pearce et al. 2016
Groundwater recharge potential	SAGBI 2016; O'Green et al. 2015

Table 2. Acreage by class for areas of potentially suitable habitat for target species within irrigated agricultural land in the San Joaquin Desert. Target species include: San Joaquin kit fox, giant kangaroo rat, blunt-nosed leopard lizard, and San Joaquin wooly-thread. Protected areas were designated by TNC scientists as representing primarily desert habitat only, wetland habitat only, or desert and wetland habitat.

Class	Acres
One or more target species	2,549,390
Two or more target species	2,122,807
One or more target species / Within 5 km of a Protected Area (total)	1,031,170
One or more target species / Within 5 km of a Protected Area (desert habitat only)	555,906
One or more target species / Within 5 km of a Protected Area (wetland habitat only)	252,772
One or more target species / Within 5 km of a Protected Area (both desert and wetland habitat)	222,492
Two or more target species / Within 5 km of a Protected Area (total)	838,585
Two or more target species / Within 5 km of a Protected Area (desert habitat only)	484,011
Two or more target species / Within 5 km of a Protected Area (wetland habitat only)	222,951
Two or more target species / Within 5 km of a Protected Area (both desert and wetland habitat)	131,621

Table 3. Acreage by class for areas of potentially suitable habitat for target species within irrigated agricultural land in the San Joaquin Desert that was fallowed between 2011 and 2016. Target species include: San Joaquin kit fox, giant kangaroo rat, blunt-nosed leopard lizard, and San Joaquin woolly-thread. Annual fallowing datasets were used from 2011, 2013, 2014, 2015, and 2016. Protected areas

were designated by TNC scientists as representing primarily desert habitat only, wetland habitat only, or desert and wetland habitat.

Class	**Acres**
One or more target species / Never fallowed	1,937,195
One or more target species / Fallowed once	354,227
One or more target species / Fallowed more than once	257,967
Two or more target species / Never fallowed	1,598,841
Two or more target species / Fallowed once	298,982
Two or more target species / Fallowed more than once	224,983
One or more target species / Within 5 km of a Protected Area / Never fallowed	777,767
One or more target species / Within 5 km of a Protected Area / Fallowed once	132,271
One or more target species / Within 5 km of a Protected Area / Fallowed more than once	121,132
Two or more target species / Within 5 km of a Protected Area / Never fallowed	619,297
Two or more target species / Within 5 km of a Protected Area / Fallowed once	114,408
Two or more target species / Within 5 km of a Protected Area / Fallowed more than once	104,879

Table 4. Acreage by class for areas of potentially suitable habitat for target species within irrigated agricultural land in the San Joaquin Desert that was identified as a potential least conflict area (Priority for PV solar energy development in the 2016 report "A Path Forward: Identifying least-conflict solar PV development in California's San Joaquin Valley". Target species include: San Joaquin kit fox, giant kangaroo rat, blunt-nosed leopard lizard, and San Joaquin woolly-thread.

Class	**Acres**
One or more target species / Priority Least Conflict Areas	90,955
One or more target species / Least Conflict Areas	46,358
One or more target species / Potential Least Conflict Areas	95,195

Figure 1. Potentially suitable habitat for one or more target species within irrigated agricultural land. Species include SJ kit fox, giant kangaroo rat, blunt-nosed leopard lizard, and SJ woolly-thread.

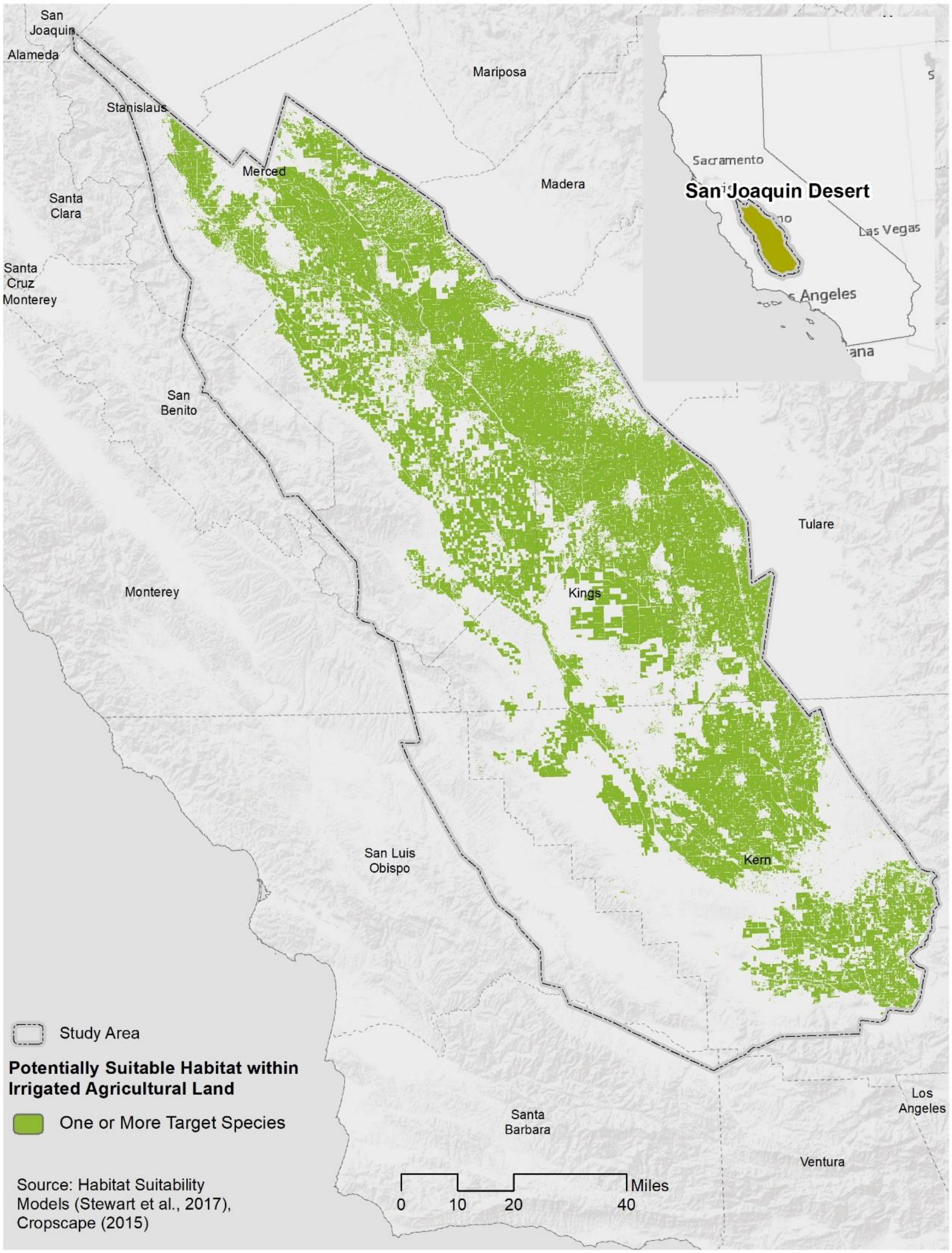

Figure 2. Potentially suitable habitat for two or more target species within irrigated agricultural land. Species include SJ kit fox, giant kangaroo rat, blunt-nosed leopard lizard, and SJ woolly-thread.

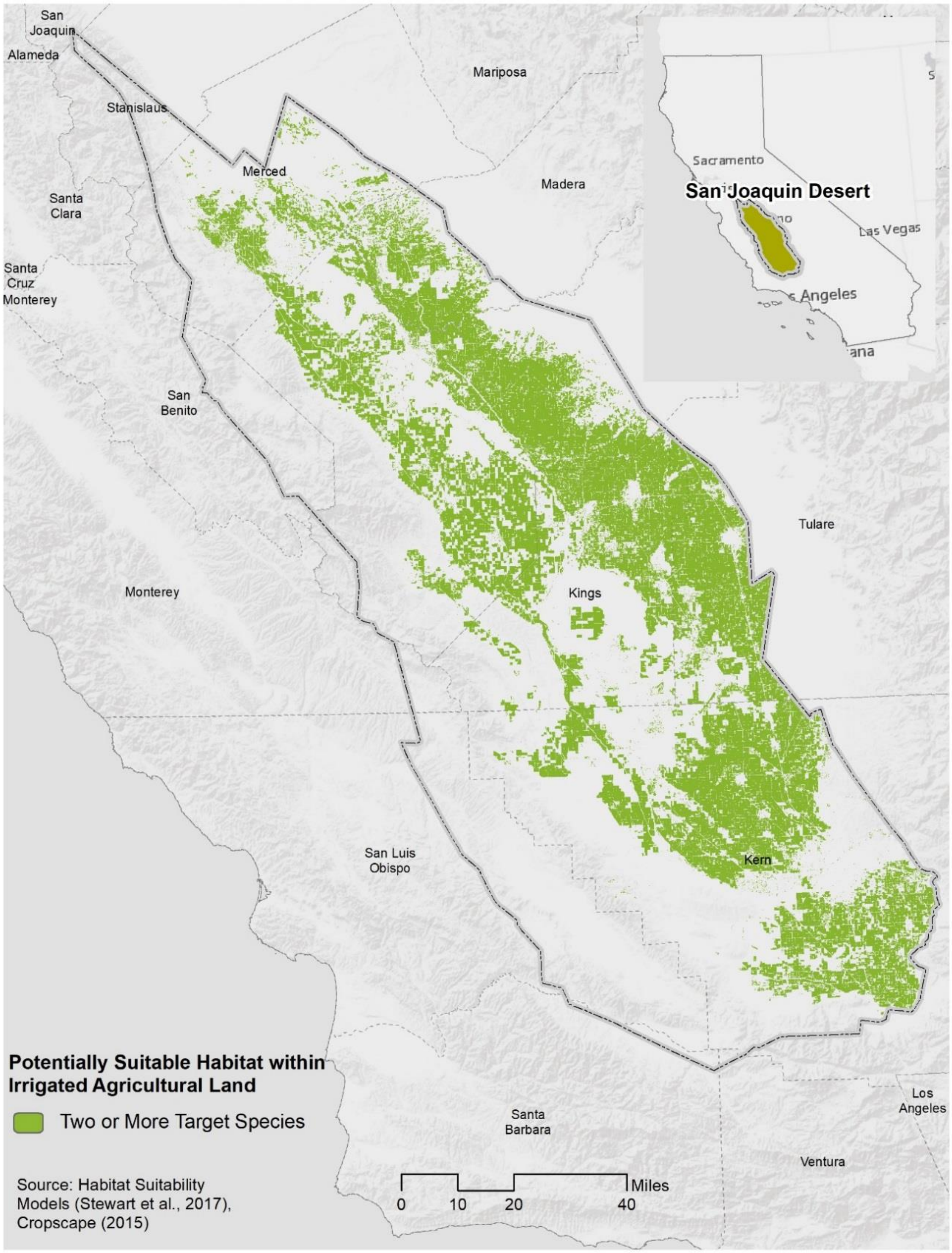

Figure 3. Potentially suitable habitat for one or more target species within irrigated agricultural land and within 5-km of a protected area. Protected areas were designated as desert only, wetland only, or both based on expert review of their dominant land cover types.

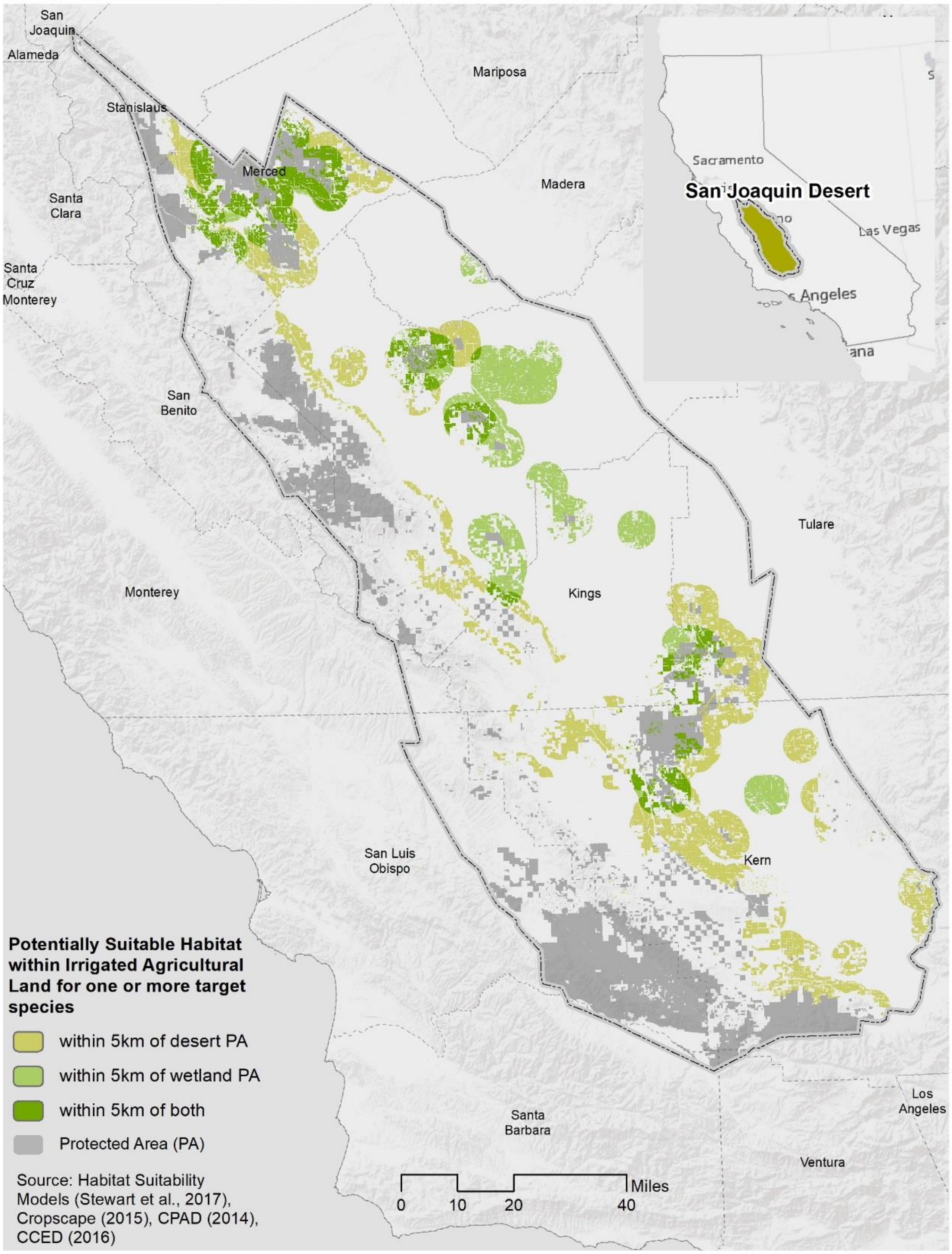

Figure 4. Potentially suitable habitat for two or more target species within irrigated agricultural land and within 5-km of a protected area. Protected areas were designated as desert only, wetland only, or both based on expert review of their dominant land cover types.

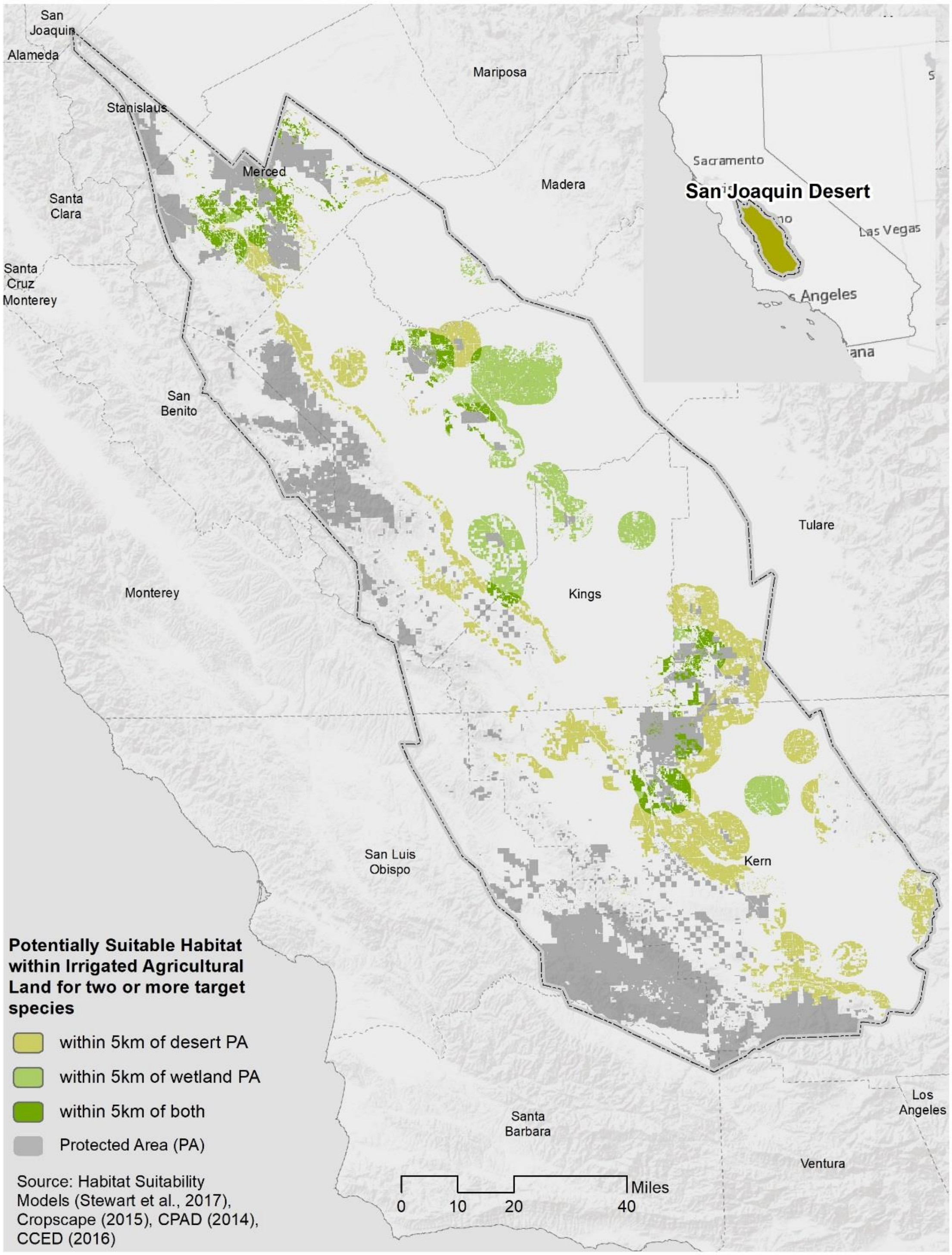

Figure 5. Fallowing within potentially suitable habitat for one or more target species within irrigated agricultural land. Fallowing data was available for 2011, 2013, 2014, 2015, 2016.

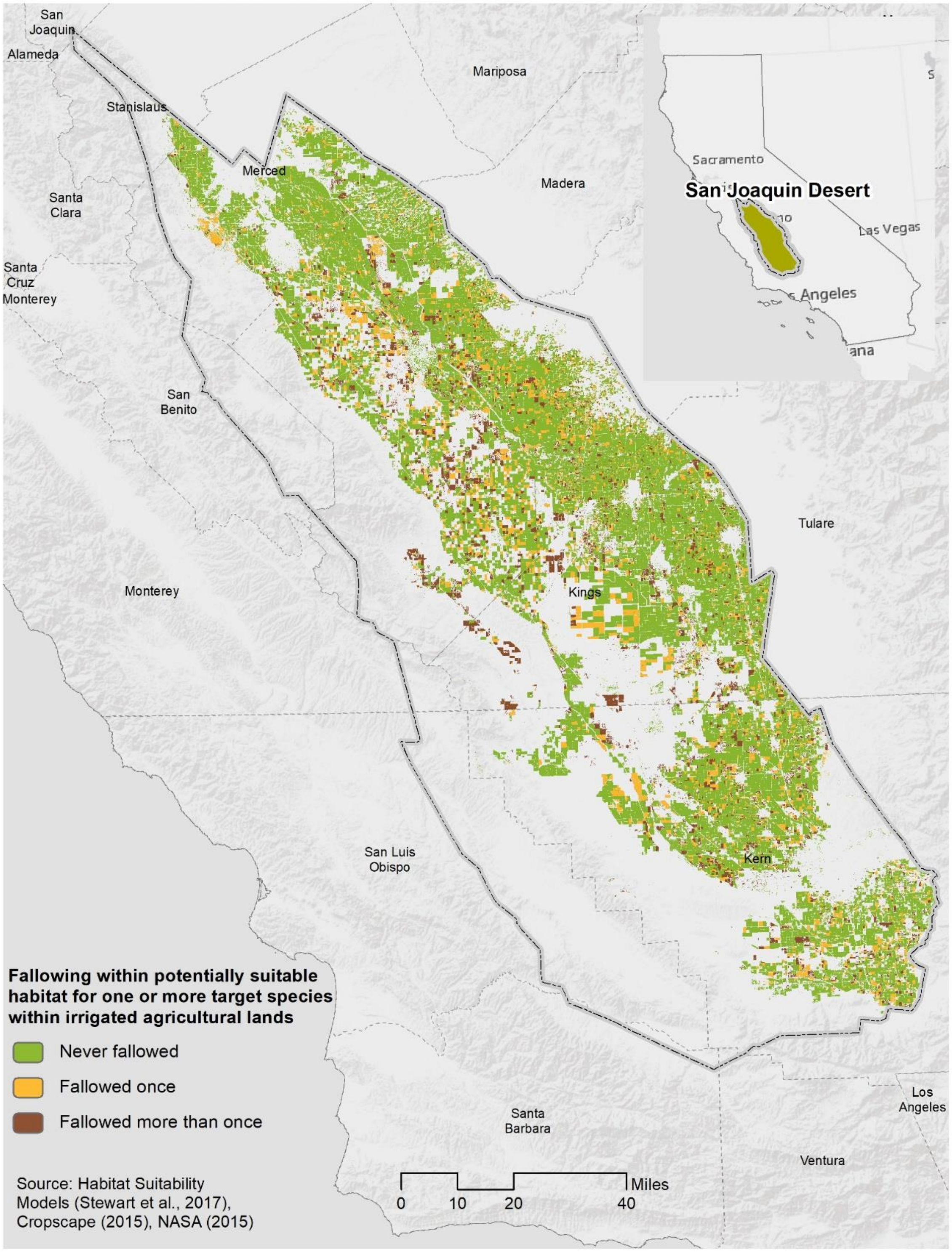

Figure 6. Fallowing within potentially suitable habitat for two or more target species within irrigated agricultural land. Fallowing data was available for 2011, 2013, 2014, 2015, 2016.

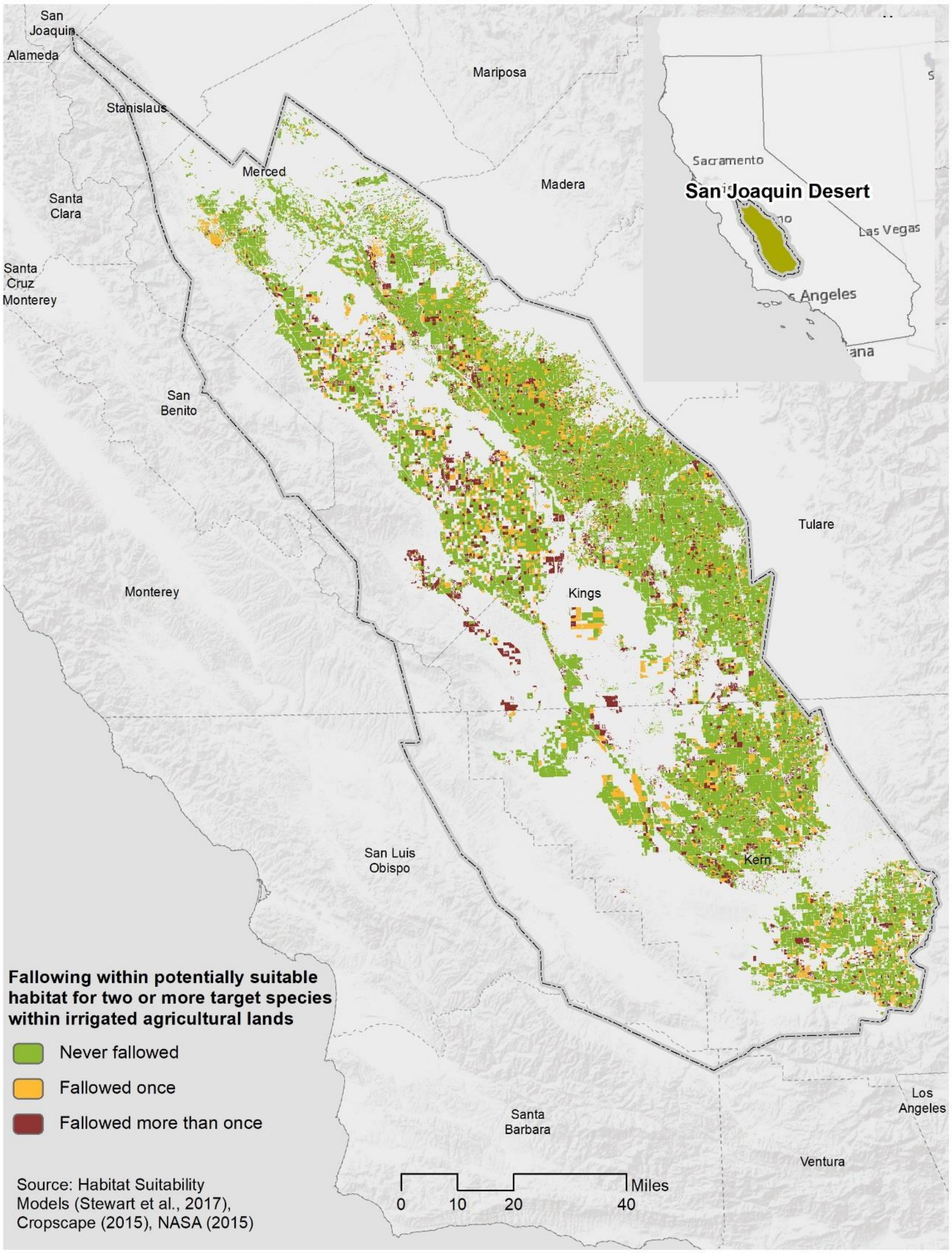

Figure 7. Fallowing within potentially suitable habitat for one or more target species within irrigated agricultural land and within 5-km of a protected area. Fallowing data was available for 2011, 2013, 2014, 2015, 2016.

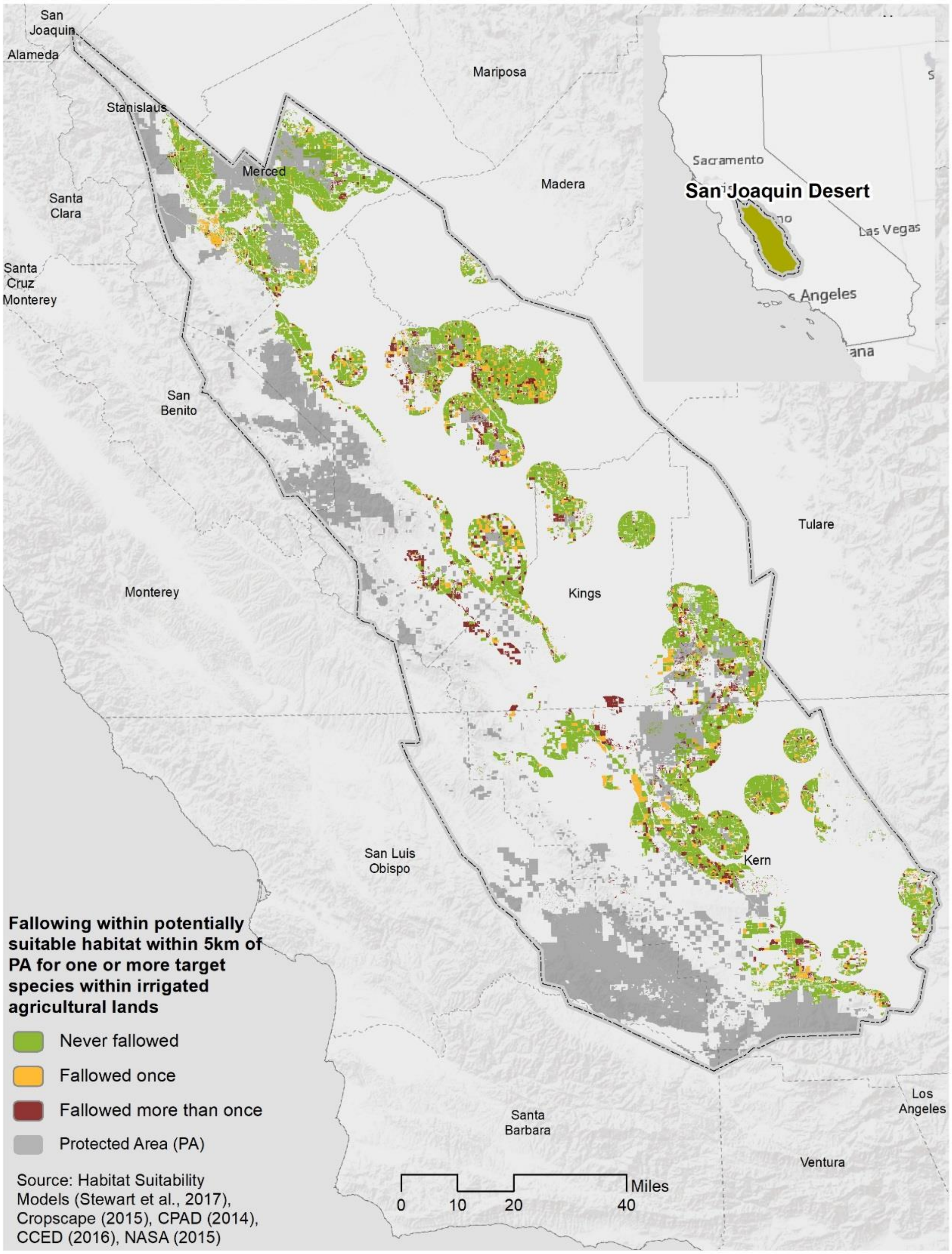

Figure 8. Fallowing within potentially suitable habitat for two or more target species within irrigated agricultural land and within 5-km of a protected area. Fallowing data was available for 2011, 2013, 2014, 2015, 2016.

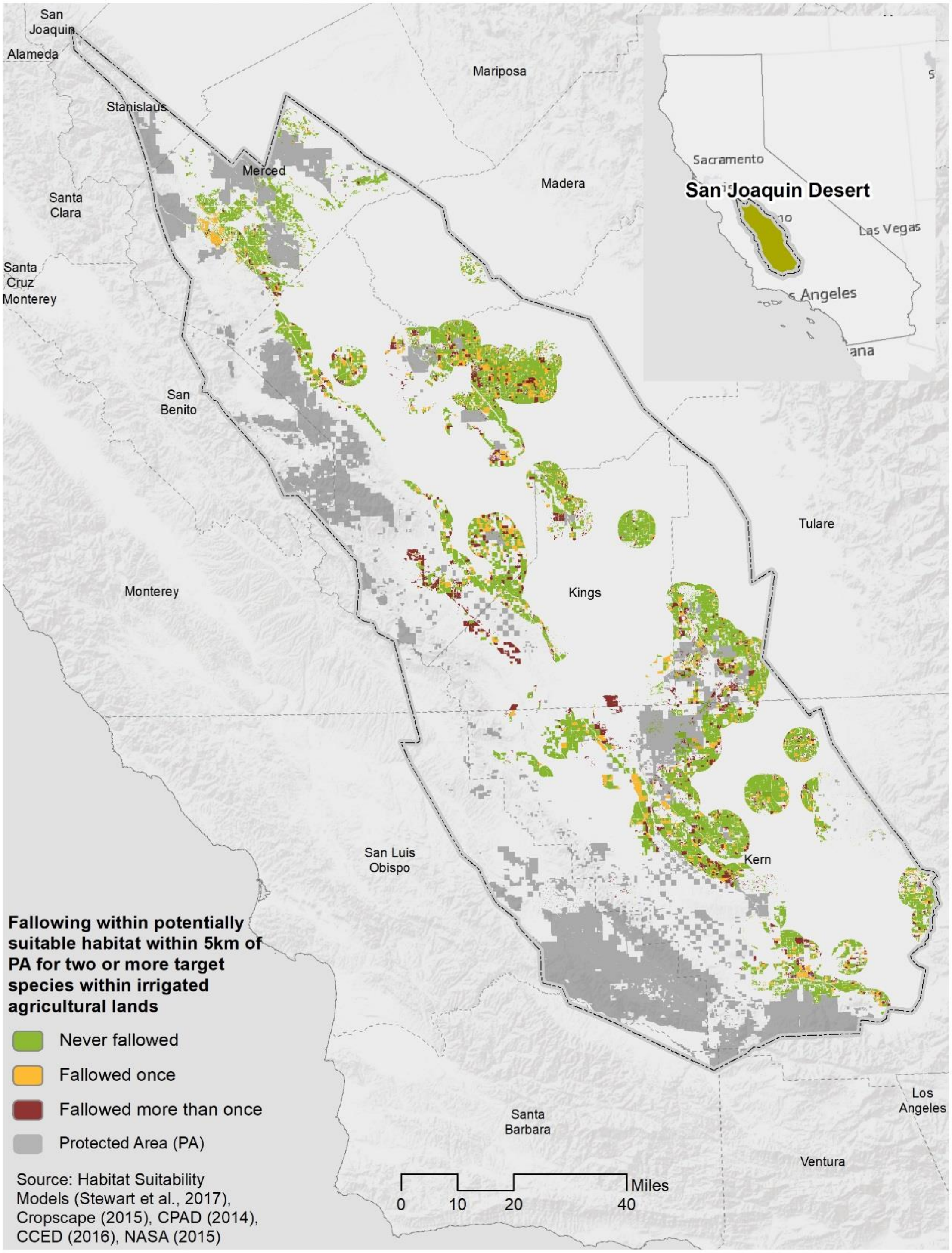

Figure 9. Overlap between areas of least conflict for solar PV energy development and potentially suitable habitat for one or more target species within irrigated agriculture.

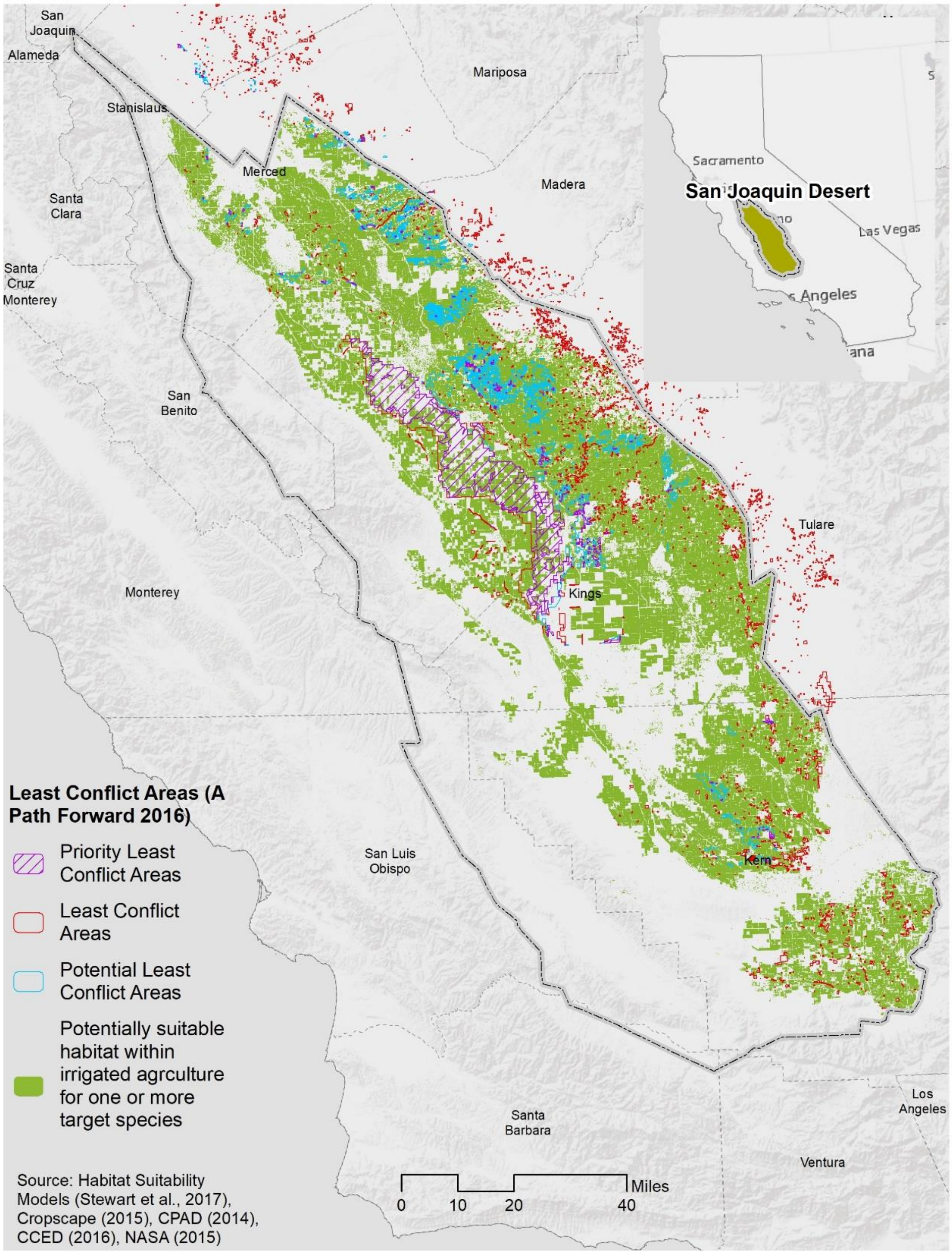

Figure 10. Groundwater recharge potential, as defined by Soil Agricultural Groundwater Banking Index, within potentially suitable habitat for one or more target species within irrigated agricultural land.