Species Status Assessment Report for the Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*)

Photo by Andrew Lawrence, New Mexico State University

Version 2.3

March 2022

U.S. Fish and Wildlife Service
Southwest and Mountain-Prairie Regions
Albuquerque, NM, and Denver, CO

Suggested Citation:

> U.S. Fish and Wildlife Service. 2022. Species status assessment report for the lesser prairie-chicken (*Tympanuchus pallidicinctus*), Version 2.3. 109 pp. + Appendices.

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Electronic version available online at http://fws.ecos.gov/

Version History:

Version 2.3 *This version of the Lesser Prairie-Chicken Species Status Assessment and resulting report (SSA) was completed in March 2022 following review and comments from the public review of Version 2.2 along with the proposed listing rule published on June 1, 2021. Only minor revisions were made throughout the report, and current population estimates for the species were updated through 2021.*

Version 2.2 *This version of the Lesser Prairie-Chicken Species Status Assessment Report (SSA) was completed in January 2021 following very minor revisions from Version 2.1. This version is supported the Service's 12-month petition finding, June 1, 2021.*

Version 2.1 *This version of the Lesser Prairie-Chicken Species Status Assessment and resulting report (SSA) was completed in October 2020 following review and comments from peer and partner review of Version 2.0.*

> *We appreciate the four peer reviewers that provided comments on Version 2.0 of this draft report: A. Gregory, D. Haukos, S. Oyler-McCance, and V. Winder.*

Version 2.0 *This version of the Lesser Prairie-Chicken Species Status Assessment and resulting report (SSA) are updates from Version 1.0. This draft report was produced in August 2020 to facilitate additional peer and partner (State and Federal agency) review. Much of the report and analytical framework in this version remained the same as Version 1.0, but we have updated the data and information, including the spatial analysis.*

> *This report was prepared by biologists from the U.S. Fish and Wildlife Service (Service): Clay Nichols, Chris O'Meilia, Jennifer Davis, Patricia Echo-Hawk, Kevin Burgess, Jim Dick, Mike Dick, Sabrina West, and Nathan Allan. We received significant assistance from State biologists*: Grant Beauprez, New Mexico Department of Game and Fish; Brett Cooper, Oklahoma Department of Wildlife Conservation; Kent Fricke, Kansas Department of Wildlife and Parks; Russell Martin, Texas Parks and Wildlife Department; and Liza Rossi, Colorado Parks and Wildlife Department.*

Version 1.0 *We completed a draft of this SSA report in 2018. The draft report had undergone peer and partner review in 2017. However, we did not complete the related 12-month finding at that time, and we did not release the draft SSA report to the public.*

> *During the development of the SSA, version 1.0, we engaged a group of biological experts*. This informal working group assisted the Service in gathering the best available information to use in this assessment. Individuals on the working group also provided comments on the preliminary draft of the report, as the partner review, concurrent with independent peer review. We appreciate the assistance of these experts*: Liza Rossi, Colorado Parks and Wildlife Department; Allan Janus, Oklahoma Department of Wildlife Conservation; Kent Fricke, Kansas Department of Wildlife and*

Parks; Brad Simpson, Texas Parks and Wildlife Department; Grant Beauprez, New Mexico Department of Game and Fish; Jim Pitman, Western Association of Fish and Wildlife Agencies; Christian Hagen, USDA, Natural Resources Conservation Service (at Oregon State University); Sam Fuhlendorf, Oklahoma State University; Michael Patten, University of Oklahoma; David Haukos, Kansas State University, USGS Coop Unit; Clint Boal, Texas Tech University, USGS Coop Unit.

We also received substantial assistance (supported by an interagency funding agreement) from Jonathan Cummings, Sarah Converse, David Smith, and Clint Moore, of the U.S. Geological Survey. We appreciate the four peer reviewers that provided comments on Version 1.0 of this draft report: J. Augustine, R. Baydack, A. Gregory, and J. Johnson.*

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*The Service very much appreciates the time and assistance provided by all of the individuals who contributed to this assessment. While these experts provided various assistance in the development of this assessment, this report is a Service document, and the analysis, assumptions, and conclusions reported here represent those of the Service and do not imply endorsement by any of the working group participants or their respective organizations.

Executive Summary

ES.1 Introduction (Chapter 1)

The lesser prairie-chicken (*Tympanuchus pallidicinctus)* (LEPC) is a species of prairie grouse that occurs in the grasslands and shrublands of the Southern Great Plains in parts of Colorado, Kansas, New Mexico, Oklahoma, and Texas. The LEPC has experienced substantial and protracted declines in distribution and abundance due to habitat loss and fragmentation across its range prompting concern about its status. This report summarizes the U.S. Fish and Wildlife Service's (Service, we) Species Status Assessment (SSA) for the LEPC. The purpose of the SSA is to summarize the most relevant information regarding LEPC life history and ecology, document the current condition of the LEPC and its habitat, and forecast the future condition of LEPC and its habitat, accounting for those environmental factors and anthropogenic changes that are most influencing the LEPC and its habitat.

The LEPC became a candidate for listing under the Endangered Species Act (ESA) in 1998 and was listed as a threatened species in 2014. The listing was vacated in 2015 following a lawsuit. In September 2016, we received a new petition to list the LEPC as endangered, and in November 2016, we made a 90-day petition finding that the petition provided substantial information that the petitioned action may be warranted. We evaluated the LEPC to make a 12-month petition finding to determine whether listing under the ESA is warranted. This SSA Report does not result in, nor predetermine, any ESA decisions; instead, the SSA Report provides the biological information and analysis to inform the 12-month petition finding.

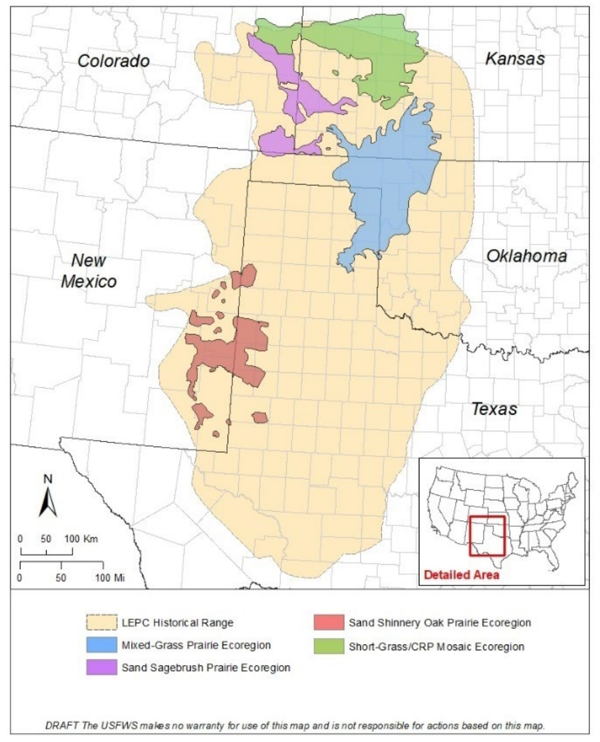

Figure ES.1 The estimated historical range and the analysis areas of the four ecoregions of the LEPC.

ES.2 Species Ecology (Needs) (Chapter 2)

The LEPC is a unique species of prairie grouse that once ranged across the Southern Great Plains. Its range has been much reduced, and the LEPC now occurs within four ecoregions (Figure ES.1). Each ecoregion is associated with unique environmental conditions based on habitat and climatic variables and some genetic differentiation. These four ecoregions are the Short-Grass Prairie/Conservation Reserve Program Mosaic Ecoregion in Kansas and Colorado; Sand Sagebrush Prairie Ecoregion in Colorado, Kansas, and Oklahoma; Mixed-Grass Prairie Ecoregion in Kansas, Texas, and Oklahoma; and Sand Shinnery Oak Prairie Ecoregion in New Mexico and Texas.

We consider the four ecoregions to be four representative areas within which the LEPC can maintain the remaining ecological and genetic diversity for future adaptive capacity. For LEPC populations within the ecoregions to be healthy and resilient, they require large, ecologically functioning grasslands and shrublands with a diversity of grass and low-growing shrub species with limited anthropogenic structures and trees. LEPC avoid using areas with trees, vertical structures, and other human disturbances in areas with otherwise adequate habitat conditions. The home range of the individuals from a single lek can encompass between 12,000 ac (4,900 ha) to more than 50,000 ac (20,000 ha), depending on the quality and intactness of the habitat. A complex of multiple leks that interact with each other is required for an LEPC population to be resilient over time. Maintaining multiple, highly resilient populations (groups of leks) within the four ecoregions contributes to overall species' viability.

ES.3 Current Condition (Chapter 3)

We assessed the current condition of the LEPC through an analysis of existing habitat; a review of factors that have impacted the species in the past, including a geospatial analysis to estimate areas of land cover impacts on the current landscape; a summary of the current potentially usable area available based upon our geospatial analysis; and a summary of past and current population estimates. Available grassland habitat for the LEPC has been much reduced (on the order of 80 to 90%) and fragmented compared to historical conditions across its range. Habitat loss has been both direct (loss of grassland) and indirect (disturbances that result in otherwise suitable grasslands not being used by LEPC) and has caused the remaining LEPC populations to be smaller and more isolated and disconnected compared to past conditions.

Human development of the Great Plains, first for agriculture and then for energy production, has resulted in a reduction in overall habitat availability and corresponding reductions in LEPC distribution and abundance. In addition to development activities, the alteration of historical fire and grazing regimes has resulted in encroachment of woody vegetation, further increasing habitat loss and fragmentation.

The past sources of grassland habitat loss and fragmentation within the range of the LEPC include: the largescale past conversion of prairie to cultivated agriculture; the construction of infrastructure for petroleum production; recent construction of infrastructure to support wind energy development; the encroachment of woody vegetation; and the construction of roads and electrical distribution lines. All of these landscape changes result in eliminating large grassland areas from being used by LEPC, and all have occurred throughout the historical and current LEPC range. We conducted a geospatial analysis using available land cover data to estimate these landscape changes within each ecoregion of the current LEPC range. Other factors that have influenced the LEPC in the past that we considered but were not able quantify in our geospatial habitat analysis include: livestock grazing; shrub control and eradication; anthropogenic noise; hunting and recreation; collision mortality from fences; predation; parasites and diseases; wildfires; insecticides; and extreme weather events.

We also evaluated and summarized the benefit of the extensive conservation efforts that are ongoing throughout the LEPC range to enhance and conserve the species and its habitat. Range-wide efforts include the Western Association of Fish and Wildlife Agencies' (WAFWA) LEPC Range-wide Conservation Plan, the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service's (NRCS) LEPC Conservation Initiative and Environmental Quality Incentives Program, and the USDA Farm Service Administration's Conservation Reserve

Program. In addition, there are numerous conservation efforts being led by state and regional programs such as: Kansas Department of Wildlife and Parks' Habitat First; the Service's Partners for Fish and Wildlife Program in all five LEPC states; the Shortgrass Prairie Initiative in Colorado by The Nature Conservancy and Colorado Department of Transportation; Colorado Parks and Wildlife LEPC Habitat Improvement Program; U.S. Forest Service (USFS) Cimarron and Comanche National Grasslands management; Oklahoma Department of Wildlife Conservation LEPC Candidate Conservation Agreement with Assurances (CCAA); Oklahoma Department of Wildlife Conservation Wildlife Management Areas; Texas Parks and Wildlife Department LEPC CCAA; The Nature Conservancy properties in New Mexico; the New Mexico Candidate Conservation Agreement and CCAA; U.S. Bureau of Land Management (BLM) Lesser Prairie-Chicken Habitat Preservation Area of Critical Environmental Concern; and Prairie Chicken Areas owned by New Mexico Department of Game and Fish.

Our geospatial analysis included an assessment of the current impacts of landscape changes within each ecoregion. The results indicate that the proportion of current LEPC potential usable unimpacted land cover that have at least 60% grassland or shrubland within one mile (mi) (1.6 kilometers (km) is about 19% of the total range-wide LEPC analysis area and ranges from 12% to 33% within ecoregions (Table ES.1).

Table ES.1 Results of LEPC geospatial analysis by ecoregion and range-wide estimating total area, potential usable area, potential usable unimpacted area, areas with 60% or greater unimpacted potential usable land cover within one mile (1.6 km), and proportion of the total ecoregion of each total for areas with at least 60% potential usable unimpacted land cover within one mile (1.6 km).

Ecoregion	(All Results in Acres) Ecoregion Total Area	Potential Usable Area	Potential Usable Unimpacted Area	Potential Usable Unimpacted Area (60% within 1 mile)	Percent of Total Area
Short-Grass/CRP	6,298,014	2,961,318	1,985,766	1,023,894	16.3%
Mixed-Grass	8,527,718	6,335,451	2,264,217	994,483	11.7%
Sand Sagebrush	3,153,420	1,815,435	1,358,405	1,028,523	32.6%
Shinnery Oak	3,850,209	2,626,305	1,423,417	1,023,572	26.6%
Range-wide Totals	21,829,361	13,738,509	7,031,805	4,070,472	18.6%

There are several important limitations to our geospatial analysis. First, it is a landscape-level analysis based on available land cover data, so the results only represent broad trends at the ecoregional and range-wide scales. Secondly, this analysis does not incorporate different levels of habitat quality, as the data do not exist at the spatial scale or resolution needed to incorporate into this analysis. Our analysis only considers areas as either potentially usable or not usable by LEPC based upon land cover classifications. We recognize that some habitat, if managed as high-quality grassland, may have the ability to support higher densities of LEPC than other habitat that exists at lower qualities. Additionally, we also recognize that some areas of land cover which we identified as suitable could be of such poor quality that it is of limited value to the LEPC. We recognize there are many important limitations to this landscape analysis, including variation and inherent error in the underlying data and unavailable data. We interpret the results of this analysis with those limitations in mind.

In response to landscape-scale loss and fragmentation of habitat, the estimated mean current abundance of LEPC has declined when compared to historical estimates (Figure ES.2). Recent population estimates from aerial surveys suggest low population numbers for three of the four ecoregions compared to historical estimates, with approximately 67% of the current population occurring within the Short-Grass/CRP ecoregion (Nasman *et al*. 2021, p. 14). The aerial survey results from 2012 through 2021 (Figure ES.2) estimated the LEPC population abundance, averaged over the most recent 5 years of surveys (2016–2021, no surveys in 2019), at 29,502 (90% confidence interval: 8,868, 60,617) (Nasman *et al*. 2021, p. 14).

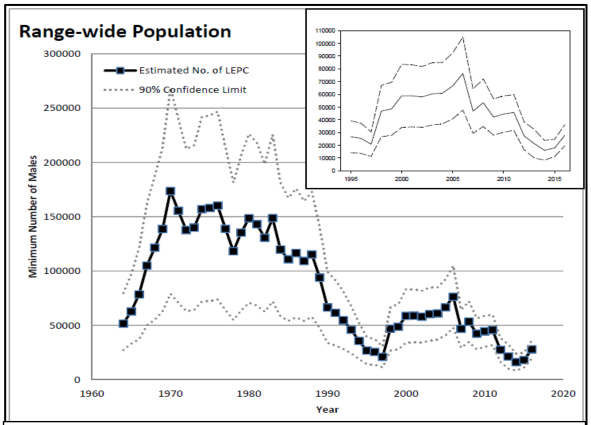

Figure ES.2 Estimated range-wide minimum number of Lesser Prairie-Chicken males attending leks 1964–2016 (90% confidence interval) based on population reconstruction using 2016 aerial survey as the initial population size (reproduced from Hagen *et al.* 2017).

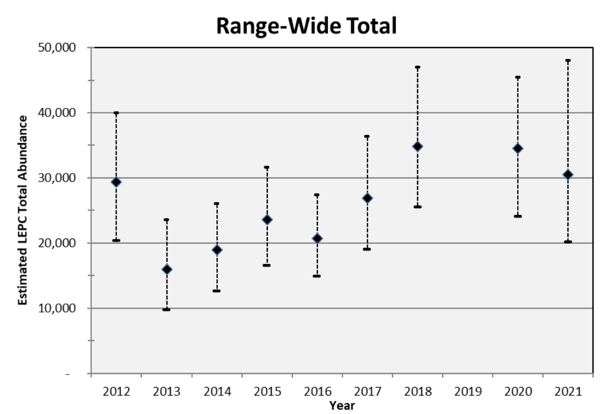

Figure ES.3 Annual estimates of total range-wide population size of lesser prairie-chicken from 2012–2021; bars represent the bootstrapped 90% confidence intervals. Graph generated from Nasman *et al.* (2021, p. 14). There were no surveys in 2019.

Table ES.2 Range-wide and ecoregional estimated LEPC total population sizes averaged from 2015 to 2021, lower and upper 90% confidence intervals (CI) over the 5 years' of estimates, and percent of range-wide totals for each ecoregion (from Nasman *et al.* 2021, p. 14). No surveys were conducted in 2019.

Ecoregion	5-year Average Estimate	*5-year Minimum Lower CI*	*5-year Maximum Upper CI*	Percent of Total
Short-Grass/CRP	**19,870**	*6,521*	*36,329*	67%
Mixed-Grass	**5,202**	*1,662*	*10,441*	18%
Sand Sagebrush	**1,182**	*55*	*4,547*	4%
Shinnery Oak	**3,249**	*630*	*9,300*	11%
Range-wide Totals	**29,502**	*8,868*	*60,617*	100%

ES.4 Future Condition (Chapter 4)

We assessed the future condition of the LEPC by projecting potential future changes in usable area within each of the four ecoregions. For some of the main sources of habitat loss and fragmentation, we used a geospatial model to project the possible land cover changes based on five plausible future scenarios of differing levels of habitat impacts and habitat restoration. Included in that geospatial model were projections of future impacts related to the conversion of grassland to cropland, the infrastructure associated with petroleum production and wind energy development, and encroachment of woody vegetation. These projections of impacts are offset to some degree by the projected conservation efforts in the form of habitat restoration. Restoration of LEPC habitat includes restoring grasslands from croplands, removal of infrastructure, and removal of woody vegetation.

Using our analysis of the current condition as a baseline, we projected these estimated changes using our geospatial model for 25 years into the future and found that overall LEPC habitat declines in all but the most optimistic scenario. The most optimistic scenario (Scenario 1, with projected low impacts and high conservation efforts) had estimated changes in habitat availability in the different ecoregions ranging from a 5% net loss to a 12% net gain and an overall range-wide net gain of about 0.5%. The other four scenarios resulted in overall net habitat loss ranging from 7% to 26% depending on the scenario (Table ES.3).

Table ES.3 Projected future median acreage of LEPC areas with 60% or greater potential usable unimpacted land cover within one mi (1.6 km) and percent change in acreage from estimated current areas with 60% or greater potential usable unimpacted land cover within one mile (1.6 km), in 25 years.

Ecoregion	(All Results in Acres) Total Area	Current Condition	Scenario 1 Low Impacts High Restoration		Scenario 2 Low Impacts Continuation Restoration		Scenario 3 Moderate Impacts Continuation Restoration		Scenario 4 High Impacts Continuation Restoration		Scenario 5 High Impacts Low Restoration	
			Median	% Change	Median	% Change	Median	% Change	Median	% Change	Median	% Change
Short-Grass/CRP	6,298,014	1,023,894	975,047	**-4.8%**	956,190	**-6.6%**	877,663	**-14.3%**	808,152	**-21.1%**	776,111	**-24.2%**
Mixed-Grass	8,527,718	994,483	974,200	**-2.0%**	864,780	**-13.0%**	742,855	**-25.3%**	649,227	**-34.7%**	630,633	**-36.6%**
Sand Sagebrush	3,153,420	1,028,523	992,632	**-3.5%**	980,302	**-4.7%**	932,477	**-9.3%**	887,224	**-13.7%**	884,851	**-14.0%**
Shinnery Oak	3,850,209	1,023,572	1,149,759	**12.3%**	988,072	**-3.5%**	868,761	**-15.1%**	771,923	**-24.6%**	711,933	**-30.4%**
Range-wide Totals	**21,829,361**	**4,070,473**	**4,091,638**	**0.5%**	**3,789,343**	**-6.9%**	**3,421,756**	**-15.9%**	**3,116,525**	**-23.4%**	**3,003,529**	**-26.2%**

There are other factors that may continue to negatively influence the LEPC into the future but were not explicitly projected into the future as part of the geospatial analysis, including, for example, grazing practices, road construction, power line and transmission construction, and shrub control. In addition, many conservation practices that result in habitat enhancements for LEPC are expected to continue through the multitude of LEPC programs that are working to conserve the species and its habitat across its range. We explicitly projected these enhancement efforts into the future at different levels and factored them into our overall assessment (Table ES.4), but not in the geospatial model. The enhancement efforts shown in ES.4 only includes efforts occurring above and beyond those outlined within the current condition discussion. The enhancement efforts are primarily targeted at maintaining or improving the quality of the existing LEPC habitat.

Table ES.4 Projected acreage of LEPC habitat enhancement over the next 25 years.

Enhancement Efforts	Total Level of Future Effort (Acres) at Year 25		
	Low	Continuation	High
Short-Grass/CRP Ecoregion			
KDWP Enhancement Contract	0	6740	17,500
NRCS LPCI Grazing Plan	0	0	4,000
USFWS PFW Contract	14,000	14,000	20,000
Mixed-Grass Ecoregion			
WAFWA Management Plan	0	0	118,245
KDWP Enhancement Contract	0	120	3,100
ODWC Management	1,400	3,300	6,400
ODWC Additional CCAA Enrollment	0	50,000	100,000
NRCS LPCI Grazing Plan	0	0	58,000
USFWS PFW Contract	50,000	50,000	70,000
TPWD Additional CCAA Enrollment	0	0	50,000
Sand Sagebrush Ecoregion			
KDWP Enhancement Contract	0	720	4,400
CPW Enhancement Contract	0	12,200	37,900
NRCS LPCI Grazing Plan	0	0	13,000
USFWS PFW Contract	0	6,000	18,000
Shinnery Oak Ecoregion			
WAFWA Management Plan	0	0	8,129
NRCS LPCI Grazing Plan	0	0	39,000
BLM Prescribed Fire	0	25,000	100,000
NM CCA/A Prescribed Fire	50,000	100,000	150,000
USFWS PFW Contract	5,000	15,000	50,000
TPWD Additional CCAA Enrollment	0	0	60,000

The effects of climate change were also not included in our geospatial model but are anticipated to have significant influences on future LEPC populations. Climate change in the Southern Great Plains is expected to result in generally warmer and drier weather with more frequent and more intense droughts. These changes are likely to directly impact LEPC reproduction and survival rates and possibly cause large scale shifts in the vegetation community. Of greatest concern is the increase in the effects of long-term droughts that place stress on LEPC populations and can put them at high risk of extirpation depending on the intensity and duration of the time period with below normal levels of precipitation accompanied by above normal temperatures.

Several calculations of population growth rates have been compiled, primarily using matrix models, for the LEPC with 19 out of the 23 calculated growth rates indicating declining populations. Another explicit evaluation of the future risk of extinction of the LEPC has been conducted using the historical ground surveys to assess the risk of quasi-extinction in each of the four ecoregions and range-wide for 30 and 100 years into the future (Hagen *et al.* 2017, entire). The results suggest a wide range of risks among the ecoregions depending partially on whether we consider movement between the ecoregions, but the Sand Sagebrush Ecoregion consistently had the highest risks of quasi-extinction (47 to 100% probability of quasi-extinction) and the Short-Grass/CRP Ecoregion had the lowest (0 to 88% probability of quasi-extinction). This analysis was based only on simulating demographic variability of populations based upon lek surveys and did not incorporate changing environmental conditions related to future habitat or climate variables. The results of future population trends should be interpreted with caution as there are uncertainties and limitations associated with all of these analyses and underlying data.

ES.5 Conclusions: Viability and Species Risk (Chapter 5)

Throughout the process of conducting this analysis, the Service and our partners discussed many limitations and assumptions associated with this assessment, including inherent uncertainty and accuracy issues associated with spatial data, spatial analysis methods, and future population projections (which are further discussed throughout the document). We draw the following conclusions based upon analyzing the best available information with all of the uncertainty and limitations in mind. The LEPC depends on large continuous expanses of grasslands of the Southern Great Plains to complete its life history and to maintain healthy populations. Over the past century and a half, the Great Plains ecosystems have been greatly altered by human land use practices, primarily for agriculture and energy development. The vast majority of the LEPC range occurs on private lands and public lands that are available for energy development. These land uses resulted in either the direct loss of grassland habitat (largely through conversion to croplands and land development), the indirect loss of grassland habitat (largely through construction of infrastructure for petroleum and wind energy development, roads, power lines and invasion of woody species—all of which the LEPC will avoid), or by degradation of habitat quality due to incompatible grazing or other land management practices. The results of these changes have made the current distribution and abundance of the LEPC much reduced from historical conditions. The remnant grassland has been reduced in both quantity and quality and has been fragmented such that limited appropriate spaces remain to support healthy LEPC populations. The remaining four ecoregions contains a small fraction of the likely overall historical LEPC habitat on the order of 10 to 20% of historical range. And the range-wide abundance of the LEPC has declined from estimates in the hundreds of thousands of birds (or even millions) to most recent 5 year average estimate of about 27,000 birds (90% confidence intervals around estimates over the last 5 years range from 16,000 to 60,000 birds).

In our assessment of the viability of the LEPC, we characterize the biological status of the species in terms of the representation, redundancy, and resiliency, so that we can consider its risk of extinction and, in contrast, its ability to maintain populations into the future. We structured our analysis geographically around the four ecoregions to account for representation, which considers within-species diversity and future adaptive capacity, and redundancy, which considers spreading populations out within ecoregions to reduce the risk of loss of any ecoregions due to catastrophic events. The viability of the LEPC over the next 25 years will primarily depend on the future habitat availability within each of the four ecoregions with the implications of climate change and the quality of existing habitat also impacting the species. Given the already reduced range of the species, an evaluation of the resiliency of populations (ability to withstand stochastic events) within these four ecoregions takes into account the already reduced species' range and associated reduction in redundancy and representation compared to historical conditions.

We used a geospatial analysis of land cover as a basis from which to assess future changes in the amount of potential usable area that could support LEPC populations. We explicitly projected changes in potential usable area over the next 25 years by forecasting both future impacts on habitat and future restoration of habitat. The results (Table ES.3) suggest that, in all but the most optimistic future scenario, future impacts outpace future habitat restoration with range-wide changes as high as a 26% reduction in available habitat in 25 years[1].

One important aspect of LEPC habitat we were not able to explicitly evaluate is the habitat quality of the remaining or future projected grasslands. As the quality of the grassland improves with appropriate vegetative structure to support the life history needs of the species, areas can support higher densities of LEPC. Conversely, as weather and management impact grassland quality in a negative manner, the remaining blocks of LEPC habitat will support lower densities of LEPC. Many conservation efforts have been undertaken in recent years to encourage and incentivize private landowners managing rangeland to promote increased quality of grassland conditions that will be favorable to LEPC populations. The projected future scope for a variety of these land practices is quantified in Table ES.4. Maximizing habitat quality on relatively small areas can potentially temporarily increase the size of local LEPC populations; however, the long term persistence of the LEPC is dependent upon having large blocks of available habitat that are connected to other large habitat blocks to allow them to be sustainable through stochastic events such as drought. The degree to which these habitat enhancement efforts can offset the ongoing loss in overall amount of habitat and ongoing habitat fragmentation is dependent upon several factors. The results from most of these efforts are expected to be temporary, depending on future management, and limited to relatively localized, short-duration increases in bird densities without concomitant efforts for larger-scale habitat restoration. As discussed by Fuhlendorf *et al.* (2017b, pp. 12–13), the benefits of conservation efforts focused on altering site-specific habitat quality for prairie grouse is constrained by higher-level processes of habitat loss and fragmentation. Concentrating conservation efforts on localized management to affect habitat quality, while not addressing the overarching limiting factor of habitat loss and fragmentation, is not addressing the long-term population needs for the LEPC. Therefore, as the amount of habitat decreases and habitat fragmentation increases in the future, the number of LEPC that can be supported by the ecoregions will also decrease. This decline in habitat availability results in long-term population declines with population peaks during years with above average annual precipitation being lower and population lows in following years of poor precipitation continuing to decrease.

Another future influence on LEPC habitat and populations not expressly included in our geospatial model is the effect of future climate change. All of the current climate models and research suggest that the expected environmental changes over the next 30 to 80 years associated

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[1] As discussed in Chapter 4, these projections do not account for all potential sources of future habitat loss for the LEPC. Due to data limitations, we were not able to project potential additional habitat loss resulting from construction of new roads, distribution lines, and transmission lines with any degree of certainty. Thus, the projections of habitat loss should be considered a minimum.

with future global climate change are likely to have mostly negative effects on the LEPC through direct impacts on survival of eggs and young and the indirect exacerbating influence of degradation of grassland quality to support LEPC. Weather conditions are critical aspects influencing the temporal fluctuations of LEPC populations that can produce dramatic annual fluctuations in LEPC abundance. Under wet and mild weather conditions, LEPC populations will increase, and under drought or other extreme weather conditions, LEPC populations will decrease. The effects of climate change are presumed to result in more stochastic events associated with extreme weather conditions, particularly more severe and extended drought conditions that will increase stress on LEPC populations in the future.

A summary of the status of each of the four ecoregions is provided below. Each of the ecoregions contains genetic and ecological diversity that may provide important adaptive capacity for the species.

Short-Grass Prairie/CRP Mosaic Ecoregion

The Short-Grass Prairie/CRP Mosaic Ecoregion has maintained the largest LEPC population since the early 2000s, with the most recent 5 year average of population estimates exceeding 15,000 birds, and it likely represents the most resilient ecoregion compared to the other ecoregions based on the relatively large number of birds present. The genetic structure of the populations in this ecoregion indicates that birds have dispersed into this area primarily from the Mixed-Grass Ecoregion and, to a lesser degree, from the Sand Sagebrush Ecoregion. This is logical as there were very few birds in this area in the 1980s. Evaluations of LEPC population growth trends in this ecoregion have resulted in four of six estimates indicate declining population growth rates, although there is substantial variability around many of the estimates. Quasi-extinction risks calculated from past ground-based surveys for this ecoregion were at or near 0 in the 30-year projections. The risk projections for this ecoregion suggest a lower probability of extirpation compared to other ecoregions because the recent population size and trajectory indicates it is likely reasonably resilient to withstand future stochastic events. However, these projections do not consider potential for future habitat declines.

The projections for changes in future usable area in the Short-Grass/CRP Ecoregion indicate declines ranging from 5 to 24% over the next 25 years. The future of LEPC habitat in this ecoregion will be most influenced by habitat loss and fragmentation from ongoing energy development (oil and gas and wind projects) and future trends in CRP enrollment, as conservation efforts are expected to focus primarily on habitat enhancement programs to manage for high-quality LEPC habitat. While the Short-Grass/CRP Ecoregion is estimated to have the largest population of LEPC, the conditions supporting these populations are reliant upon continued implementation of voluntary, short-term conservation efforts, primarily CRP, to provide available habitat. And future impacts are projected to outpace restoration efforts resulting in a decrease in available habitat over the next 25 years. Climate change is expected to have the least effects in this ecoregion because of projections for generally wetter conditions, although periodic, high-intensity droughts are still of concern.

Mixed-Grass Prairie Ecoregion

The Mixed-Grass Prairie Ecoregion has experienced substantial declines in the LEPC population, with the most recent 5 year average estimates at around 6,000 birds. The genetic structure of the birds in this ecoregion shows distinct difference in genetic variation compared to the other ecoregions, with the exception that birds from here are moving into the Short-Grass/CRP Ecoregion. Quasi-extinction risks for this ecoregion range from 3 to 23% over 30 years, depending on the effective population size threshold and the model considered. All but one of the population growth rate estimates were below 1, suggesting generally declining populations. Projections for this ecoregion suggest an elevated probability of extirpation as the current population size and trajectory makes it challenging to withstand future stochastic events. And none of these population projections account for future habitat loss.

The projections for future habitat loss in the Mixed-Grass Ecoregion are the largest among the four ecoregions, with results indicating potential usable area declines ranging from 2 to 37% over the next 25 years. This ecoregion also has the highest levels of habitat fragmentation compared to the other ecoregions. The future of LEPC habitat in this ecoregion will be most influenced by habitat loss and fragmentation from ongoing energy development (oil and gas and wind projects) and encroachment by eastern red cedar. Conservation efforts are expected to focus on habitat enhancement programs to manage for high-quality LEPC habitat as well as restoration efforts to remove eastern red cedar.

Sand Sagebrush Prairie Ecoregion

The Sand Sagebrush Prairie Ecoregion has experienced the most precipitous declines in the LEPC population, with the most recent 5 year average estimates at around 1,200 total birds, and this ecoregion likely has the most reduced resiliency compared to other ecoregions. The genetic structure of the birds in this ecoregion shows distinct difference in genetic variation compared to the other ecoregions, with the exception that birds from here are moving into the Short-Grass/CRP Ecoregion. Evaluations of LEPC population growth trends in this ecoregion have resulted in all seven estimates indicating declining population growth rates. Quasi-extinction risks for this ecoregion range from 47 to 100% over 30 years, depending on the effective population size threshold and the timeframe considered. From 2016-2019 State Wildlife Agencies from Colorado and Kansas translocated LEPC from the Short-Grass/CRP Ecoregion into this ecoregion and have released 411 birds in an attempt to augment the low populations.

While the projections for future habitat loss in the Sand Sagebrush Ecoregion are less than other ecoregions, the results still indicate potential usable area declines ranging from 3 to 14% over the next 25 years. The future of LEPC habitat in this ecoregion will be most influenced by habitat loss and fragmentation from ongoing energy development (oil and gas and wind projects), persistence of planted grasslands (CRP), and conservation efforts are expected to focus on habitat enhancement programs to reduce incompatible grazing and manage for high-quality LEPC habitat.

Sand Shinnery Oak Prairie Ecoregion

The Sand Shinnery Oak Prairie Ecoregion has experienced substantial declines in the LEPC population, with the most recent 5 year average estimates at around 3,000 birds. The genetic structure of the birds in this ecoregion shows distinct difference in genetic variation compared to the other ecoregions, and this ecoregion is isolated by distance from the other three ecoregions. Quasi-extinction risks for this ecoregion range from 0 to 16%, over the next 30 years depending on the effective population size threshold and the model considered. Three of the four population growth rate estimates were below 1, suggesting generally declining populations. These current projections for this ecoregion suggest an elevated probability of extirpation as the current population size and trajectory makes it challenging to withstand future stochastic events. None of these population projections account for future habitat loss.

The projections for future habitat loss in the Shinnery Oak Ecoregion indicate changes in potential usable area from a 12% increase in Scenario 1 to declines ranging from 3 to 30% in the other scenarios. The future of LEPC habitat in this ecoregion will be most influenced by habitat loss and fragmentation from ongoing energy development (oil and gas and wind projects) and encroachment by mesquite. Conservation efforts are expected to focus on habitat enhancement programs to manage for high-quality LEPC habitat and restoration via the removal of mesquite. Because its southern-most geographic location, this ecoregion is most susceptible to the effects of climate change, as this area is already relatively drier and is projected to experience additional hotter and drier conditions in the future. The potential for population extirpation due to extended drought events is high.

Summary

As DeYoung and Williford (2016, p. 91) summarized, "…the plight of the LEPC is primarily a problem of habitat loss, both amount and spatial extent. Concerns about habitat loss are paramount because loss of genetic variation, small population size, and amount of habitat, and stochastic events operate in a synergistic, not isolated, manner." If habitat availability continues to decline in the future as projected and the populations supported by that habitat are lost without the necessary connected habitat for recolonization, redundancy within the ecoregions will decline, increasing the risk of losing one or more representative ecoregions. The Sand Sagebrush Ecoregion is already at a very high risk of extirpation. Even as conservation activities continue, all of the ecoregions are at some elevated level of risk of extirpation, depending on the assumptions used to project the future and the timeframe considered. If entire ecoregions are extirpated in the future, then the LEPC will lose broad redundancy, putting it more at risk from species-wide extinction due to catastrophic events such as large-scale, extreme droughts that are predicted to increase in frequency due to climate change. In addition, the loss of ecoregions would be expected to result in the decline in the species' capacity to adapt to future changes in environmental conditions, causing additional risks of species extinction in the future. Over the past 150 years, LEPC populations and their habitats have been drastically reduced. As indicated by our analysis, additional future habitat loss and fragmentation across the range of the LEPC is likely to occur and conservation actions will not be enough to offset those habitat losses. Our analysis finds that the expected conservation efforts are inadequate to prevent continued declines in total habitat availability, much less restore some of what has been lost, and species viability for this species will continue to decline.

Commonly Used Acronyms

AWEA	American Wind Energy Association
BLM	U.S. Bureau of Land Management
CCA	Candidate Conservation Agreement
CCAA	Candidate Conservation Agreement with Assurances
CDL	Department of Agriculture’s Cropland Data Layer
CEHMM	Center of Excellence for Hazardous Material Management
CHAT	Southern Great Plains Crucial Habitat Assessment Tool
CPW	Colorado Parks and Wildlife
CRP	Conservation Reserve Program
DOE	Department of Energy
DSL	dunes sagebrush lizard (*Sceloporus arenicolus*)
EOR	Estimated Occupied Range
EOR+10	Estimated Occupied Range plus a 10-mile buffer
ERC	eastern red cedar (*Juniperus virginiana*)
ESA	Endangered Species Act of 1973, as amended
EVT	LANDFIRE Existing Vegetation Type
FAA	Federal Aviation Administration
FSA	U.S. Department of Agriculture, Farm Service Agency

GIS	Geographic Information System
KDWP	Kansas Department of Wildlife and Parks
LEPC	Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*)
LPCI	Lesser Prairie-Chicken Initiative
NLCD	National Land Cover Dataset
NMDGF	New Mexico Department of Game and Fish
NRCS	U.S. Department of Agriculture, Natural Resources Conservation Service
ODWC	Oklahoma Department of Wildlife Conservation
PFW	USFWS Partners for Fish and Wildlife Program
RMPA	BLM’s Special Status Species Resource Management Plan Amendment
RWP	Lesser Prairie-Chicken Range-Wide Plan (Van Pelt *et al*. 2013)
SSA	Species Status Assessment
TNC	The Nature Conservancy
TPWD	Texas Parks and Wildlife Department
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service (Service)
USGS	U.S. Geological Survey
WAFWA	Western Association of Fish and Wildlife Agencies

Table of Contents

1. INTRODUCTION

1.1 Introduction

The lesser prairie-chicken (*Tympanuchus pallidicinctus)* (LEPC) is a species of prairie grouse that occurs in the grasslands and shrublands of the Southern Great Plains in parts of Colorado, Kansas, New Mexico, Oklahoma, and Texas. The LEPC has experienced substantial and protracted declines in distribution and abundance due to habitat loss and fragmentation[2] across its range, prompting concern about the conservation status of the species. This report summarizes the latest Species Status Assessment (SSA) for the LEPC, as the U.S. Fish and Wildlife Service (Service, our, we) has been periodically reviewing the status of the LEPC for nearly two decades.

1.2 SSA Overview

The Service's Endangered Species Program has developed a framework to guide how we assess the biological status of species (Figure 1.1; Service 2016c, p. 6). Because biological status assessments are frequently used in all of our Endangered Species Program areas, developing a single, scientifically sound document is more efficient than compiling separate documents for use in our listing, recovery, consultation, and other conservation programs. Therefore, we have developed this SSA Report to summarize the most relevant information regarding life history, biology, and considerations of current and future risk factors facing the LEPC. In addition, we forecast the possible response of the species to various future risk factors, conservation efforts, and environmental conditions to provide a complete biological risk assessment for the LEPC.

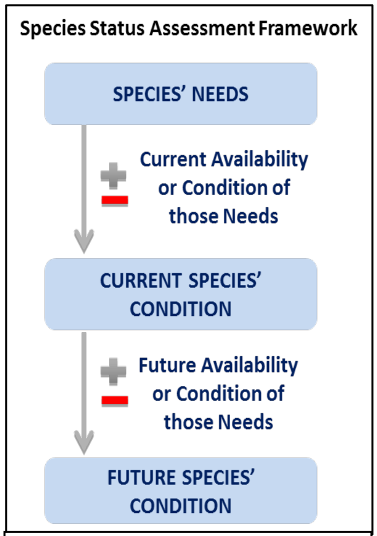

Figure 1.1 Species Status Assessment Framework.

The objective of the SSA is to evaluate the viability of the LEPC based on the best scientific and commercial information available. In conducting this analysis, we took into consideration the likely changes that are happening in the environment – past, current, and future – to help us understand what factors drive the viability of the species. Through this SSA Report, we will describe what the species needs to support viable populations, its current condition in terms of those needs, and its forecasted future condition under plausible future scenarios.

For the purpose of this assessment, we consider viability to be a description of the ability of a species to sustain populations in the wild beyond a biologically meaningful time frame. Viability is not a specific state, but rather a continuous measure of the likelihood that the species will sustain populations over time (Service 2016c, p. 9). Using the SSA framework, we consider what the species needs to maintain viability by characterizing the status of the species in terms of its representation, resiliency, and redundancy (3Rs).

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[2] Select terms used in this report are underlined and defined in the glossary in Appendix A.

- **Representation** describes the ability of a species to adapt to both near-term and long-term changes in its physical (climate conditions, habitat conditions, habitat structure, etc.) and biological (pathogens, competitors, predators, etc.) environments. This ability to adapt to new environments-- referred to as adaptive capacity--is essential for viability, as species need to continually adapt to their continuously changing environments. Species adapt to novel changes in their environment by either [1] moving to new, suitable environments or [2] by altering their physical or behavioral traits (phenotypes) to match the new environmental conditions through either plasticity or genetic change. The latter occurs via the evolutionary processes of natural selection, gene flow, mutations, and genetic drift. We structured our analysis across four ecoregions to consider the genetic and ecological diversity of the LEPC.

- **Resiliency** is the ability of a species to withstand environmental stochasticity (normal, year-to-year variations in environmental conditions such as temperature, rainfall), periodic disturbances within the normal range of variation (fire, floods, storms), and demographic stochasticity (normal variation in demographic rates such as mortality and fecundity). Simply stated, resiliency is the ability to sustain populations through the natural range of favorable and unfavorable conditions. Resiliency is positively related to population size and growth rate and may be influenced by connectivity among populations. Generally speaking, populations need abundant individuals within habitat patches of adequate area and quality to maintain survival and reproduction in spite of stochastic events. In the case of the LEPC, the primary indicators of resiliency we measured were habitat availability, population abundance, growth rates and quasi-extinction risk as metrics to withstand severe weather events (such as drought or blizzards).

- **Redundancy** is the ability of a species to withstand catastrophic events. Catastrophes are stochastic events that are expected to lead to population collapse regardless of population heath and for which adaptation is unlikely. Redundancy is about spreading the risk and can be measured through the duplication and broad distribution of resilient populations which are connected across the range of the species. The larger the number of resilient populations the species has, distributed over a larger area, the better chances that the species can withstand catastrophic events. For the LEPC, we used the geographic distribution of predicted available habitat within and across four ecological regions, and the juxtaposition of that habitat to other habitat and non-habitat, to measure redundancy.

1.3 SSA Methodology

There is a substantial amount of scientific information available regarding the LEPC. Much of the scientific information used to inform our analysis is available in a recently published book titled, "Ecology and Conservation of Lesser Prairie-Chickens" (Haukos and Boal 2016, entire). We also relied heavily on the Lesser Prairie-Chicken Range-Wide Conservation Plan (RWP) (Van Pelt *et al.* 2013, entire), an annotated LEPC bibliography (Zavaleta and Haukos 2013, entire), our previous proposed and final rules to list the LEPC as a threatened species with a special rule (Service 2012, 2014c), the listing petition we received on September 8, 2016 (Molvar 2016, entire), and other publicly available scientific publications and data. We did not attempt to reproduce all of the biological and ecological information available on the LEPC. We strove to summarize the key findings of past research and publications, as they relate to the future viability of the LEPC and our decisions under the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 et seq.). All the literature referenced in this report is cited in Appendix F. In addition, to improve clarity, some select terms used in this report are underlined and defined in the glossary in Appendix A.

This LEPC SSA Report is a summary of information analyzed by the Service and incorporates the best scientific and commercial data available. This SSA Report documents the results of the comprehensive status review for the LEPC to inform the upcoming 12-month petition finding under the Endangered Species Act of 1973, as amended (ESA).

1.4 Decision Context

The LEPC was made a candidate for listing under the ESA by the Service in 1998. We listed the LEPC as a threatened species with a special rule under the ESA in March 2014. This final listing determination was vacated by the United States District Court in the Western District of Texas on September 1, 2015. We then issued a direct final rule in July 2016 removing the LEPC from the List of Endangered and Threatened Wildlife (50 CFR 17.11 (h)) in accordance with the court order. On September 8, 2016, the Service received a petition from WildEarth Guardians, Defenders of Wildlife, and Center for Biological Diversity to list the LEPC as endangered throughout its entire range or in three distinct population segments (Molvar 2016, entire). On November 30, 2016, we published a 90-day petition finding that concluded that the petition to list the LEPC provided substantial information that the petitioned action may be warranted (81 FR 86315). We are now evaluating the LEPC to make a new 12-month petition finding to determine whether listing under the ESA is warranted.

1.5 ESA Determinations

Importantly, this SSA Report does not result in, nor does it predetermine, any decisions by the Service under the ESA. In the case of the LEPC, the SSA Report does not determine whether the LEPC warrants the protections of the ESA or whether it should be proposed for listing as a threatened or endangered species under the ESA, nor does it establish recovery criteria or critical habitat should the species be listed. Those decisions will be made by the Service after reviewing this document, along with the supporting analysis, and all applicable laws, regulations, and policies. The results of any ESA determinations will be published in the *Federal Register*, and, if appropriate depending on the determination, provide opportunity for public review and comment. This SSA Report provides a strictly scientific, objective review and application of the available information related to the biological status of the LEPC.

The conclusion of the SSA characterizes the viability of the LEPC by considering the risks of extinction, in light of the 3Rs, under a range of plausible future conditions. The decision whether to list a species is based not only on a prediction of the most likely future for the species, but rather on an assessment of the species' overall risk of extinction. Therefore, to inform this assessment of extinction risk, we describe the species' current biological status and assess how this status may change in the future under a range of scenarios to account for the uncertainty of the species' future. We evaluate the current biological status of the LEPC by assessing the primary influences that are negatively and positively affecting the species resulting in its current condition in terms of the 3Rs. We then evaluate the future biological status of the LEPC by describing a range of plausible future scenarios. As a matter of practicality, the full range of potential future scenarios, and the range of potential future conditions for each potential scenario, are too large (virtually infinite) to individually describe and analyze. The scenarios we evaluate then do not include all possible futures, but rather include specific plausible scenarios that represent examples from the continuous spectrum of possible futures. Consequently, the results of this SSA cannot fully describe all the potential risks to the species. Recognizing these limitations, the results of this SSA nevertheless provide a framework for considering the overall risk to the species through a range of plausible scenarios in making ESA decisions.

2. SPECIES ECOLOGY (NEEDS)

2.1 Summary

This chapter provides a summary of the biology and ecology of the LEPC. This summary includes the conditions the species needs to maintain healthy populations across its range. The LEPC is recognized as a unique species of prairie grouse that once ranged across the Southern Great Plains of Southeastern Colorado, Southwestern Kansas, Western Oklahoma, the Panhandle and South Plains of Texas, and Eastern New Mexico. Its range has been much reduced, and the LEPC now occurs within four ecoregions. Each ecoregion is associated with unique environmental conditions based on habitat and climatic variables and some genetic differentiation. Those four ecoregions are the Short-Grass Prairie/Conservation Reserve Program Mosaic Ecoregion in Kansas; Sand Sagebrush Prairie Ecoregion in Colorado, Kansas, and Oklahoma; Mixed-Grass Prairie Ecoregion in Kansas, Texas, and Oklahoma; and Sand Shinnery Oak Prairie Ecoregion of New Mexico and Texas.

Most LEPC adults live for two to three years and reproduce in the spring and summer. Males congregate on leks during the spring to attract and mate with females. Males tend to exhibit strong site fidelity, often returning to a specific lek many times, even in cases of declining female attendance and habitat condition. Females tend to establish nests relatively close to the lek, commonly within 0.6 to 2.4 mi (1 to 4 km), where they incubate 8 to 14 eggs for 24 to 27 days and then raise broods of young throughout the summer. Some females will attempt a second nesting if the first nest fails. Eggs and young LEPC are susceptible to natural mortality from environmental stress and predation. The appropriate vegetative community and structure is vital to provide cover for nests and young and to provide food resources as broods mature into adults.

We consider the four ecoregions as four representative areas within which the LEPC can maintain their remaining ecological and genetic diversity for future adaptive capacity. For LEPC populations within the ecoregions to be healthy and resilient, they require large, ecologically functioning grasslands and shrublands with a diversity of grass and shrub species and limited anthropogenic structures and trees. Lesser prairie-chickens tend to avoid using areas with trees, vertical structures, and other disturbances (see section 3.3 for a full discussion of avoidance issues) in areas with otherwise adequate habitat conditions. The home range of the individuals from a single lek can encompass between 12,000 ac (4,900 ha) to more than 50,000 ac (20,000 ha), depending on the quality, availability, and intactness of the habitat. A single LEPC lek is not considered to be a population that can persist on its own. Instead, a complex of multiple leks that interact with each other is required for an LEPC population to be persistent over time. These metapopulation dynamics, where individuals interact on the landscape to form larger populations, is dependent upon the specific biotic and abiotic landscape characteristics of the site and how those characteristics influence space use, movement, patch size, and fragmentation. Maintaining multiple, highly resilient populations (groups of leks) within the four ecoregions is essential to overall species viability.

2.2 Taxonomy

The LEPC is in the order Galliformes, family Phasianidae, subfamily Tetraoninae; it is generally recognized as a species separate from the greater prairie-chicken (*Tympanuchus cupido pinnatus*) (Jones 1964, pp. 65–73; American Ornithologist's Union 1998, p. 122). The LEPC is closely related to the other prairie grouse that are included in the genus *Tympanuchus*. While the LEPC is related to the sharp-tailed grouse (*Tympanuchus pasianellus*), it is most closely related to the greater prairie-chicken, the federally endangered Attwater's prairie-chicken (*Tympanuchus cupido attwateri*) and the extinct Heath Hen (*Tympanuchus cupido cupido*) (Boal and Haukos 2016, p. 3).

The taxonomy of LEPC was first described as a subspecies of the greater prairie-chicken (Ridgway 1873, p. 199) and later named a full species in 1885 (Ridgway 1885, p. 355). As recently as the early 1980s, some species experts (Johnsgard 1983, p. 316) still regarded the extinct Heath Hen, the greater prairie-chicken, the LEPC, and the Attwater's prairie-chicken to be four subspecies within *Tympanuchus cupido*. However, estimates of population divergence and migration between several morphologically similar subspecific taxa, including the greater prairie-chicken, the Attwater's prairie-chicken, and the extinct Heath Hen suggest these taxa are as differentiated from each other as they are from other *Tympanuchus* species (Johnson 2008, p. 165). While genetic resolution within the *Tympanuchus* genus may be relatively low as discussed in DeYoung and Williford (2016, pp. 78–82), LEPC, sharp-tailed grouse, and greater prairie-chickens all clearly display behavioral and morphological differences. For further discussion of the genetic and morphological differences within the *Tympanuchus* genus see DeYoung and Williford (2016, pp. 77–97).

For purposes of this SSA, we will follow the American Ornithologist's Union taxonomic classification, which is based on observed differences in appearance, morphology, behavior, social interaction, and habitat affinities. The species classification adopted here is:

Class: Aves

Order: Galliformes

Family: Phasianidae

Subfamily: Tetraoninae

Genus and Species: *Tympanuchus pallidicinctus*

2.3 Species Description

Figure 2.1 Male Lesser Prairie-Chicken. Photo credit: Andrew Lawrence New Mexico State University.

The LEPC is a species of prairie grouse endemic to the southern and central high plains of the United States, commonly recognized for its feathered tarsi (legs), stout build, ground-dwelling habit, and lek mating behavior (Figure 2.1). The LEPC is closely related and generally similar in life history strategy, although not identical in every aspect of behavior and life history, to other species of North American prairie grouse (e.g., greater prairie-chicken, Attwater's prairie-chicken, sharp-tailed grouse, greater sage-grouse (*Centrocercus urophasianus*), and Gunnison's sage-grouse (*C. minimus*)). Plumage of the LEPC is characterized by a cryptic pattern of alternating brown and buff-colored barring and is similar in appearance to, although somewhat lighter in color than, the greater prairie-chicken. Males have long tufts of feathers on the sides of the neck, termed pinnae, which are erected during courtship displays. Pinnae are smaller and less prominent in females. Males also display brilliant yellow supraorbital eyecombs and dull reddish esophageal air sacs during courtship displays (Copelin 1963, p. 12; Sutton 1977, entire; Johnsgard 1983, p. 318). A more detailed summary of the physical appearance of the LEPC is provided in Hagen and Giesen (2005, unpaginated).

Lesser prairie-chickens are dimorphic in size, with the females being smaller than the males (See Table 1 in Hagen and Giesen 2005, unpaginated). Adult LEPC body length varies from 15 to 16 inches [in] (38 to 41 centimeters (cm)) (Johnsgard 1973, p. 275; Johnsgard 1983, p. 318), and adult body mass varies from 1.4 to 2.0 pounds (lbs) (618 to 897 grams (g)) for males and 1.1 to 1.7 lbs (517 to 772 g) for females (Haukos *et al*. 1989, p. 271; Giesen 1998, p. 14).

2.4 Historical Range, Current Range, and Ecoregions

Prior to description by Ridgway in 1885 (and for some time afterward), most observers did not differentiate between the lesser and greater prairie-chickens. Consequently, estimating historical abundance and occupied range is difficult. Historically, the LEPC is known to have occupied grasslands in portions of Southeastern Colorado (Giesen 1994b, pp. 175–182), Southwestern Kansas (Baker 1953, p. 9; Schwilling 1955, p. 10), Western Oklahoma (Duck and Fletcher 1944, p. 68), the South Plains and Panhandle of Texas (Henika 1940, p. 15; Oberholser 1974, p. 268), and Eastern New Mexico (Ligon 1927, pp. 123–127).

There have been several estimates of the potential maximum historical range of the LEPC (e.g., Johnsgard 2002, p. 32; Taylor and Guthery 1980a, p. 1, based on Aldrich 1963, p. 537; Playa Lakes Joint Venture 2007, p. 1) with a wide range of estimates on the order of about 100,000 to 180,000 square miles (64 to 115 million ac, 26 to 47 million ha). Figure 2.2 shows the most recent estimate of the historical range as depicted in the RWP (Van Pelt *et al.* 2013, p. 3) and referenced by Boal and Haukos (2016, p. 6). Presumably not all of the area within this range was evenly occupied by LEPC, and some of the area was not likely to have been suitable to regularly support LEPC populations (Boal and Haukos 2016, p. 6).

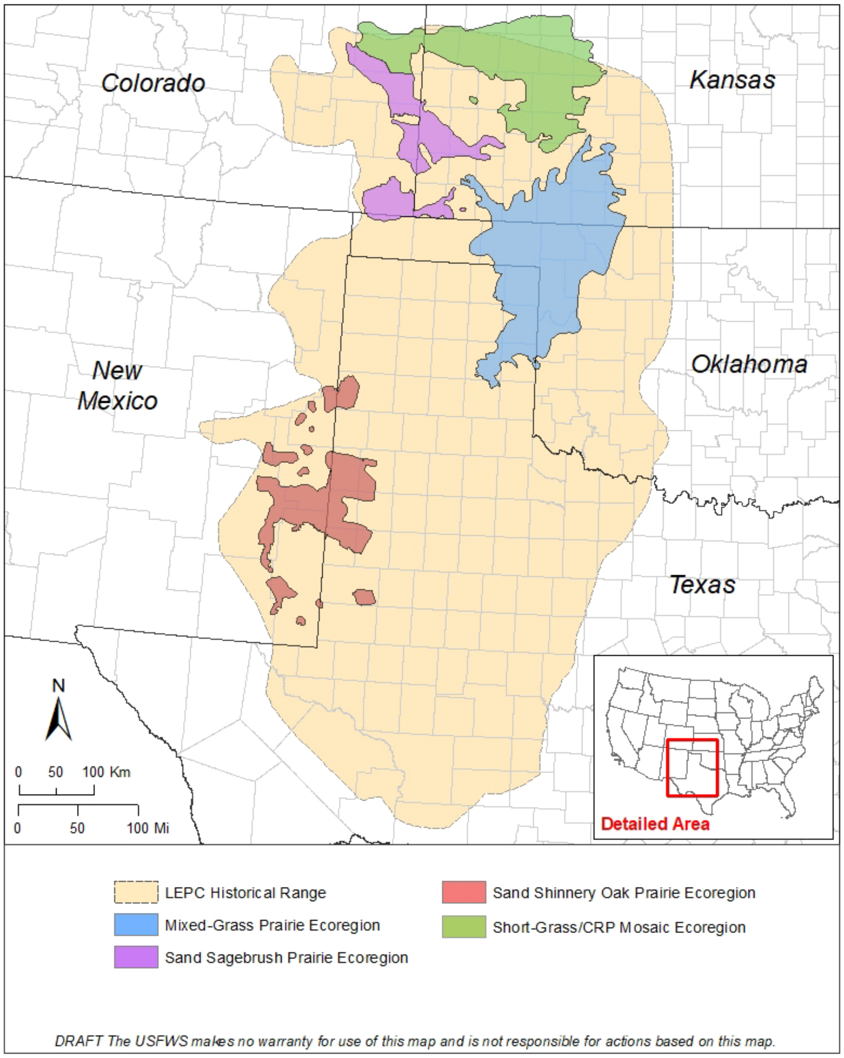

Figure 2.2 The estimated historical range and our SSA analysis area for each of the four lesser prairie-chicken ecoregions.

Throughout this report, we evaluate the range of the LEPC (estimated occupied range, EOR revised[3]) as presently occurring in four ecoregions as defined by Van Pelt *et al*. (2013, p. 3) and depicted in Figure 2.2. These ecoregions represent differences across the LEPC range in terms of vegetation communities, environmental conditions, and land uses that result in variation in LEPC limiting factors, reproductive potential, density, and abundance (Boal and Haukos 2016, p. 5). Each of the four ecoregions was treated separately throughout the SSA analysis for the characterization of current and future conditions. Those four ecoregions are the Short-Grass Prairie/Conservation Reserve Program Mosaic Ecoregion in Kansas and Colorado; Sand Sagebrush Prairie Ecoregion in Colorado and Kansas; Mixed-Grass Prairie Ecoregion in Kansas, Texas, and Oklahoma; and Sand Shinnery Oak Prairie Ecoregion of New Mexico and Texas (Table 2.1). Detailed accounts of the ecology and management of LEPC in each ecoregion are provided in chapters 14−17 in Haukos and Boal (2016, pp. 259−344).

Table 2.1 Ecoregions of the lesser prairie-chicken current range.

LEPC Ecoregion	Abbreviations	States	Reference
Short-Grass Prairie/Conservation Reserve Program Mosaic Ecoregion	Short-Grass/CRP Ecoregion; SGPE	Kansas, Colorado	Dahlgren *et al.* 2016, pp. 259–279
Sand Sagebrush Prairie Ecoregion	Sand Sagebrush Ecoregion; SSBPE	Kansas, Colorado, Oklahoma	Haukos *et al.* 2016, pp. 281–298
Mixed-Grass Prairie Ecoregion	Mixed-Grass Ecoregion; MGPE	Kansas, Oklahoma, Texas	Wolfe *et al.* 2016, pp. 299–314
Sand Shinnery Oak Prairie Ecoregion	Shinnery Oak Ecoregion; SSOPE	New Mexico, Texas	Grisham *et al.* 2016a, pp. 315–344

2.5 Life History and Ecological Needs of Individual LEPC

Throughout the life cycle, different micro-habitats are selected by the LEPC. Below is a general description of the life history and ecological needs for the species, although we recognize there is variation among ecoregions for each topic. For further discussion of specifics for each ecoregion please see the references in Table 2.1. Also, for an extensive discussion and review of the existing literature on LEPC habitat see Haukos and Zavaleta (2016, pp. 99–132).

2.5.1 Life Span and Life Stages

Lesser prairie-chickens have a relatively short lifespan and high annual mortality. Campbell (1972, p. 694) estimated a 5-year maximum lifespan, although an individual nearly 7 years old has been documented in the wild by the Sutton Avian Research Center (Sutton Center) (Wolfe

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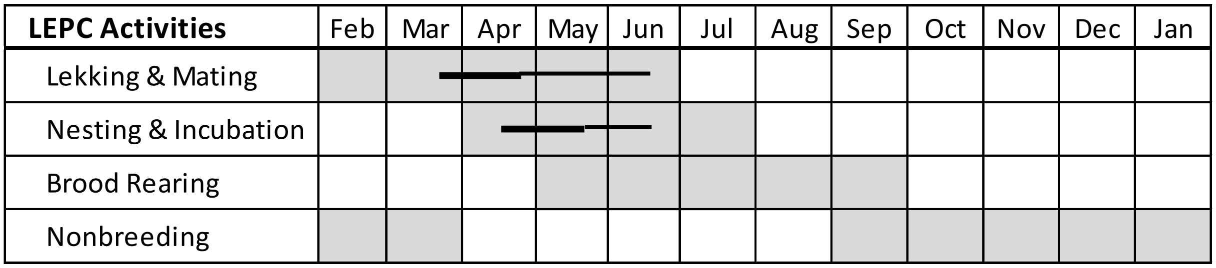
[3] The boundaries of the EOR for this analysis were revised in minor ways by the state biologists assisting with the analysis to account for new lek observations (Fricke 2020, pers. comm.). These changes were for the exclusive application in this SSA and do not alter other existing uses of the previous EOR boundaries.

2010, pers. comm.). However, the average generation time was calculated, based on work by Farner (1955, entire), to be 1.95 years (Van Pelt *et al*. 2013, p. 130). Pruett *et al*. (2011, p. 1209) also estimated generation time in LEPC and found generation times were similar in Oklahoma (1.92 years) but lower than in New Mexico (2.66 years). We estimate that most LEPC adults likely live less than 5 years and have a generation time of 2 to 3 years.

Figure 2.3 shows the approximate timing of the annual reproductive activities of the LEPC. Activities critical to LEPC populations include mating on leks in the spring from February through June, peaking in mid-April, followed by nesting and egg incubation from March to May and potential renesting in June. Rearing of chicks in broods occurs throughout the summer until September (Boal and Haukos 2016, p. 4).



LEPC Activities	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Lekking & Mating	▨	▨	▨	▨	▨							
Nesting & Incubation			▨	▨	▨	▨						
Brood Rearing				▨	▨	▨	▨	▨				
Nonbreeding	▨	▨						▨	▨	▨	▨	▨

Figure 2.3 Approximate annual cycle of major lesser prairie-chicken reproductive activities (adapted from Hagen and Giesen 2005). Shaded months indicate general activity times; thick lines indicate peak activities for first mating and nesting attempts; and thin lines indicate peak activity times for second mating and nesting attempts.

The specific resource needs, in terms of micro-habitat conditions, for individual life stages of LEPC vary to some degree by life stage and activity. Table 2.2 summarizes the basic resource needs and the following sections discuss these needs in more detail.

Table 2.2 Summary of localized resource (habitat) needs for individual lesser prairie-chickens.

Life Stage/Activity	**Resource Needs**	**Function**	**Citation**
Reproduction: Adults on leks	Relatively small open areas with sparse vegetation on elevated ridges or knolls; near adequate nesting habitat	Visual and vocal displays for mate attraction and selection	Copelin 1963, p. 26; Jones 1963, p. 771; Taylor and Guthery 1980a, p. 8; Giesen 1998, p. 4
Reproduction: Nesting females	Tall and dense herbaceous cover, including residual cover from the previous growing season; free of vertical structures and anthropogenic disturbance	Concealment of nests and females from predators and weather events	Suminski 1977, p. 32; Riley 1978, p. 36; Riley *et al*. 1992, p. 386; Giesen 1998, p. 9
Recruitment: Brood rearing of chicks	More open than nesting habitat; high density of forbs which supports high biomass of invertebrate prey base	Food and cover	Jamison *et al*. 2002, pp. 520, 524; Pitman *et al*. 2006b, p. 680; Bell *et al*. 2010, entire; Hagen *et al*. 2013, p. 4
Winter Survival: Juvenile and Adult	Large spans of short- and mixed-grass prairies providing physical cover to protect from predation and weather, and provide food resources	Dispersal, food, and cover	Giesen 1998, p. 4; Robinson *et al.* 2018, entire

2.5.2 Reproduction: Mating on Leks

Lesser prairie-chickens are polygamous (a mating pattern in which a male mates with more than one female in a single breeding season) and exhibit a lek mating system. The lek is a place where males traditionally gather to conduct a communal, competitive courtship display. The males use their specialized plumage and vocalizations (commonly referred to as booming) to attract females for mating. Leks are normally located on the tops of wind-swept ridges, exposed knolls, sparsely vegetated dunes, and similar features in areas having low vegetation height (4 in (10 cm) or less or bare soil and enhanced visibility of the surrounding area (Copelin 1963, p. 26; Jones 1963, p. 771; Taylor and Guthery 1980a, p. 8; Giesen 1998, p. 4). Disturbed habitats with sparse vegetation, such as those found after early spring fires (Cannon and Knopf 1979, pp. 44–45) or on roads, oil and gas pads, and similar forms of human disturbance (Giesen 1998, p. 4), can create habitat conditions that may encourage lek establishment. However, the human disturbance often associated with artificial lek sites can be detrimental during the breeding season (Taylor 1979, p. 707). The physical characteristics of the landscape associated with lek sites also may contribute to the transmission of sounds produced during lekking (Sparling 1983, pp. 40–41; Butler *et al*. 2010, entire), and these sounds may aid females in locating lek sites (Hagen and Giesen 2005, unpaginated).

Lesser prairie-chicken females arrive at the lek in early spring after the males begin displaying, with peak hen attendance at leks typically occurring in early to mid-April (Copelin 1963, p. 26; Hoffman 1963, p. 730; Crawford and Bolen 1975, p. 810; Davis *et al*. 1979, p. 84; Merchant 1982, p. 41; Haukos 1988, p. 49). Males will continue to visit lek sites into June to mate with females that were not successful with their first nesting attempt. Females may visit multiple leks before copulating (Giesen 1994a, pp. 97–98).

2.5.3 Reproduction: Nesting

Within 1 to 2 weeks of successful mating, the hen will select a nest site based upon available nesting habitat, normally within 0.6 to 2.4 mi (1 to 4 km) of an active lek[4] (Copelin 1963, p. 44; Giesen 1994a, p. 97), construct a nest, and lay a clutch of 8 to 14 eggs with regional variability (Bent 1932, p. 282; Copelin 1963, p. 34; Merchant 1982, p. 44; Fields 2004, pp. 88, 115–116; Hagen and Giesen 2005, unpaginated; Pitman *et al*. 2006a, p. 26). Females may return to nest in areas of previously successful nests (Riley 1978, p. 36). Nesting is generally initiated in mid-April and concludes in late May (Copelin 1963, p. 35; Snyder 1967, p. 124; Merchant 1982, p. 42; Haukos 1988, pp. 7–8). Hens most commonly lay one egg per day and initiate incubation once the clutch is complete (Hagen and Giesen 2005, unpaginated). Incubation lasts 24 to 27 days (Coats 1955, p. 18; Sutton 1968, p. 679; Pitman *et al*. 2006a, p. 26) with hatching generally peaking in late May through mid-June (Copelin 1963, p. 34; Merchant 1982, p. 42; Pitman *et al*. 2006a, p. 26). Hens typically leave the nest within 24 hours after the last egg hatches (Hagen and Giesen 2005, unpaginated). Re-nesting may occur when the first attempt at a nest fails to produce offspring (Johnsgard 1973, pp. 63–64; Merchant 1982, p. 43; Pitman *et al*. 2006a, p. 25). Re-nesting is more likely when nest failure occurs early in the nesting season and becomes less common as the nesting season progresses (Pitman *et al*. 2006a, p. 27). Re-nesting rates also vary among the different ecoregions (Patten *et al*. 2005b, entire).

Relatively tall, dense, herbaceous cover, including residual cover from the previous growing season, are important vegetation components influencing nest success, primarily by providing concealment of the nest to reduce the chance of predation and to provide thermal refugia (Suminski 1977, p. 32; Riley 1978, p. 36; Riley *et al*. 1992, p. 386; Giesen 1998, p. 9). Typical nesting habitat can be generally described as native grassland, although vegetation structure, such as the height and density of forbs and residual grasses, is frequently greater at nesting locations than on adjacent grassland (Giesen 1998, p. 9). Concealment of the nest is important as successful nests are often associated with greater heights and cover of shrubs and perennial grasses than are unsuccessful nests. Nest success (proportion of nests that hatch at least one egg) varies widely based upon effects of precipitation and temperature as well as variation between ecoregions but has been reported to average about 30% (range of 0–67%) (Hagen and Giesen 2005, unpaginated). Overall, LEPC exert more effort toward reproductive activities and have higher reproductive parameters (clutch size, nest success, re-nest frequency, etc.) in the northern part of the species' range than the southern part (Fields 2004, entire; Pitman *et al*. 2006a, p. 33; Hagen *et al*. 2007, entire). Individuals in the southern part of the species' range have been shown to put less effort toward reproductive activities in years with less optimal climatic and environmental conditions and exert more reproductive effort in years with more favorable conditions (Grisham *et al*. 2016a, pp. 325–326).

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[4] But not necessarily the same lek at which copulation occurred.

2.5.4 Recruitment of Broods

Chicks are mobile upon hatching and typically leave the nest within hours of hatching (Coats 1955, p. 5). Broods may remain with females for up to 18 weeks (Giesen 1998, p. 9; Pitman *et al*. 2006c, p. 93), but brood breakup generally occurs by September when the chicks are approximately 70 days of age (Taylor and Guthery 1980a, p. 10). Availability of food and cover are key environmental needs that affect chick and juvenile survival. High-quality brood rearing habitat is vital for brood survival and should be found close to nesting areas. Good brood rearing habitat will have less grass cover and more forb cover than nesting habitat, as dense grass cover impedes movements of the chicks (Hagen *et al*. 2013, p. 4; Pitman *et al*. 2006b, p. 680). Habitats used by broods often occur in areas with a greater biomass of invertebrates and forbs, emphasizing the importance of forbs in providing the invertebrate prey base used by young LEPC (Jamison *et al*. 2002, pp. 520, 524). Chick survival averages only about 25% during the first 35 days following hatching (Hagen 2003, p. 135). Multiple studies throughout the species' range have reported brood survival rates of 17 to 65% and caution that these variable survival rates are likely heavily influenced by local habitat conditions (Jamison 2000, p. 57; Hagen 2003, p. 135; Pitman *et al*. 2006b, p. 677; Hagen *et al*. 2009, p. 1326). When brood survival was extended to actual species recruitment, a survival rate of an individual from hatching to the start of the first breeding season was reported to be only 12% (Pitman *et al*. 2006b, pp. 678–680).

2.5.5 Home Range, Dispersal, and Wintering Habitat

Typically, LEPC home ranges vary both by sex and by season and may be influenced by a variety of landscape conditions (Haukos and Zavaleta 2016, pp. 108–112). Lesser prairie-chickens are not territorial, except for the small area defended by males on the lek, so home ranges of individual birds likely overlap to some extent. Habitat quality presumably influences the extent to which individual home ranges overlap. Adults tend to spend much of their daily and seasonal activity within 3.0 mi (4.8 km) of a lek (Giesen 1994a, p. 97; Riley *et al*. 1994, p. 185; Woodward *et al*. 2001, p. 263). Males tend to have smaller home ranges than do females, with the males generally remaining closer to the leks than do the females (Giesen 1998, p. 11). Male LEPC exhibit strong site fidelity to their lek (Copelin 1963, pp. 29–30; Hoffman 1963, p. 731; Campbell 1972, pp. 698–699, Hagen *et al*. 2005, entire). Once a lek site is selected, males persistently return to that same lek year after year (Hagen *et al*. 2005, entire; Wiley 1974, pp. 203–204) and may remain faithful to that site for life. They often will continue to use these traditional areas even when the surrounding habitat has declined in value (for example, concerning greater sage-grouse; see Harju *et al*. 2010, entire). Davis (2005, p. 3) states that the combined home range of all LEPC at a single lek is about 12,000 ac (4,900 ha).

Dispersal plays an important role in maintaining healthy, robust LEPC populations by contributing to population expansion, recolonization, and gene flow (Sutherland *et al*. 2000, unpaginated). Many grouse species are known to exhibit relatively limited dispersal tendencies and juvenile dispersal is normally less than 25 mi (40 km) (Braun *et al*. 1994, pp. 432–433; Ellsworth *et al*. 1994, p. 666). Environmental conditions may influence dispersal patterns in LEPC, particularly in fragmented landscapes where predation rates may be higher and habitat suitability may be reduced in smaller-sized patches (Kraft 2016, pp. 113, 116–119). Lesser prairie-chickens appear to be sensitive to the size of habitat patches and may avoid using patches below a particular size. As the landscape becomes more fragmented, longer dispersal distances over areas of unusable habitat may be required (Patten *et al*. 2011, pp. 60−61). While long-distance movement of breeding-age birds has been documented to exceed 44 mi (71 km), this long of a movement distance is likely rare, depending on the specific landscape conditions through which birds are moving, since the mean distance reported was 10 mi (16 km) (Earl *et al*. 2016, p. 10). Thus, it is important, for LEPC movements, to have relatively small distances between usable habitat patches.

Fall and wintering habitat for juveniles and adults is similar to that used for breeding with the exception that small grain agricultural fields can be used more heavily for feeding during this period than during the breeding season (Giesen 1998, p. 4). Robinson *et al*. (2018, p. 374) found 6-month nonbreeding season home range sizes of GPS-marked birds were 2.8 times larger than breeding season, with between-year differences ranging from 1,223 ac (495 ha) to 3,187 ac (1,290 ha), but they found no differences in average home-range size between sexes. Female nonbreeding season survival was higher than breeding season by 39-44% (Robinson *et al*. 2018, p. 374).

In general, adult LEPC diet consists largely of plant materials especially during the fall, winter, and early spring when insects are less common. Insects are a key component of the diet during the late spring and summer and are especially important for broods to provide nutrition for early growth periods. For a complete discussion of LEPC diet, refer to Haukos and Zavaleta (2016, pp. 113–116) and Sullins *et al*. (2018, entire).

2.6 Ecological Requirements of Populations and Species

At the population scale, the most important requirement for the LEPC is having large, intact, ecologically diverse grasslands to complete their life history and maintain healthy populations (Fuhlendorf *et al.* 2017b, entire). Historically, these ecologically diverse grasslands and shrublands were maintained by the occurrence of wildfires (keeping woody vegetation restricted to drainages and rocky outcroppings) and by grazing by bison and other large ungulates. Most experts characterize the LEPC as a species which is area-sensitive and which requires large, intact grasslands for functional self-sustaining populations (Giesen 1998, pp. 3–4; Bidwell *et al.* 2002, pp. 1–3; Hagen *et al*. 2004, pp. 71, 76–77; Haukos and Zavaleta 2016, p.107). We present these ecological requirements at the species and population scales in terms of having representation, resiliency, and redundancy to contribute to overall species' viability.

2.6.1 Representation

Representation describes the ability of a species to adapt to both near-term and long-term changes in its physical (climate conditions, habitat conditions, habitat structure, etc.) and biological (pathogens, competitors, predators, etc.) environments. The more representation, or adaptive capacity, the species has, the higher its potential of adapting to future changes (natural or human caused) in its environment. To evaluate representation as a component of LEPC viability, we consider the need for multiple healthy LEPC populations within each of the four ecoregions to consider the genetic and ecological diversity of the LEPC. Each of the four ecoregions varies considerably in terms of vegetative communities and environmental conditions, resulting in differences in abundance and distribution and management strategies (Boal and Haukos 2016, p. 5). Despite reduced range and census size, most LEPC populations appear to have maintained comparatively high levels of neutral genetic variation (DeYoung and Williford 2016, p. 86). Recent genetic studies also show significant genetic variation across the

LEPC range based on neutral markers (Figure 2.4), which supports management separation of these four ecoregions and highlights important genetic differences between them (Oyler-McCance *et al.* 2016, p. 653). While it is unknown how this genetic variation relates to differences in adaptive capacity between the ecoregions, maintaining healthy LEPC populations across this range of diversity increases the likelihood of conserving inherent ecological and genetic variation within the species to enhance its ability for adaptation to future changes in environmental conditions.

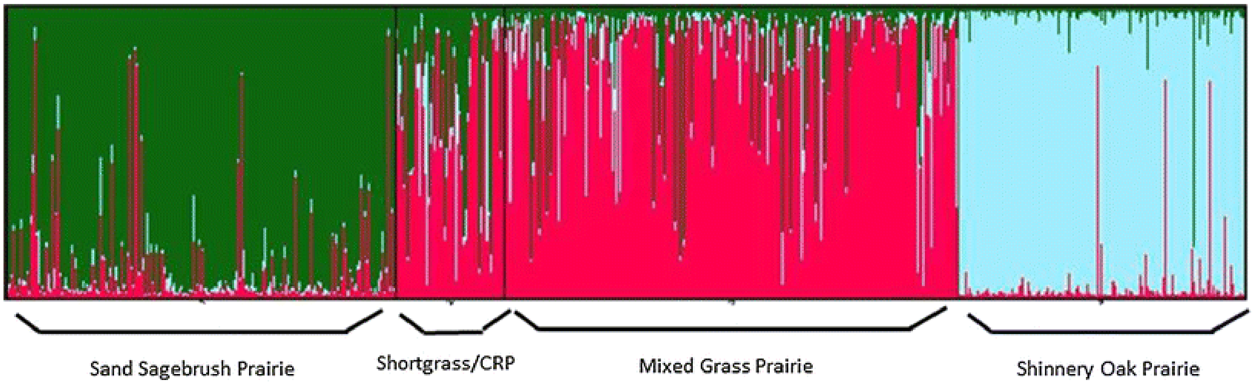

Figure 2.4 Estimated population genetic structure based on allele frequency variation from 13 microsatellite loci as calculated in STRUCTURE. Genetic structure among all individuals with the optimal number of distinct genetic clusters (K) of three. Each distinct cluster is represented by a unique color. Each vertical bar represents an individual LEPC. The colors on each vertical bar represent the individual's estimated membership in each of the three unique genetic clusters (Reproduced from Oyler-McCance *et al.* 2016, p. 652, Fig. 3).

2.6.1.1 *Short-Grass/CRP Ecoregion*

The Short-Grass/CRP Ecoregion for the LEPC falls within the mixed- and short-grass prairies of Central and Western Kansas (McDonald *et al*. 2012, p. 2). As the name implies, much of this ecoregion historically consisted of short-grass prairie interspersed with mixed-grass prairie as well as sand sagebrush prairie along some drainages (Dahlgren *et al*. 2016, p. 260). Conversion for crop production began shortly after this area was settled and by the 1970s, center pivot irrigation had become a widely used technique among farmers which allowed them to access the Ogallala Aquifer and increase areas available for irrigated crop production. Due to these advancements in farming practices, by the 1980s large expanses of prairies had been converted from native grass for crop production in this ecoregion. After the introduction of the Conservation Reserve Program (CRP) in 1985, landowners began to have enhanced incentives to convert croplands to perennial grasslands to provide cover for the prevention of soil erosion. The state of Kansas required those enrolling in the CRP to plant native mixed- and tall grass species which is notable because the grasses in this area historically consisted largely of short-grass species, which generally do not provide adequate habitat for the LEPC. There is little information available about what portions of this ecoregion were historically occupied by the LEPC and, if it was occupied, what the actual densities of birds in those areas were (Hagen 2003,

p. 3). This infusion of tall- and mixed-grass species resulted in increased habitat availability for the LEPC and, thus, an expansion of the known LEPC range and an increase in the abundance of the LEPC (Rodgers 1999, p. 18–19; Fields 2004, p. 11; Fields *et al*. 2006, p. 931; Sullins *et al.* 2018, p. 1617). The Short-Grass/CRP ecoregion is now estimated to contain the majority of LEPC compared to the other ecoregions (see Section 3.5.3). Recent genetic studies indicate that LEPC have moved northward largely from the Mixed-Grass Ecoregion and, to a lesser extent, Sand Sagebrush Ecoregion into the Short-Grass/CRP Ecoregion (Oyler-McCance *et al.* 2016*,* p. 653). For additional information on the Short-Grass/CRP Ecoregion refer to Dahlgren *et al*. (2016, pp. 259–279).

2.6.1.2 *Sand Sagebrush Ecoregion*

The Sand Sagebrush Ecoregion occurs in Southeast Colorado, Southwest Kansas, and a small portion of Western Oklahoma (McDonald *et al*. 2012, p. 2). The vegetation community in this area primarily consists of sand sagebrush (*Artemisia filifolia*) and the associated mixed and tall grass species which are usually found in the sandier soils adjacent to rivers, streams, and other drainages in the area. Historically, the Sand Sagebrush Ecoregion supported the highest density of LEPC and was considered the core of the LEPC range (Haukos *et al*. 2016, p. 282), but more recent survey efforts estimate less than 5% of all LEPC occur in this ecoregion (see Section 3.5.3). Genetic studies of neutral markers indicate that LEPC from the Sand Sagebrush Ecoregion form a distinct genetic cluster from other ecoregions but has likely contributed some individuals to the Short-Grass/CRP Ecoregion through dispersal (Oyler-McCance *et al.* 2016, p. 653). This genetic differentiation may be important for maintaining genetic diversity and adaptive capacity as environmental conditions change. For additional information on the Sand Sagebrush Ecoregion refer to Haukos *et al*. (2016, pp. 281–298).

2.6.1.3 *Mixed-Grass Ecoregion*

The Mixed-Grass Ecoregion for the LEPC lies in the northeastern panhandle of Texas, panhandle of northwestern Oklahoma, and south-central Kansas (McDonald *et al*. 2012, p. 2). The Mixed-Grass Ecoregion is separated from the Short-Grass/CRP Ecoregion in Kansas by the Arkansas River. The vegetation community in this ecoregion consists largely of a mix of perennial grasses and shrubs such as sand sagebrush, sand plum (*Prunus angustifolia*), yucca (*Yucca* spp.), and sand shinnery oak (*Quercus havardii*) (Wolfe *et al*. 2016, p. 300). Although historical population estimates in the ecoregion reported some of the highest densities of LEPC in the range (Wolfe *et al*. 2016, p. 299), more recent survey work estimates about 18% of LEPC occur in this ecoregion (see Section 3.5.3). Recent genetic studies indicate that LEPC from the Mixed-Grass Ecoregion are similar in genetic variation with the Short-Grass/CRP Ecoregion, with individuals likely moving from the Mixed-Grass Ecoregion to the Short-Grass/CRP Ecoregion through dispersal (Oyler-McCance *et al.* 2016, p. 653). For additional information on the Mixed-Grass Ecoregion, refer to Wolfe *et al*. (2016, pp. 299–314).

2.6.1.4 *Shinnery Oak Ecoregion*

The Shinnery Oak Ecoregion for the LEPC occupies portions of Eastern New Mexico and the South Plains of Texas (McDonald *et al*. 2012, p. 2). The Shinnery Oak Ecoregion has a variable vegetation community that contains a mix of shrubs such as sand shinnery oak and sand sagebrush, as well as mixed and tall grasses and forbs (Grisham *et al*. 2016a, p. 317). Population estimates for the Shinnery Oak Ecoregion have varied over recent years, but the most recent surveys indicate approximately 11% of all LEPC occur in this ecoregion (see Section 3.5.3). Genetic studies demonstrate that LEPC from the Shinnery Oak Ecoregion are genetically distinct and geographically isolated from other ecoregions and considered isolated from the other three ecoregions (Oyler-McCance *et al.* 2016, p. 653). For additional information on the Shinnery Oak Ecoregion, refer to Grisham *et al*. (2016a, pp. 315–344).

2.6.2 Resiliency

Resiliency describes the ability of a species to withstand stochastic disturbance. Resiliency is positively related to population sizes and growth rates and may be influenced by connectivity among populations. Generally, populations need abundant individuals within habitat patches of adequate area and quality to maintain survival and reproduction in spite of disturbance. Stochastic events are those arising from random processes such as weather or fire. In the case of the LEPC, the primary indicators of resiliency we considered were habitat availability, population abundance, growth rates, and quasi-extinction risk. Lesser prairie-chicken populations within ecoregions must have sufficient habitat and population growth potential to recover from natural disturbance events such as extensive wildfires, extreme hot or cold events, extreme precipitation events, or extended local periods of below average rainfall. These events can be particularly devastating to populations when they occur during the late spring or summer when nesting and brood rearing are occurring, and individuals are more susceptible to mortality.

The LEPC is considered a “boom-bust” species based on its high reproductive potential, but with a high degree of annual variation in rates of successful reproduction and recruitment. These variations are largely driven by the influence of seasonal precipitation patterns (Grisham *et al*. 2013, pp. 6–7), which impact the population through effects on the quality of habitat. Periods of below average precipitation and higher spring/summer temperatures result in less appropriate grassland vegetation cover and less food available, resulting in decreased reproductive output (bust periods). Periods with above normal precipitation and cooler spring/summer temperatures will support favorable LEPC habitat conditions and result in high reproductive success (boom periods). In years with particularly poor weather conditions, individual female LEPC may even forgo nesting for the year. This population characteristic highlights the need for habitat conditions to support large population growth events during favorable climatic conditions so they can withstand the declines during poor climatic conditions without a high risk of extirpation.

The selected habitat of the LEPC is mixed-grass prairies, except in the Short-Grass/CRP Ecoregion where shrubs play a lesser role. And when available, LEPC appear to select areas having a shrub component dominated by sand sagebrush or sand shinnery oak (Donaldson 1969, pp. 56, 62; Taylor and Guthery 1980a, p. 6; Giesen 1998, pp. 3–4). They select areas absent of trees or other tall woody vegetation or vertical structures (see sample photos in Figure 2.5). In the southern and central portions of the LEPC range, small shrubs, such as sand shinnery oak, have been reported to be important for summer shade (Copelin 1963, p. 37; Donaldson 1969, pp. 44–45, 62), winter protection, and as supplemental foods (Johnsgard 1979, p. 112) while in the Short-grass/CRP ecoregion, stands of grass which provide adequate structure likely serve the same roles. The absence of anthropogenic features as well as other vertical structures is important, as research has demonstrated that LEPC will avoid areas around vertical structures (see Section 3.3.1).

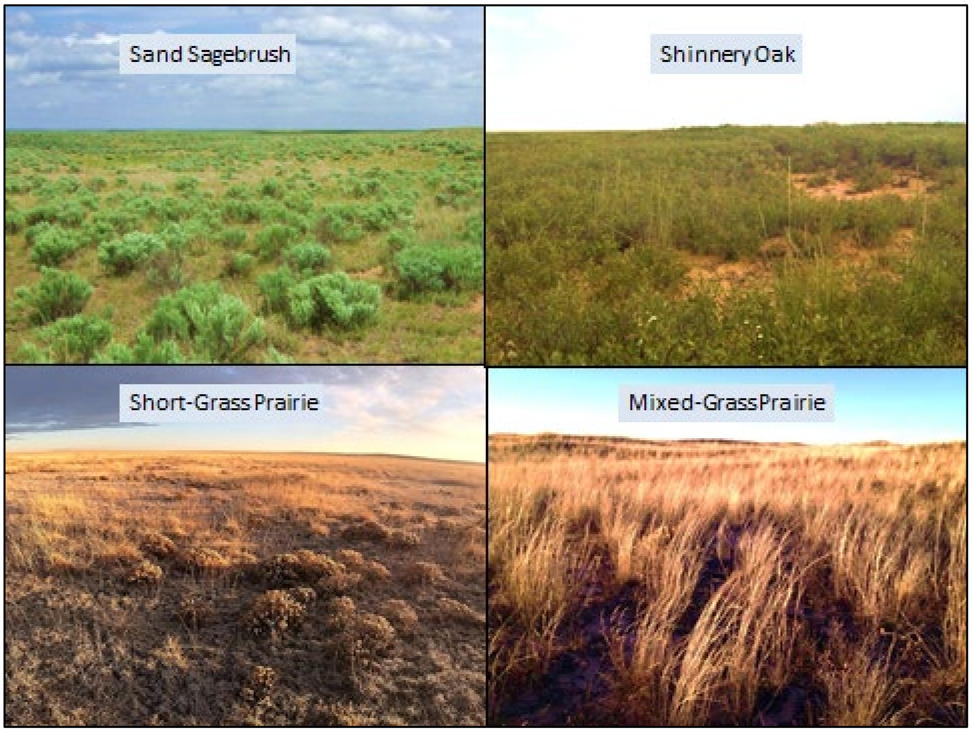

Figure 2.5 Typical vegetation types within the four ecoregions that support lesser prairie-chicken grassland habitat.

Historically, the LEPC had large expanses of grassland habitat to maintain populations. Early European settlement and development of the Southern Great Plains for agriculture initially, and for energy extraction later, substantially reduced the amount and connectivity of the grasslands of this region. Additionally, if historically some portions of the range were drastically impacted or eliminated due to a stochastic event, that area could be reestablished from other populations. Today, those characteristics of the grasslands have been degraded due to many reasons (discussed in detail in Chapters 3 and 4) that have resulted in the loss and fragmentation of grasslands in the Southern Great Plains. Under present conditions, the potential LEPC habitat is limited to small, fragmented grassland patches (relative to historical conditions) (see Section 3.5). The larger and more intact the remaining grassland patches are, with appropriate vegetation structure, the larger, healthier, and more resilient the LEPC populations will be. Exactly how large habitat patches should be to support healthy populations depends on the quality and intactness of the patches. Haukos and Zavaleta (2016, p. 107) reviewed current estimates of the recommended total space needed for persistence of LEPC populations. They reported a range of sizes of areas from a minimum of about 12,000 ac (4,900 ha) (Davis 2005, p. 3) up to more than 50,000 ac (20,000 ha) to support single leks, depending on the quality and intactness of the area (Applegate and Riley 1998, p. 14; Haufler *et al.* 2012, p. 7–8).

A single LEPC lek is not considered a population that can persist on its own. Instead, complexes of multiple leks that interact with each other are required for a LEPC population to be persistent over time. These metapopulation dynamics, in which individuals interact on the landscape to form larger populations, are dependent upon the specific biotic and abiotic landscape characteristics of the site and how those characteristics influence space use, movement, patch size, and fragmentation (DeYoung and Williford 2016, pp. 89–91). Maintaining multiple, highly resilient populations (complexes of leks) within the four ecoregions with the ability to interact with each other will increase the probability of persistence in the face of environmental fluctuations and stochastic events. Applegate and Riley (1998, p. 14) considered a LEPC lek complex to contain 6 to 10 viable leks, which would require larger connected grassland patches to maintain multiple leks close enough for individuals to move between them[5]. Because of this concept of metapopulations and their influence on long term persistence, when evaluating LEPC populations, site specific information is informative. However, as exhibited in Fuhlendorf *et al.* (2002, entire), many of the factors affecting LEPC populations should be analyzed at larger spatial scales.

2.6.3 Redundancy

Redundancy describes the ability of a species to withstand catastrophic events. Catastrophes are stochastic events that are expected to lead to population collapse regardless of population heath and for which adaptation is unlikely. Redundancy spreads the risk and can be measured through the duplication and distribution of resilient populations that are connected across the range of the species. The larger the number of highly resilient populations the LEPC has, distributed over a large area within each ecoregion, the better chances that it can withstand catastrophic events. Catastrophic events for LEPC might include extreme drought (as defined by U.S. Drought Monitor, https://droughtmonitor.unl.edu/), widespread, extended droughts or a disease outbreak. Measuring redundancy for LEPC is a difficult task due to the physiological and biological characteristics of the species which make it difficult to survey and limit the usefulness of survey results. To estimate redundancy for the LEPC, we estimated the geographic distribution of predicted available habitat within each of the four ecoregions and the juxtaposition of that habitat to other habitat and non-habitat. As the amount of large grassland patches decrease and grassland patches become more isolated to reduce or preclude LEPC movement between them, the overall redundancy of the species is reduced. As redundancy decreases within any representative ecoregion, the likelihood of extirpation within that ecoregion increases. As large grassland patches, the connectivity of those patches increases, and the number of LEPC increase, so does the redundancy within an ecoregion.

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[5] We note that this information is not to be used as specific requirements for management but instead to illustrate the need for a larger landscape view beyond a single lek and the need to consider metapopulation dynamics.

3. CURRENT CONDITION

3.1 Summary

We assessed the current condition of the LEPC through an analysis of existing habitat; a review of factors that have impacted the species in the past, including a geospatial analysis to estimate areas of land cover impacts on the current landscape condition; a summary of the current potential usable area[6] based upon our geospatial analysis; and a summary of past and current population estimates. Available grassland habitat for the LEPC has been much reduced and fragmented compared to historical conditions across its former and current range. Habitat loss has been both direct (loss of grassland) and indirect (disturbances that result in grasslands not being used or being used at a reduced rate by LEPC) and has caused the remaining LEPC populations to be smaller and more isolated and disconnected.

The current distribution and abundance of the LEPC has declined significantly in comparison to historical conditions primarily due to loss and fragmentation of its grassland habitat caused by human land use and alterations to natural disturbance regimes. Development of the Southern Great Plains, first for agriculture and then for energy production, has resulted in a reduction in overall habitat availability and corresponding reductions in LEPC distribution and abundance. In addition to development activities, the alteration of historical fire and grazing regimes has resulted in encroachment of woody vegetation in large portions of the range, further increasing habitat loss and fragmentation.

The past sources of grassland habitat loss and fragmentation within the range of the LEPC include: the largescale conversion of prairie to cultivated agriculture; the construction of infrastructure for petroleum production; construction of infrastructure to support wind energy development; the encroachment of woody vegetation; and the construction of roads and electrical distribution lines. All these landscape changes result in eliminating large grassland areas from being used by LEPC, and all have occurred throughout the current LEPC range. Using our geospatial analysis, we estimated these changes by source within each ecoregion of the current LEPC range. Other factors that may have influenced LEPC in the past that we assessed, but were not quantified in our geospatial analysis, include: livestock grazing; shrub control and eradication; anthropogenic noise; hunting and other recreation; collision mortality from fences; predation; parasites and diseases; wildfires; and extreme weather events.

We also evaluated and summarized the benefit of the extensive conservation efforts that are ongoing throughout the LEPC range to conserve the species and its habitat. Range-wide efforts include the WAFWA LEPC Range-wide Conservation Plan, the USDA-NRCS LEPC Conservation Initiative, and the USDA-Farm Service Agency's (FSA) CRP. In addition, there are numerous conservation efforts being led by state and regional programs such as: Kansas Department of Wildlife and Parks' Landowner Incentive Program and State Wildlife Habitat

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[6] The spatial data do not exist at the scale and resolution needed to adequately evaluate the condition of the vegetative structure and composition of the landscape thus we could not directly estimate available habitat. Instead, we estimate the amount of grassland and shrubland within the analysis area which could potentially serve as LEPC habitat if the correct vegetative structure and composition on the given site are present. The implications of this is that the actual amount of available habitat is something less than what we have estimated as potential usable area.

Improvement Program; the Service Partners for Fish and Wildlife Program in all five LEPC states; the Shortgrass Prairie Initiative in Colorado by The Nature Conservancy (TNC) and Colorado Department of Transportation; Colorado Parks and Wildlife LEPC Habitat Improvement Program; efforts on the National Grasslands; Oklahoma Department of Wildlife CCAA for the LEPC; Oklahoma Department of Wildlife Conservation Wildlife Management Areas; Texas Parks and Wildlife CCAA for the LEPC; management of TNC properties in New Mexico and Kansas; the New Mexico Candidate Conservation Agreement (CCA) and CCAA; and management of properties owned by New Mexico Department of Game and Fish.

The results of our geospatial analysis indicate that the estimated area of current potential usable area for the LEPC is approximately 19% of the total analysis area and ranges from approximately 12 to 33% of the analysis area within each of the ecoregions. Recent population estimates from aerial surveys suggest low population numbers for three of the four ecoregions with approximately 67% of the current population occurring within the Short-Grass/CRP Ecoregion (Nasman *et al*. 2021, p. 14), although the estimated current abundance of all LEPC populations has generally declined substantially when compared to historical estimates in response to landscape-scale loss and fragmentation of grassland habitat. Aerial survey results estimated the LEPC population abundance, averaged over the most recent 5 years of surveys (2016-2021, no surveys in 2019), at 29,502 (90% confidence interval: 8,868, 60,617) (Nasman *et al*. 2021, p. 14).

3.2 Geospatial Analysis Summary

We estimated unimpacted land cover that may provide the landscape and vegetative characteristics necessary to support the biological needs of the LEPC using a Geographic Information System geospatial analysis of land cover data and other available spatial datasets. A complete description of this analysis is provided in Appendix B, Parts 1, 2, 3. We used LANDFIRE (Existing Vegetation Type, EVT; https://landfire.gov) as the base land cover and reclassified each land cover class as to its ability to support LEPC[7]. All areas within the analysis area for all ecoregions were classified as either potential usable (may support the biological needs of LEPC), potential woody cover restoration (could be restored to usable area by removing existing woody vegetation), potential cropland restoration (could be restored to usable area by converting existing cropland to grassland), and non-usable (is not now and not likely to become usable) based on the most recent data available (most datasets are from the last three to five years). We then removed exclusion areas, which were features such as roads, urban areas, and wetlands, that are not expected to support the appropriate biotic and abiotic features required by the LEPC during our 25-year evaluation period. We then identified areas such as oil and gas wells, wind turbines, and woody vegetation, and we accounted for indirect effects of these features by treating the surrounding areas as impacted. This resulted in a current estimate of

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[7] We did not attempt to evaluate the condition of the vegetative composition or structure of these areas but instead only classify as potential usable area if they appear in a grassland or shrubland category that appears compatible with LEPC space use. We know a wide variety of vegetative structure and composition exists on the landscape which will determine if these areas are suitable LEPC habitat. The implication of this process is the resulting potential usable area likely represents an overestimate of actual LEPC habitat.

impacted and unimpacted potential usable LEPC land cover within all four ecoregions within the analysis area.

To assess LEPC habitat at a larger scale and incorporate some measure of connectivity and fragmentation, we then grouped the areas of potential usable, unimpacted land cover based on the proximity of other areas with potential usable, unimpacted LEPC land cover. To do this, we used a "nearest-neighbor" geospatial process to determine how much potential usable land cover is within 1 mi (1.6 km) of any area of potential usable land cover. This analysis gives an estimate of how closely potential usable, unimpacted land cover is clustered together, versus spread apart, from other potential usable, unimpacted land cover. Areas with at least 60% potential usable, unimpacted land cover within 1 mi (1.6 km) were grouped[8]. This methodology eliminates small, isolated, and fragmented patches of otherwise potential usable land cover that are not likely to support persistent populations of the LEPC. A separate analysis found that the areas with 60% or greater unimpacted potential usable land cover within one mile (1.6 km) captured approximately 90% of known leks[9] (see Appendix B, Part 3).

Finally, a further step of the geospatial analysis was conducted to examine the size and proximity of these resulting habitat blocks. As part of this step in the analysis process, we included rural roads, plus a 67-m (220-ft) buffer per side (for 134-m [440-ft] total), as suitable land cover rather than exclude these areas from our analysis. Even though these features may fragment potentially larger blocks in the geospatial analysis, they are small enough to allow LEPC movement between the individual habitat patches. A buffering technique was then used to select and group the habitat blocks within 70 m (230 ft) per side (140 m 460 ft] total) of each other. The resulting connected habitat blocks were then evaluated by a frequency analysis of the resulting areas to demonstrate the general sizes of connected habitat blocks (see Appendix B, Part 4). The result of this analysis is shown in Figure 4.2.

For this assessment, the extent of the geospatial analysis was constrained to the LEPC EOR as defined by Van Pelt *et al*. (2013, p. 3) and revised by Fricke[10] (2020, pers. comm.). Most LEPC planning efforts consider the EOR plus a 10-mi (16-km) buffer area (EOR+10), which is appropriate for long-term conservation planning for the species to encompass a portion of the historical range and potential future range expansion due to restoration. However, based on the best available information of current known leks and expert knowledge about existing habitat conditions, the EOR+10 approach likely substantially overestimates potential LEPC habitat in many areas (particularly in the Shinnery Oak Ecoregion, for example). The EOR+10 area (40 million ac (16 million ha)) is roughly double the size of the EOR (about 20 million ac (8 million ha)). Conducting our analysis using the EOR (as revised) ensures focus on the primary known

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[8] As identified by many authors (Ross *et al.* 2016a, entire; Hagen and Elmore 2016, entire; Spencer *et al.* 2017, entire; Sullins *et al.* 2019, entire), maintaining grassland in large blocks is vital to conservation of the species and largely suggest that landscapes consisting of greater than 60% grassland are required to support LEPC populations.

[9] We acknowledge the spatial and temporal limitations of this analysis, as it relates to available lek data, and the results should be interpreted with those limitations in mind.

[10] The boundaries of the EOR for this analysis were revised by the state biologists assisting with the analysis to account for new lek observations (Fricke 2020, pers. comm.). These changes were for the exclusive application in this SSA and do not alter other existing uses of the previous EOR boundaries.

occupied range as currently identified by the Lesser Prairie-Chicken Interstate Working Group (Interstate Working Group) (see Section 3.4.1.1 for more information). Analyses with purposes different than the SSA, such as conservation planning or regulatory permitting, may benefit from inclusion of the larger EOR+10 and other expanded spatial extents, such as Northwestern Kansas. For the purposes of this SSA, the EOR boundary, as revised, provides for a complete and appropriate assessment area. We acknowledge that our spatial analysis does not include areas where there are a few documented LEPC leks outside of the current EOR and within areas that historically supported the LEPC. Limiting the spatial extent of our analysis to the EOR, as revised, will underestimate the calculations of impacts to LEPC and its habitat that occurs outside of the EOR but within the historical range. However, this is better than using EOR+10 which would substantially overestimate current impacts to LEPC. From this point forward in this report, we will only refer to the area we analyzed as our "analysis area" or by the ecoregion name.

The results of our analysis for the LEPC current condition and estimates of potential usable areas are reported in Section 3.4 below. We recognize there are important limitations to this landscape analysis, including variation and inherent error in the underlying data as well as unavailable data[11]. We know a wide range of LEPC habitat quality (which is primarily influenced by weather, soils, and land management) exists across the remaining grasslands. Populations of LEPC respond to the relative quality of habitat with various levels of LEPC density and carrying capacity. Important characteristics of habitat quality include the vegetative composition and structure; the size and configuration of the existing grassland patches; and local weather trends. The approach we used in this spatial analysis does not attempt to assess quality of habitat or verify actual conditions on the ground, but rather results in simplified categories of either "potential usable areas" or "non-usable areas." Our geospatial analysis does not address grassland quality based on vegetation condition because adequate data at the appropriate scale and resolution do not exist to reliably evaluate the condition of the vegetative structure and composition of the landscape; thus, we could not directly estimate available habitat. Instead, the purpose of this spatial analysis is to estimate the amount of grassland and shrubland within the analysis area which could potentially serve as LEPC habitat if the correct vegetative structure and composition on the given site are present. The implication of this approach is that the actual amount of available habitat is something less than what we have estimated as potential usable area. However, for our purposes of a landscape scale analysis, this method provides an index that reasonably approximates LEPC habitat amounts to inform our decisions for the species in its current condition and for forecasting possible future conditions. For a complete description of the methodologies, data sources, and limitations, please refer to Appendix B, Parts 1, 2, and 3.

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[11] The Service worked with FSA to perform a supplemental analysis to determine how many acres enrolled in the Conservation Reserve Program appeared in spaces which the Service classified as either cropland or non-usable areas. The results show only a very small amount of CRP enrolled lands were not captured as potential usable area in our analysis, representing about 1.3% of the range-wide total potential usable area. Further details and the results of this analysis are presented in Appendix B, Part 5.

3.3 Factors Influencing Current Condition

3.3.1 Habitat Degradation, Loss, and Fragmentation

The grasslands of the Great Plains are among the most threatened ecosystems in North America (Samson *et al*. 2004, p. 6) and have been impacted more than any other major ecosystem on the continent (Samson and Knopf 1994, p. 418), and temperate grasslands are also one of the least conserved ecosystems (Hoekstra *et al.* 2005, p. 25). The vast majority of the LEPC range (>95%) occurs on private lands that have been in some form of agricultural production since at least the early 1900s. Past land cover evaluations have estimated grassland loss in the Great Plains at approximately 70% (Samson *et al*. 2004, p. 7), with nearly 93,000 square km (23 million ac; 9.3 million ha) of grasslands in the United States lost between 1982 and 1997 alone (Samson *et al*. 2004, p. 9). As a result, available habitat for grassland species, such as the LEPC, has been much reduced and fragmented compared to historical conditions across its range.

Habitat impacts occur in three general categories that often work together synergistically at the landscape scale. Habitat degradation results in changes to a species' habitat that reduces its suitability to the species, but without making the habitat entirely unsuitable. Degradation may result in lower carrying capacity, lower reproductive potential, higher predation rates, or other effects. Habitat loss may result from the same anthropogenic sources that cause degradation, but the habitat has been altered to the point where it has no suitability for the species at all. Habitat fragmentation occurs when habitat loss is patchy and leaves a matrix of grassland habitat behind. While habitat degradation continues to be a concern, we focus our analysis on habitat loss and fragmentation from the cumulative effects of multiple sources of activities as the long-term drivers of the species viability.

Initially, reduction in the total area of available habitat (i.e., habitat loss) may be more significant than fragmentation and can exert a much greater effect of extinction (Fahrig 1997, pp. 607, 609). However, as habitat loss continues, the effects of fragmentation often compound effects of habitat loss and produce even greater population declines than habitat loss alone (Bender *et al.* 1998, pp. 517–518, 525). Spatial habitat fragmentation occurs when some form of disturbance, usually habitat degradation or loss, results in the separation or splitting apart of larger, previously contiguous, functional components of habitat into smaller, often less valuable, noncontiguous patches (Wilcove *et al*. 1986, p. 237; Johnson and Igl 2001, p. 25; Franklin *et al*. 2002, entire). Habitat loss and fragmentation influence habitat availability and quality in three primary ways: (1) total area of available habitat constrains the maximum population size for an area; (2) size of habitat patches within a larger habitat area, including edge effects, influence habitat quality and size of local populations; and (3) patch isolation influences the amount of species movement between patches, which constrains demographic and genetic exchange and ability to recolonize local areas where the species might be extirpated (Johnson and Igl 2001, p. 25; Stephens *et al.* 2003, p. 101).

Habitat loss, fragmentation, and degradation correlate with the ecological concept of carrying capacity. Within any given block, or patch, of LEPC habitat, carrying capacity is the maximum number of birds that can be supported indefinitely by the resources available within that area, i.e., sufficient food, shelter, and lekking, nesting, brood rearing, and wintering areas. As habitat loss increases and the size of an area decreases, the maximum number of birds that can inhabit that particular habitat patch also decreases. Consequently, a reduction in the total area of available habitat can negatively influence biologically important characteristics such as the amount of space available for establishing territories and nest sites (Fahrig 1997, p. 603). Over time, the continued conversion and loss of habitat will reduce the capacity of the landscape to support historical population levels, causing a decline in population sizes.

Habitat loss not only contributes to overall declines in usable area for a species but also causes a reduction in the size of individual habitat patches and influences the proximity and connectivity of these patches to other patches of similar habitat (Stephens *et al*. 2003, p. 101; Fletcher 2005, p. 342), reducing rates of movement between habitat patches until, eventually, complete isolation results. Habitat quality for many species is, in part, a function of patch size and declines as the size of the patch decreases (Franklin *et al*. 2002, p. 23). Both the size and shape of the habitat patch have been shown to influence population persistence in many species (Fahrig and Merriam 1994, p. 53). The size of the fragment can influence reproductive success, survival, and movements. As the distances between habitat fragments increase, the rate of dispersal between the habitat patches may decrease and ultimately cease, reducing the likelihood of population persistence and potentially leading to both localized and regional extinctions (Harrison and Bruna 1999, p. 226; With *et al*. 2008, p. 3153). In highly fragmented landscapes, once a species becomes extirpated from an area, the probability of recolonization is greatly reduced (Fahrig and Merriam 1994, p. 52). The probability of recolonization is sensitive to the size of available habitat patches, distances between those habitat patches, the physical and biological dispersal capabilities of the species, and characteristics (both biological and physical) of the landscape between patches that may aid or hinder the species movement between habitat patches.

For the LEPC, habitat loss can occur due to either direct or indirect habitat impacts. Direct habitat loss is the result of the removal or alteration of grasslands, making that space no longer available for use by the LEPC. Indirect habitat loss and degradation is when the vegetation still exists, but the areas adjacent to a disturbance (the disturbance can be natural or manmade) are no longer used by LEPC, are used at reduced rates, or the disturbance negatively alters demographic rates or behavior in the affected area. In many cases, as discussed in detail below for specific disturbances, the indirect habitat loss can greatly exceed the direct habitat loss.

Lesser Prairie-Chickens appear to be relatively intolerant to habitat alteration, particularly for activities that fragment habitat into smaller patches, primarily due to their site fidelity and the need for large, ecologically diverse landscapes. The birds require habitat patches with large expanses of vegetative structure in different successional stages to complete different phases in their life cycle, and the loss or partial loss of even one of these structural components can significantly reduce the overall value of that habitat to LEPC (Elmore *et al*. 2013, p. 4). In addition to the impacts on the individual patches, as habitat loss and fragmentation increases on the landscape, the juxtaposition of habitat patches to each other and to non-habitat areas will change. This changing pattern on the landscape can be complex and difficult to predict but the results, in many cases, are increased isolation of individual patches (either due to physical separation or barriers preventing/limiting movement between patches) and direct impacts to metapopulation structure which could be important for population persistence (DeYoung and Williford 2016, pp. 88–91).

The following sections provide a discussion and quantification of the influence of habitat loss and fragmentation from difference sources of disturbance on the grasslands of the Great Plains within the LEPC analysis area and more specifically allow us to characterize the current condition of LEPC habitat.

3.3.1.1 *Conversion of Grassland to Cropland*

At the time the LEPC was determined to be taxonomically distinct from the greater prairie-chicken in 1885 and shortly after, much of the historical and current range was beginning to be altered as human settlement of the Great Plains progressed and grasslands were being used for agriculture (Bartuszevige and Daniels 2016, p. 207). Between 1915 and 1925, considerable areas of prairie had been plowed in the Great Plains and planted to wheat (Laycock 1987, p. 4). As a result, by the 1930s the LEPC had begun to disappear from areas where it had been considered abundant, with populations nearing extirpation in Colorado, Kansas, and New Mexico, and populations were reduced in Oklahoma and Texas (Bent 1932, pp. 283–284; Davison 1940, p.62; Lee 1950, p. 475; Baker 1953, p. 8; Oberholser 1974, p. 268; Crawford 1980, p. 2). Additional areas of previously unbroken grassland were brought into cultivation in the 1940s, and enhancement in farming techniques (for example, center pivot irrigation) caused additional increases in conversion in the 1970s and 1980s (Laycock 1987, pp. 4–5; Laycock 1991, p. 2). Conversion of grassland to cultivated agricultural lands has been regularly cited as an important cause in the range-wide decline in abundance and distribution of LEPC populations (Copelin 1963, p. 8; Jackson and DeArment 1963, p. 733; Crawford and Bolen 1976a, p. 102; Crawford 1980, p. 2; Taylor and Guthery 1980b, p. 2; Braun *et al*. 1994, pp. 429, 432–433; Mote *et al*. 1999, p. 3).

Because cultivated grain crops may have provided increased or more dependable winter food supplies for LEPC (Braun *et al*. 1994, p. 429), the initial conversion of smaller patches of grassland to cultivation may have been temporarily beneficial to the short-term needs of the species as primitive and inefficient agricultural practices made grain available as a food source (Rodgers 2016, p. 18). Sharpe (1968, pp. 46–50) believed that the presence of cultivated grains may have facilitated the temporary occurrence of LEPC in Nebraska. However, as conversion increased, more recent information suggests that landscapes having greater than 20 to 37% cultivated grains may not support stable LEPC populations (Crawford and Bolen 1976a, p. 102). More recently, Ross *et al*. (2016, entire) found a response to the gradient of cropland to grassland land cover. Specifically, they found abundances of LEPC increased with increasing cropland until a threshold of 10% cropland was reached and then abundance declined with increasing cropland cover. This indicates that a relatively small amount of cropland could have a positive influence on LEPC abundance, but levels of conversion to cropland which exceed 10% are detrimental to the LEPC. While LEPC may forage in agricultural croplands, croplands do not provide for the habitat requirements of the species life cycle (cover for nesting and thermoregulation), and thus they avoid landscapes dominated by cultivated agriculture, particularly where small grains are not the dominant crop (Crawford and Bolen 1976a, p. 102).

As part of the geospatial analysis discussed above in Section 3.2, we estimated the amount of cropland that currently exists in the four ecoregions of the LEPC[12]. We did not include any

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[12] A recent analysis estimated that approximately 770,500 ac (311,800 ha) were converted to agriculture from 2016–2020 within the EOR+10 mile buffer (Defenders of Wildlife 2020, entire). However, much of this area is likely

indirect effects of cropland in our analysis. These calculations of the current analysis areas do not include historical habitat loss from conversion of prairies to cropland outside the analysis area; thus, the calculation likely underestimates the historical range-wide effects of conversion on the LEPC. A limitation associated with this portion of the analysis is that we did not have the ability to determine if a given space had the biological components necessary to support LEPC before the space was converted to cropland. Thus, these figures represent all of the conversion that has occurred in the analysis area whether it was previously usable area for LEPC or not. The geospatial analysis results indicate that about 2,334,000 ac (944,000 ha) representing about 37% of the total area in the Short-Grass/CRP Ecoregion; about 995,000 ac (403,000 ha) representing about 32% of the total area in the Sand Sagebrush Ecoregion; about 1,095,000 ac (443,000 ha) representing about 13% of the total area in the Mixed-Grass Ecoregion; and about 540,000 ac (219,000 ha) representing about 14% of the total area in the Shinnery Oak Ecoregion of grassland have been converted to cropland in the analysis area of the LEPC[13]. Range-wide, we estimate about 4,963,000 ac (2,009,000 ha) of grassland has been converted to cropland, representing about 23% of the total analysis area[14]. Maps of these areas in each ecoregion are provided in Appendix E, Figure E.1.

3.3.1.2 *Petroleum and Natural Gas Production*

Petroleum and natural gas production have occurred over much of the estimated historical and current analysis areas of the LEPC. Oil exploration began as early as the late 1800s in the Great Plains and commercial production began as early as the 1880s. By 1920, oil and gas production had dramatically increased on the Great Plains. As demand for energy has continued to increase nationwide so has oil and gas development in the Great Plains. In Texas, for example, Timmer *et al*. (2014, p. 143) stated that active oil and gas wells in the LEPC occupied range had increased by more than 80% over the previous decade. Oil and gas development involves activities such as surface exploration, exploratory drilling, field development, and facility construction, as well as access roads, well pads, and operation and maintenance. Associated facilities can include compressor stations, pumping stations, and electrical generators. Activities such as well pad construction, seismic surveys, access road development, power line construction, and pipeline corridors can all result in direct habitat loss by removal of vegetation used by LEPC. As documented in other grouse species, indirect habitat loss also occurs from avoidance of vertical structures, noise, and human presence (Weller *et al.* 2002, entire), which all can influence LEPC behavior in the general vicinity of oil and gas development areas. These

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outside of the LEPC EOR, so these acreages are not directly relatable to our spatial analysis. Additionally, the Service has some concerns about the methodology used within this analysis.

[13] These percentages do not equate to the actual proportion of habitat loss in the analysis area because not all of the analysis areas were necessarily suitable LEPC habitat. These percentages are only the estimated portion of the total analysis area converted from the native vegetation community to cropland, based on our analysis. Also note that additional acres of crop conversion occurred within our analysis area that fall within what we defined as "exclusion areas"; for additional details on exclusion areas see Appendix B.

[14] These acreages do not account for overlap that may exist with other features within the ecoregion which may have already impacted the landscape. Therefore, the total impacts are less than the sum of the individual impacts in terms of area impacted. Additional information regarding methodology and limitations of the spatial analysis can be reviewed in Section 3.2 and Appendix B.

activities affect LEPC by disrupting reproductive behavior (Hunt and Best 2004, p. 41) and through habitat loss and fragmentation (Hunt and Best 2004, p. 92).

Numerous studies demonstrate the impacts that anthropogenic features, such as oil and gas wells, have on the LEPC by affecting the behavior of individuals and altering the way in which they use the landscape (Hagen *et al*. 2011, pp. 69–73; Pitman *et al*. 2005, entire; Hagen 2010, entire; Hunt and Best 2004, pp. 99–104; Plumb *et al.* 2019, pp. 224–227; Sullins *et al.* 2019, pp. 5–8; Peterson *et al.* 2020, entire). For example, based on Monte Carlo simulations of observed and random LEPC locations, Hagen *et al*. (2011, p. 69) found that 90% of centroids (the geometric center of a polygon) of LEPC activities were farther than expected from oil wells, with a range of 794–1,050 ft (242–320 m). Based on that analysis, the authors suggest that to protect 90% of breeding and summer habitat of LEPC, oil wells should be sited greater than 984 ft (300 m) from those areas. A study in the Sand Sagebrush Ecoregion investigated nesting avoidance in LEPC related to several different anthropogenic structures including wellheads. Results indicated that LEPC generally avoided wellheads by 260 ft (80 m) when selecting nest sites (Pitman *et al.* 2005, p. 1264). Within study locations in portions of the Short-Grass/CRP, Mixed-Grass, and Sand Sagebrush Ecoregions, Plumb *et al.* (2019, p. 224, 228) found altered space use patterns for the LEPC in the presence of oil and gas wells. Specifically, the authors found that when data were pooled across study areas that LEPC used space farther from wells at greater intensities within their home range and recommend management agencies to increase buffer distances for wells to >450 meters. Also, within study locations in the Short-Grass/CRP, Mixed-Grass, and Sand Sagebrush Ecoregions, Sullins *et al.* (2019, p. 5) report that spaces with > 2 wells per 12.6 square km had 8 times lower relative probability of use by the LEPC. The WAFWA's Lesser Prairie-Chicken Range-wide Conservation Plan utilizes impact radii of 660 ft (200 m) from oil and gas pads and small compressor stations, and 2,200 ft (667 m) from large compressor stations to account for impacts to the LEPC (Van Pelt *et al.* 2013, p. 95). Another study in the Shinnery Oak Ecoregion stated that petroleum production was not compatible with healthy populations of LEPC and found that the average number of active wells near active leks was 1, while the average number of active wells within 1.6 km (1 mi) of abandoned leks during their last active year was 8 (Hunt and Best 2004, p. 99).

As part of the geospatial analysis discussed in Section 3.2, we calculated the amount of usable land cover for the LEPC which has been impacted (both direct and indirect impacts) by oil and natural gas wells (does not include all associated infrastructure) in the current analysis area of the LEPC. We used an impact radius of 984 ft (300 m) for indirect effects of oil and gas wells. These calculations were limited to the current analysis area and do not include historical impacts of habitat loss which occurred outside of the current analysis area. Thus, the calculation likely underestimates the range-wide effects of historical oil and gas development on the LEPC. The geospatial analysis results indicate that about 248,000 ac (100,000 ha) representing about 4% of the total area in the Short-Grass/CRP Ecoregion; about 164,000 ac (66,000 ha) representing about 5% of the total area in the Sand Sagebrush Ecoregion; about 860,000 ac (348,000 ha) representing about 10% of the total area in the Mixed-Grass Ecoregion; and about 162,000 ac (65,000 ha) representing about 4% of the total area in the Shinnery Oak Ecoregion of space that was identified as potential usable or potential restorable areas have been impacted due to oil and gas development in the current analysis area of the LEPC. Range-wide, we estimate about 1,433,000 ac (580,000 ha) of grassland has been lost due to oil and gas development representing about 7% of the total analysis area[15]. Maps of these areas in each ecoregion are provided in Appendix E, Figure E.2.

3.3.1.3 *Wind Energy Development and Power Lines*

Wind power is a form of renewable energy increasingly being used to meet current and projected future electricity demands in the United States. Much of the new wind energy development to meet these anticipated demands is likely to come from the Great Plains states because they have high wind resource potential, which exerts a strong, positive influence on the amount of wind energy developed within a particular state (Staid and Guikema 2013, p. 384). In both 2018 and 2019, the wind industry added over 7,500 and 9,100 megawatts (MW) nationwide of new capacity, respectively (American Wind Energy Association [AWEA] 2019a, p. 37; AWEA 2020a, p. 30). Wind energy has now surpassed hydroelectric power production to become the largest source of renewable energy capacity in the country. In 2019, three of the five LEPC states, Colorado, New Mexico, and Kansas, were within the top 10 states nationally for fastest growing states for wind generation in the past year (AWEA 2020a, p. 33). The Great Plains is one of the leading regions for wind energy development, with three of the states from the range of the LEPC occurring in the top four of installed capacity in 2019 (not all projects are in the LEPC range) (Table 3.1). While portions of the wind energy development listed in Table 3.1 are within the LEPC states, but outside the range of the species, there is substantial information (Southwest Power Pool 2020) indicating interest by the wind industry in developing wind energy within the range of the LEPC, especially if additional transmission line capacity is constructed. The entire estimated historical range of the LEPC occurs in areas determined to have average wind speeds exceeding what is recognized as necessary for large-scale wind energy development (21.3 ft/second (6.5 m/second), at 262 ft (80 m) high) (Department of Energy [DOE] National Renewable Energy Laboratory 2010b, p. 1).

Table 3.1 Wind energy state-wide project data as of April 2020 (AWEA 2020b). Wind capacities are expressed in megawatts (MW).

State	State Ranking for Installed Capacity	Installed Wind Capacity (MW)	Wind Projects Online	Number of Wind Turbines	Under Construction Wind Turbines (MW)
Texas	1	29,407	157	14,929	6,079
Oklahoma	3	8,173	45	4,013	1,250
Kansas	4	6,128	39	3,160	697
Colorado	8	3,762	26	2,275	970
New Mexico	16	1,952	19	1,110	1,020
Total	**-**	**49,422**	**286**	**25,487**	**10,016**

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[15] These acreages do not account for overlap that may exist with other features which may have already impacted the landscape. Additional information regarding methodology and limitations of the spatial analysis can be reviewed in Section 3.2 and Appendix B.

Wind energy development is a relatively recent occurrence in the Southern Great Plains, with the first multi-turbine commercial wind energy developments occurring in the LEPC analysis area in 2003 in Harper and Woodward Counties, Oklahoma. This wind energy development included 68 turbines of 1.5 MW for a total nameplate capacity of 102 MW. As applied in our current condition, there are approximately 1,792 wind turbines located within the LEPC analysis area as of May 2020 (Hoen *et al.* 2020, entire). Not all areas within the analysis area are habitat for the LEPC, so not all turbines located within the analysis area affect the LEPC and its habitat.

The tubular towers of most commercial, utility-scale onshore wind turbines are between 213 ft (65 m) and 328 ft (100 m) tall, and with blades in place, a typical system will exceed 328 ft (100 m) in height, and sizes continue to increase (Deign 2017, entire). Installation of wind turbines throughout the United States in 2019 saw average hub heights of 295 ft (90 m) and average rotor diameter of 397 ft (121 m) (AWEA 2020a, pp. 87–88). The average size of installed wind turbines continues to increase (DOE 2015a, p. 63; AWEA 2020a, p. 87–88). Wind energy developments range from 20 to 400 towers, each supporting a single turbine. The individual permanent footprint of a single turbine unit, about 0.75 to 1 ac (0.3 to 0.4 ha), is relatively small in comparison with the overall footprint of the entire array (DOE 2008, pp. 110–111). In this region of the United States, wind turbine rotor diameters typically range from 328 to 426 ft (100 to 130 m), and they need spacing between each turbine of usually 5 to 10 rotor diameters, which equates to approximately 1,640 to 4,265 ft (500 to 1,300 m) to avoid turbulence interference between turbines. Review of previous annually reported metrics of wind energy developments indicates a continued increase in all size aspects of wind energy developments (AWEA 2014, entire; AWEA 2015, entire; AWEA 2016, entire; AWEA 2017, entire; AWEA 2018, entire; AWEA 2019a, entire; AWEA 2020a, entire). Roads are necessary to access the turbine sites for installation and maintenance. One or more electrical substations, where the generated electricity is collected and transmitted on to the power grid, also may be built depending on the size of the wind energy development. Considering the initial capital investment, and that the service life of a single turbine is at least 20 years (DOE 2008, p. 16), we expect most wind energy developments to be in place for at least 30 years. Repower of existing wind energy developments at the end of their service life is increasingly common with 2,803 MW of operating projects partially repowering in 2019 (AWEA 2020a, p. 2).

Few peer reviewed studies exist that measure cause and effect relationships with regard to wind energy development impacts on grouse species. Of the available studies on grouse, comparability of those studies is greatly limited due to inconsistencies in study method and designs (Marques *et al*. 2021, entire), and likely contributes to the mixed results (Coppes *et al.* 2019, entire). These issues have been noted for wind energy development and wildlife research in general (Agha *et al.* 2020, entire). The direct study of LEPC and wind energy development is even more limited, such that we infer some aspects of the effects of wind energy based on studies of other grouse species. The Service reviewed the potential effects of wind energy development on LEPC and summarized that analysis (Service 2016b, entire), and subsequently reviewed new information available as of July 2020. Below is a summary of that review, including recent work.

Hagen *et al*. (2004, p. 79) recommended that wind turbines and other large vertical structures be placed greater than 1.6 mi (2 km) from known or potentially occupied LEPC habitat. Hagen *et al*. (2010, entire) reported the effects of anthropogenic features on displacement and demographics of several species of prairie grouse by compiling and analyzing existing data from 22 studies (which included data on various kinds of development) that reported quantitative data on prairie grouse response to energy development. This report suggested that prairie grouse appear to be tolerant of disturbances beyond minimum distances of less than 1.1 mi (1.8 km) in many cases. Additionally, Hagen *et al*. (2011, entire) used minimum behavioral avoidance distances based on Monte Carlo simulations of data obtained from 226 radio-marked female LEPC in Kansas to recommend a distance of greater than or equal to 0.9 mi (1.4 km) to account for the impact of wind energy development until empirical data are available.

Previously in 2004, based on a synthesis of multiple literature sources and communications with multiple grouse specialists, Service/Manville (2004, p. 13) recommended a distance of 5 mi (8 km) to avoid impacts of wind energy development on grouse. Winder *et al*. (2015a, p. 290–292), whose research measured lek persistence and lek attendance by male greater prairie-chickens using lek counting and mark/recapture techniques at various distances ranging from 0 to 17 mi (0 to 28 km) from turbines, reported evidence of negative effects from wind turbines on persistence of leks less than 5 mi (8 km) from turbines, and additional additive influences affecting lek persistence that included number of males and habitat loss. No effect to greater sage-grouse lek attendance was detected using pre- and post-construction assessment of wind energy development in Wyoming, but the authors still recommended designated buffers size out to 0.9 mi (1.5 km) to avoid impacts from wind energy infrastructure on males attending leks (LeBeau *et al.* 2017b, p. 24).

Winder *et al*. (2014a, entire) also documented negative behavioral effects to female greater prairie-chicken from wind energy development within 5 mi (8 km) of wind turbines that resulted in increased space use away from turbines and an approximate doubling of home range size. In LeBeau *et al*. (2014, entire), nest, brood, and female survival rates of greater sage-grouse were estimated using data gathered from 116 radio-marked females that were monitored though the breeding and brood-rearing life stages from 2009 to 2010 at a wind energy facility in Wyoming. They recommended placing wind turbines at least 3 mi (5 km) from nesting and brood-rearing habitat to reduce short-term negative influences. LeBeau *et al*. (2016, entire; 2017a, entire), investigated population-level effects of wind energy development on seasonal habitat selection and demographics of female greater sage-grouse by monitoring 346 radio-marked individuals in treatment and control groups. The probability of habitat selection was modeled during nesting, brood rearing, and summer periods based on relocation of marked birds and resulted in a recommendation that facilities of similar size and in similar habitats be placed 0.7 mi (1.2 km) from any occupied sage-grouse nesting, brood-rearing, or summer habitat (LeBeau *et al*. 2016, p. 66). In contrast, another recent site-specific study of greater prairie-chickens found no effects to nest survival or nest site selection (Harrison *et al.* 2017, pp. 665, 667). Also in contrast, McNew *et al*. 2014 (p. 1089) located greater prairie-chicken nests before and after development of a 201-MW wind energy facility in greater prairie-chicken nesting habitat and assessed nest site selection and nest survival relative to proximity to wind energy infrastructure and habitat conditions. Proximity to turbines did not negatively affect nest site selection or nest survival. Instead, nest site selection and survival were strongly related to vegetative cover and other local conditions determined by management for cattle production (McNew *et al*. 2014, entire). In an unfragmented Nebraska landscape, using a disturbance gradient study design, greater prairie-chicken were reported to show no negative effects to nest site selection or nest survival relative to turbine location after the development of a small 36 turbine facility (Harrison *et al.* 2017, p.

667–668). Responding differentially, greater prairie-chicken hens did show avoidance of roads, with 74% of nest sites selected greater than 700 m from roads, but they did not avoid transmission lines (Harrison *et al.* 2017, p. 668–669).

Research investigating implications of noise effects to prairie-chickens has been recently explored as a way to evaluate potential negative effects of wind energy development. For a site in Nebraska, wind turbine noise frequencies were documented at less than or equal to 0.73 kHz (Raynor *et al.* 2017, p. 493), and reported to overlapped the range of lek-advertisement vocalization frequencies of LEPC, 0.50–1.0 kHz. Building upon initial work, Raynor *et al.* (2019, entire) concluded that female greater prairie-chickens avoided wooded areas and row crops but showed no response in space use based on wind turbine noise or distance to wind turbines. Additionally, Whalen *et al.* (2019, entire) reported differences in background noise and signal-to-noise ratio of boom chorus of leks in relation to distance to turbine, but they cautioned that the underlying cause and response needs to be further investigated, especially since the study of wind energy development noise on grouse is almost unprecedented.

Manier *et al*. (2014, entire) reported recommended buffer distances for greater sage-grouse based on the energy development category (which included wind energy). The minimum and maximum values at which effects from energy development were observed in the scientific literature were 2.0 mi (3.2 km) and 12 mi (20 km), respectively (Manier *et al*. 2014, p. 7). Manier *et al*. (2014, entire) also reported proposed values for potential conservation buffer distances based on multiple sources ranging from 3 to 5 mi (5 to 8 km). Lastly, the RWP identified a 2,188-ft (667-m) impact radius for use within their mitigation strategy to account for the indirect effects of wind turbines.

In a recent report to American Wind and Wildlife Institute, LeBeau *et al.* (2020, entire) studied LEPC response to wind development in an already highly fragmented landscape. Their results indicated no evidence of LEPC displacement during multiple seasons and at multiple scales; no negative effects on nest survival; and no barrier effect to local scale movements. Survival of LEPC was reported at higher rates closer to the wind turbines. Limitations associated with this study includes that significant fragmentation already existed on the landscape prior to wind turbine construction, the study was of short duration (3 years), and there were no pre-construction LEPC data for comparison.

The effects of wind energy development on the LEPC must also take into consideration the influence of the transmission lines critical to distribution of the energy generated by wind turbines. Transmission lines[16] can traverse long distances across the landscape and can be both above ground and underground, although the vast majority of transmission lines are erected above ground. Most of the impacts to LEPC associated with transmission lines are with the above ground systems. Support structures vary in height depending on the size of the line. Most high-voltage power line towers are 98 to 125 ft (30 to 38 m) high but can be higher if the need arises. Local distribution lines are usually much shorter in height but still contribute to

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[16] We recognize there is a variety of types and sizes of electrical power lines. For our SSA purposes, we refer to transmission lines as generally larger, longer electrical power lines in contrast to smaller distribution lines discussed in Section 3.3.1.5.

fragmentation of the landscape. Local distribution lines, while more often are erected above ground, can be placed below ground.

The physical footprint of transmission line installation is typically much smaller than the effect of the transmission line infrastructure itself. Information on grouse and power lines is relatively limited with more studies needed. The available data includes a range of reported impacts, as seen in Nonne *et al*. (2013, entire), Dinkins *et al*. (2014, entire), Hansen *et al*. (2016, entire), Jarnevich *et al*. (2016, entire), Kohl *et al*. (2019, entire), LeBeau *et al*. (2019, entire), Londe *et al*. (2019, entire), and England and Robert (2021, entire).

Transmission lines can indirectly lead to alterations in LEPC behavior and space use (avoidance), decreased lek attendance, and increased predation on LEPC. Transmission lines, particularly due to their length, can be a significant barrier to dispersal of prairie grouse, disrupting movements to feeding, breeding, and roosting areas. Pruett *et al*. 2009a (entire) also summarizes evidence for avoidance behavior associated with transmission lines in prairie grouse. Both lesser and greater prairie-chickens avoided otherwise usable habitat near transmission lines and crossed these power lines much less often than nearby roads, suggesting that power lines are a particularly strong barrier to movement (Pruett *et al*. 2009a, pp. 1255–1257). Because LEPC avoid tall vertical structures like transmission lines and because transmission lines can increase predation rates, leks located in the vicinity of these structures may see reduced attendance by new males to the lek, as was reported by Braun *et al*. (2002, pp. 11–13) for sage-grouse. Decreased probabilities of use by LEPC was shown with the occurrence of more than 0.15 km of major roads, or transmission lines within a 1.2 mile (2 km) radius (Sullins *et al.* 2019, unpaged). Additionally, Plumb *et al*. (2019, entire) corroborated numerous authors' (Pitman *et al*. 2005; Pruett *et al*. 2009a; Hagen *et al*. 2011; Grisham *et al*. 2014; Hovick *et al*. 2014a) findings of negative effects of power lines on prairie grouse, and they report a minimum avoidance distance of 1,925.8 ft (587 m), which is similar to other studies of lesser prairie-chickens. LeBeau *et a*l. (2020, p. 24) largely aggregated their findings of wind turbines and a transmission line on lesser prairie-chicken into effects of "wind energy infrastructure", but they specifically noted evidence that females selected home ranges farther from transmission lines. Using a definition for transmission powerlines that included powerlines transmitting >69 kV, Peterson *et al*. (2020, p. 9) indicated that taller anthropogenic structures (i.e., transmission powerlines and towers) generally had larger estimated avoidance response distances of all studied features, but there was also large regional variation. They found the largest estimated avoidance response of 5.6 mi (9 km) in Northwest Kansas and the smallest in Oklahoma of approximately 1.8 mi (3 km). Patten *et al*. (2021, entire) also reported effects from anthropogenic features, including power lines, varied by region, and the degree of effect often depended on the presence of other anthropogenic features.

As part of the geospatial analysis discussed above in Section 3.2 we calculated the amount of otherwise usable land cover for the LEPC that has been impacted (both direct and indirect impacts) by wind energy development in the current analysis area of the LEPC. We used impact radii of 1,800 m (5,906 ft) for indirect effects of wind turbines and 700 m (2,297 ft) for indirect effects of transmission lines. The geospatial analysis results indicate that about 146,000 ac (59,000 ha) representing about 2% of the total area in the Short-Grass/CRP Ecoregion; about 192,000 ac (78,000 ha) representing about 2% of the total area in the Mixed-Grass Ecoregion; and about 91,000 ac (37,000 ha) representing about 2% of the total area in the Shinnery Oak

Ecoregion of space identified as potential usable or potential restorable areas have been impacted due to wind energy development within the analysis areas. Range-wide, we estimate about 428,000 ac (173,000 ha) of grassland has been impacted by wind energy development, representing about 2% of the total analysis area[17]. Maps of these areas in each ecoregion are provided in Appendix E, Figure E.3.

Additionally, using the results of the geospatial analysis, about 437,000 ac (177,000 ha) representing about 7% of the total area in the Short-Grass/CRP Ecoregion; about 167,000 ac (68,000 ha) representing about 5% of the total area in the Sand Sagebrush Ecoregion; about 577,000 ac (233,000 ha) representing about 7% of the total area in the Mixed-Grass Ecoregion; and about 373,000 ac (151,000 ha) representing about 10% of the total area in the Shinnery Oak Ecoregion have been impacted (accounts for both direct and indirect impacts) due to the construction of transmission lines in the analysis area of the LEPC. Our analysis was limited to power lines in the transmission class, because of the lack of availability of geospatial data depicting most other classes of power lines. Range-wide, we estimate about 1,553,000 ac (629,000 ha) of grassland has been impacted by transmission lines representing about 7% of the total analysis area17[17]. Maps of these areas in each ecoregion are provided in Appendix E, Figure E.4.

3.3.1.4 *Woody Vegetation Encroachment*

Selected LEPC habitat is characterized by expansive regions of treeless grasslands interspersed with patches of small shrubs (Giesen 1998, pp. 3–4). Prior to extensive Euro-American settlement, frequent fires and grazing by large, native ungulates helped confine trees like eastern red cedar (*Juniperus virginiana*) to river and stream drainages and rocky outcroppings. However, settlement of the Southern Great Plains altered the historical ecological context and disturbance regimes. The frequency and intensity of these disturbances directly influenced the ecological processes, biological diversity, and patchiness typical of Great Plains grassland ecosystems, which evolved with frequent fire and ungulate herbivory and that maintained prairie habitat for LEPC (Collins 1992, pp. 2003–2005; Fuhlendorf and Smeins 1999, pp. 732, 737).

Once these historical fire and grazing regimes were altered, the processes which helped maintain extensive areas of grasslands ceased to operate effectively. Following Euro-American settlement, fire suppression allowed trees, such as eastern red cedar, to begin invading or encroaching upon neighboring grasslands. Increasing fire suppression that accompanied human settlement, combined with government programs promoting eastern red cedar for windbreaks, erosion control, and wildlife cover, facilitated the expansion of eastern red cedar distribution in grassland areas (Owensby *et al*. 1973, p. 256; DeSantis *et al*. 2011, p. 1838). Once a grassland area has been colonized by eastern red cedar, the trees are mature within six to seven years and provide a plentiful source of seed so that adjacent areas can readily become infested with eastern red cedar. Despite the relatively short viability of the seeds (typically only one growing season) the large cone crop, potentially large seed dispersal ability, and the physiological adaptations of eastern red cedar to open, relatively dry sites help make the species a successful invader of

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[17] These acreages do not account for overlap that may exist with other features which may have already impacted the landscape. Additional information regarding methodology and limitations of the spatial analysis can be reviewed in Section 3.2 and Appendix B.

grassland landscapes (Holthuijzen *et al*. 1987, p. 1094). Most trees are relatively long-lived species and, once they become established in grassland areas, require intensive management to remove trees and return areas to a grassland state.

Within the southern- and western-most portions of the estimated historical and occupied ranges of LEPC in Eastern New Mexico, Western Oklahoma, and the South Plains and Panhandle of Texas, honey mesquite (*Prosopis glandulosa*) is another common woody invader within these grasslands (Riley 1978, p. vii; Boggie *et al*. 2017, entire). Mesquite is a particularly effective woody invader in grassland habitat due to its ability to produce abundant, long-lived seeds that can germinate and establish in a variety of soil types and moisture and light regimes (Lautenbach *et al*. 2017, p. 84). Though not as widespread as mesquite or eastern red cedar, other tall, woody plants, such as redberry or Pinchot juniper (*Juniperus pinchotii*), black locust *(Robinia pseudoacacia*), Russian olive (*Elaeagnus angustifolia*), and Siberian elm (*Ulmus pumila*) can also be found in grassland habitat historically and currently used by LEPC and may become invasive in these areas.

Fire is often the best method to control or preclude tree invasion of grassland. However, to some landowners and land managers, burning of grassland can be perceived as a high risk activity due to the potential liability of escaped fire impacting non-target lands and property, undesirable for optimizing cattle production, and likely to create wind erosion or “blowouts” in sandy soils. Consequently, wildfire suppression is common, and relatively little prescribed burning occurs on private land. Often, prescribed fire is employed only after significant tree invasion has already occurred and landowners consider forage production for cattle to have diminished. Preclusion of woody vegetation encroachment on grasslands of the southern Great Plains using fire requires implementing fire at a frequency which mimics historical fire frequencies of 2-14 years (Guyette *et al.* 2012, p. 330) and thus further limits the number of landowners implementing fire in a manner which would truly preclude future encroachment. Additionally, in areas where grazing pressure is heavy and fuel loads are reduced, a typical grassland fire may not be intense enough to eradicate eastern red cedar (Briggs *et al*. 2002a, p. 585; Briggs *et al*. 2002b, p. 293; Bragg and Hulbert 1976, p. 19) and will not eradicate mesquite.

Invasion of grasslands by certain opportunistic woody species, like eastern red cedar and mesquite, cause otherwise usable grassland habitat to no longer be used by LEPC and contributes to the loss and fragmentation of grassland habitat (Lautenbach 2017, p. 84; Boggie *et al*. 2017, p. 74). More specifically, in Kansas LEPC were found to be 40 times more likely to use areas that had no trees than areas with 1.6 trees per ac (5 trees per ha), and no nests were placed in areas with a tree density greater than 0.8 trees per acre (2 trees per ha), at a scale of 89 ac (36 ha) (Lautenbach 2017, pp. 104–142). Similarly, within the Shinnery Oak Ecoregion, Boggie *et al.* (2017, entire) documents that LEPC space use in all seasons is altered in the presence of mesquite, even at densities of less than 5% canopy cover. Woody vegetation encroachment has a direct effect on LEPC by making the area not usable. In addition, Boggie *et al*. (2017, pp. 72–74; mesquite) and Lautenbach (2017, pp. 104–142; eastern red cedar) documented that woody vegetation encroachment also contributes to indirect habitat loss and increases habitat fragmentation because LEPC are less likely to use areas adjacent to trees.

As part of the geospatial analysis discussed above in Section 3.2, we calculated the amount of woody vegetation encroachment in the current analysis area of the LEPC. We used impact radii of 1,079.4 ft (329 m) for all eastern red cedar and 800.5 ft (244 m) for areas with greater than 5% canopy cover of honey mesquite to account for the indirect effects. We provide additional explanation of our geospatial analysis of woody vegetation in Appendix B, Part 2. These calculations of the current analysis area do not include historical impacts of habitat loss that occurred outside of the current analysis area; thus, it likely underestimates the effects of historical woody vegetation encroachment range-wide on the LEPC. An additional limitation associated with this calculation is that available remote sensing data lack the ability to detect areas with low densities of encroachment, as well as areas with shorter trees; thus, this calculation likely underestimates LEPC habitat loss due to woody vegetation encroachment. The geospatial analysis results indicate about 284,000 ac (115,000 ha) representing about 5% of the total area in the Short-Grass/CRP Ecoregion; about 68,000 ac (28,000 ha) representing about 2% of the total area in the Sand Sagebrush Ecoregion; about 2,048,000 ac (829,000 ha) representing about 24% of the total area in the Mixed-Grass Ecoregion; and about 671,000 ac (272,000 ha) representing about 17% of the total area in the Shinnery Oak Ecoregion of space that was identified as potential usable or potential restorable consists of areas with woody vegetation making it not usable for LEPC use (includes both direct and indirect impacts). Range-wide, we estimate about 3,071,000 ac (1,243,000 ha) of grassland has been impacted (includes both direct and indirect impacts) by the encroachment of woody vegetation representing about 18% of the total EOR area[18]. Maps of these areas in each ecoregion are provided in Appendix E, Figure E.5.

3.3.1.5 *Roads and Electrical Distribution Lines*

Roads and distribution power lines are linear features on the landscape that contribute to loss and fragmentation of LEPC habitat and fragment populations as a result of behavioral avoidance. Specifically, Plumb *et al.* (2019, entire) found that as distance increased from 0 to 1.9 mi (0 to 3 km) away from roads, the relative probability of LEPC home range placement and space used increased by 1.66 times; this ultimately led the authors to suggest a buffer of >1,148 ft (>350 m) for secondary roads. Sullins *et al.* (2019, entire) finds evidence to suggest decreased probability of use for areas with greater than 5 mi (8 km) of county roads within a 1.2-mi (2-km) radius and greater than 0.1 mi (0.15 km) of major roads. Additionally, roads are known to contribute to lek abandonment when they disrupt the important habitat features (such as affecting auditory or visual communication) associated with lek sites (Crawford and Bolen 1976b, p. 239). Some mammalian species known to prey on LEPC, such as red fox (*Vulpes vulpes*), raccoons (*Procyon lotor*), and striped skunks (*Mephitis mephitis*), have greatly increased their distribution by dispersing along roads (Forman and Alexander 1998, p. 212; Forman 2000, p. 33; Frey and Conover 2006, pp. 1114–1115).

Traffic noise from roads may indirectly impact LEPC. Because LEPC depend on acoustical signals to attract females to leks, noise from roads, oil and gas development, wind turbines, and similar human activity may interfere with mating displays, influencing female attendance at lek sites and causing young males not to be drawn to the leks. Within a relatively short period, leks

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[18] These acreages do not account for overlap that may exist with other features which may have already impacted the landscape. Additional information regarding methodology and limitations of the spatial analysis can be reviewed in Section 3.2 and Appendix B.

can become inactive due to a lack of recruitment of new males to the display grounds. For further discussion on noise please see Section 3.3.3.5.

Depending on the traffic volume and associated disturbances, roads also may limit LEPC dispersal abilities. Lesser prairie-chickens have been shown to avoid areas of usable habitat near roads (Pruett *et al*. 2009a, pp. 1256, 1258; Plumb *et al.* 2019, entire) and in areas where road densities are high (Sullins *et al.* 2019, p. 8). Lesser prairie-chickens are thought to avoid major roads due to disturbance caused by traffic volume and, perhaps behaviorally, to avoid exposure to predators that may use roads as travel corridors. However, the extent to which roads constitute a significant obstacle to LEPC movement and space use is largely dependent upon the local landscape composition and characteristics of the road itself.

Local electrical distribution lines are usually much shorter in height than transmission lines but can still contribute to habitat fragmentation through similar mechanisms as other vertical features described in this document. Local distribution lines, while more often are erected above ground, can be placed below ground to minimize effects to LEPC. Distribution lines are similar to transmission lines with the exception to height of poles and electrical power carried through the line. Plumb *et al.* (2019, entire) found that for LEPC within their study, as distance increased from 0 to 1.9 mi (0 to 3 km) away from roads the relative probability of home range placement and space used increased by 1.54 times; this ultimately led the authors to suggest a buffer of >1,800 ft (>550 m) for power lines. In addition to habitat loss and fragmentation, electrical power lines can directly affect prairie grouse by posing a collision hazard (Leopold 1933, p. 353; Connelly *et al*. 2000, p. 974). There were no datasets available to quantify the total impact of distribution lines on the landscape for the LEPC. Although distribution lines are a significant landscape feature throughout the Great Plains with potential to affect LEPC habitat, after reviewing all available information, we were unable to develop a method to quantitatively incorporate the occurrence of distribution lines into our geospatial analysis.

As part of the geospatial analysis, discussed above in Section 3.2, we calculated estimates of the area impacted by direct and indirect habitat loss caused by roads in the current analysis area of the LEPC. We used impact radii ranging from 30 to 850 m (98 to 2,789 ft) depending on the type of road (Appendix B, Part 2). These calculations of the current analysis area do not include historical impacts of loss which occurred outside of the current EOR; thus, it likely underestimates the historical effect of roads on range-wide habitat loss for the LEPC. The geospatial analysis results indicate about 1,076,000 ac (435,000 ha) representing about 17% of the total area in the Short-Grass/CRP Ecoregion; about 446,000 ac (180,000 ha) representing about 14% of the total area in the Sand Sagebrush Ecoregion; about 1,732,000 ac (701,000 ha) representing about 20% of the total area in the Mixed-Grass Ecoregion; and about 742,000 ac (300,000 ha) representing about 19% of the total area in the Shinnery Oak Ecoregion in the current analysis area of the LEPC consists of areas of grassland that have been impacted by roads (includes direct and indirect impacts) within the analysis area for the LEPC. Range-wide, we estimate about 3,996,000 ac (1,617,000 ha) of grassland has been impacted by roads representing about 18% of the total analysis area[19]. Maps of these areas in each ecoregion are provided in Appendix E, Figure E.6. We did not have adequate spatial data to evaluate habitat loss caused solely by power lines but much of the existing impacts of power lines occur within the impacts caused by roads. Power lines that fall outside the existing impacts of roads would be additional loss for the LEPC which is not quantified here.

3.3.2 Other Factors

3.3.2.1 *Livestock Grazing*

Grazing has long been an ecological driving force throughout the ecosystems of the Great Plains (Stebbins 1981, p. 84), and much of the untilled grasslands within the range of the LEPC is currently grazed by livestock and other animals. Historically, the interaction of fire, drought, prairie dogs (*Cynomys ludovicianus*), and large ungulate grazers created and maintained distinctively different plant communities in the Western Great Plains that resulted in a mosaic of vegetation structure and composition that maintained the prairie ecosystem that sustained LEPC and other grassland bird populations (Derner *et al*. 2009, p. 112). As such, grazing by domestic livestock is not inherently detrimental to LEPC management and, in many cases, is needed to maintain appropriate vegetative structure through disturbance. However, grazing practices that tend to result in overutilization of forage, as well as decreasing vegetation heterogeneity (incompatible grazing), can produce habitat conditions that differ in significant ways from the historical grassland mosaic by altering the vegetation structure and composition and degrading the quality of habitat for the LEPC. The more heavily altered conditions are the least valuable for the LEPC (Jackson and DeArment 1963 p. 733; Davis *et al*. 1979, pp. 56, 116; Taylor and Guthery 1980a, p. 2; Bidwell and Peoples 1991, pp. 1–2) and, in some cases, can result in areas that do not contain the biological components necessary to support the LEPC. It is important that grazing being managed at a given site to account for a variety of factors including past management, soils, precipitation and other factors to ensure that the resulting vegetative composition and structure will support the LEPC as needed management will vary across the range.

Where grazing regimes leave limited residual cover in the spring, protection of LEPC nests may be inadequate, and desirable food resources can be scarce (Bent 1932, p. 280; Cannon and Knopf 1980, pp. 73–74; Crawford 1980, p. 3; Kraft 2016, pp. 19–21). Because LEPC depend on medium and tall grass species for nesting, concealment, and thermal cover that are also preferentially grazed by cattle, these plant species needed by LEPC can easily be reduced or eliminated by cattle grazing, particularly in regions of low rainfall (Hamerstrom and Hamerstrom 1961, p. 290). In addition, when grasslands are in a deteriorated condition due to incompatible grazing and overutilization, the soils have less water-holding capacity (Blanco and Lal 2010, p. 9), and the availability of succulent vegetation and insects utilized by LEPC chicks can be greatly reduced. Grazing can be beneficial to the LEPC when management practices produce or enhance the vegetative characteristics required by the LEPC. Additionally, the interaction of fire and grazing is likely important to prairie chickens, with Starns *et al.* (2020, entire) reporting that

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[19] These percentages do not equate to the actual proportion of habitat loss in an analysis area because not all of the area was necessarily suitable LEPC habitat. These percentages are only the estimated portion of the total analysis area currently impacted by roads, based on our analysis.

pyric herbivory has significant effects on vegetation composition and structure. For example, Winder *et al*. 2017 (p. 171) found that on properties managed with patch-burn grazing regimes, female greater prairie-chickens selected areas with low cattle stocking rates and patches that were frequently burned, and they avoided areas that were recently burned. Patch-burn grazing created preferred habitats for female greater prairie-chickens, with a relatively frequent fire return interval, a mosaic of burned and unburned patches, and a reduced stocking rate in unburned areas avoided by grazers. Widespread implementation of patch-burn grazing could result in significant improvements in habitat quality for wildlife in the tall grass prairie ecosystem when managed appropriately (Winder *et al*. 2017, p. 165). Lautenbach (2017, p. 20) found that in the eastern portion of the lesser prairie-chicken range, patch-burn grazing resulted in patchy landscapes with variation in vegetation composition and structure. The heterogeneity discernable in vegetation patches was based on time-since-fire, and the resulting differential grazing pressure. Female lesser prairie-chickens use of the diversity of patches in the landscape varied throughout the full life cycle of the species, selecting patches with the greatest time-since-fire and subsequently the most visual obstruction for nesting, and selecting sites with less time-since-fire and greater bare ground and forbs for summer brooding. The biological response of both the LEPC and its habitat are highly dependent upon many variables and site specific conditions including pre- and post-disturbance precipitation patterns.

Livestock are also known to inadvertently flush LEPC and trample LEPC nests (Toole 2005, p. 27; Pitman *et al*. 2006a, pp. 27–29). Brief flushing of adults from nests can expose eggs and chicks to predation and extreme temperatures. Trampling nests can cause direct mortality to LEPC eggs or chicks or may cause adults to permanently abandon their nests, ultimately resulting in loss of young. Although these effects have been documented, the significance of direct livestock effects on the LEPC is largely unknown and is presumed not to be significant at a population scale.

In summary, domestic livestock grazing (including management practices commonly used to benefit livestock production) has altered the composition and structure of grassland habitat, both currently and historically, used by the LEPC. Much of the remaining remnants of mixed-grass grasslands, while still important to the LEPC, exhibit conditions quite different from those that prevailed prior to Euro-American settlement. These changes have likely considerably reduced the suitability of remnant grassland areas as habitat for LEPC. Grazing management which has altered the vegetation community to a point where the composition and structure are no longer suitable for LEPC and can contribute to fragmentation within the landscape, even though these areas may remain as prairie or grassland. Livestock grazing, however, is not inherently detrimental to LEPC provided that grazing management results in a plant community diversity and structure that is suitable for LEPC.

While domestic livestock grazing is a dominant land use on untilled range land within the LEPC analysis area, geospatial data do not exist at a scale and resolution necessary to calculate the total amount of livestock grazing that is being managed in a way that results in habitat conditions that are not compatible with the needs of the LEPC. Therefore, we did not attempt to spatially quantify the scope of grazing effects across the LEPC range.

3.3.2.2 *Shrub Control and Eradication*

Shrub control and eradication are additional forms of habitat alteration that can influence the availability and suitability of habitat for LEPC (Jackson and DeArment 1963, pp. 736–737). Most shrub control and eradication efforts in LEPC habitat are primarily focused on sand shinnery oak for the purpose of increasing forage for livestock grazing. Sand shinnery oak is toxic if eaten by cattle when it first produces leaves in the spring, and it also competes with more palatable grasses and forbs for water and nutrients (Peterson and Boyd 1998, p. 8), which is why it is a common target for control and eradication efforts by rangeland managers. Prior to the late 1990s, approximately 100,000 ac (40,000 ha) of sand shinnery oak in New Mexico and approximately 1,000,000 ac (405,000 ha) of sand shinnery oak in Texas were lost due to the application of tebuthiuron and other herbicides for agriculture and range improvement (Peterson and Boyd 1998, p. 2).

Shrub cover is an important component of LEPC habitat in certain portions of the range, and sand shinnery oak is a key shrub in the Shinnery Oak and portions of the Mixed-Grass Ecoregions. The importance of sand shinnery oak as a component of LEPC habitat in the Shinnery Oak Ecoregion has been demonstrated by several studies (Fuhlendorf *et al.* 2002, pp. 624–626; Bell 2005, pp. 15, 19–25). In West Texas and New Mexico, LEPC have been documented to avoid nesting where sand shinnery oak has been controlled with tebuthiuron, indicating their preference for habitat with a sand shinnery oak component (Grisham *et al*. 2014, p. 18; Haukos and Smith 1989, p. 625; Johnson *et al.* 2004, pp. 338–342; Patten and Kelly 2010, p. 2151). Where sand shinnery oak occurs, LEPC use it both for food and cover. Sand shinnery oak may be particularly important in drier portions of the range due to the more severe and frequent droughts and extreme heat events, as sand shinnery oak is more resistant to drought and heat conditions than are most grass species. And since sand shinnery oak is toxic to cattle and thus not targeted by grazing, can provide available cover for LEPC nesting and brood rearing during these extreme weather events. Loss of this component of the vegetative community likely contributed to observed population declines in LEPC in these areas. While relatively wide-scale shrub eradication has occurred in the past, geospatial data do not exist to evaluate the extent to which shrub eradication has contributed to the habitat loss and fragmentation for the LEPC and, therefore, was not included in our quantitative analysis.

3.3.2.3 *Influence of Anthropogenic Noise*

Anthropogenic noise can be associated with almost any form of human activity, and LEPC may exhibit behavioral and physiological responses to the presence of noise. In prairie-chickens, the ‘‘boom’’ call vocalization transmits information about sex, territorial status, mating condition, location, and individual identity of the signaler and thus is important to courtship activity and long-range advertisement of the display ground (Sparling 1981, p. 484). The timing of displays and frequency of vocalizations are critical reproductive behaviors in prairie grouse and appear to have developed in response to unobstructed conditions prevalent in prairie habitat and indicate that effective communication, particularly during the lekking season, operates within a fairly narrow set of acoustic conditions. Prairie grouse usually initiate displays on the lekking grounds around sunrise, and occasionally near sunset, corresponding with times of decreased wind turbulence and thermal variation (Sparling 1983, p. 41). Considering the narrow set of acoustic conditions in which communication appears most effective for breeding LEPC and the importance of communication to successful reproduction, human activities that result in noises that disrupt or alter these conditions could result in lek abandonment (Crawford and Bolen 1976b, p. 239). Anthropogenic features and related activities that occur on the landscape can create noise that exceeds the natural background or ambient level. When the behavioral response to noise is avoidance, as it often is for LEPC, noise can be a source of habitat loss or degradation leading to increased habitat fragmentation.

Anthropogenic noise may be a possible factor in the population declines of other species of lekking grouse in North America, particularly for populations that are exposed to human developments (Blickley *et al.* 2012a, p. 470; Lipp and Gregory 2018, pg. 369–370). Whalen 2015 (entire) investigated the effects of wind turbine noise on male greater prairie-chicken vocalizations and chorus on 14 leks located in the area surrounding a 36 turbine wind energy facility; they found that within 3,300 ft (1,000 m) of the wind energy facility, boom and whoop sound pressure levels were higher, boom duration was shorter, whine fundamental frequency was higher, and cackle biphonations occurred less often. These differences suggest that male greater prairie-chickens are adjusting aspects of their vocalizations in response to wind turbine noise (Whalen 2015, entire). Whalen 2015 (entire) also assessed the potential for wind turbine noise to mask the chorus under specific scenarios. The results suggested that wind turbine noise may have the potential to mask the greater prairie-chicken chorus at 296 hertz (Hz) under certain scenarios, but the extent and degree of masking is uncertain. Noise produced by typical oil and gas infrastructure can mask grouse vocalizations and compromise the ability of female sage-grouse to find active leks when such noise is present (Blickley and Patricelli 2012, p. 32). Lipp (2016, pg. 40) found that oil and gas pump jack motor noise (sound pressure level) significantly affected nest locations compared to random points, in a hierarchy of factors important to nest site selection, but not nest success or survival. This motor noise was measured having an additive effect on the background environmental noise out to greater than 3,800 m. Chronic noise associated with human activity leads to reduced male and female attendance at noisy leks. Other communications used by grouse off the lek, such as parent-offspring communication, may continue to be susceptible to masking by noise from human infrastructure (Blickley and Patricelli 2012, p. 33). Breeding, reproductive success and ultimately recruitment in areas with human developments could be impaired by inappropriate placement of such developments, impacting survival (Blickley *et al.* 2012b, entire). Because opportunities for effective communication on the display ground occur under fairly narrow conditions, disturbance during this period may have negative consequences for reproductive success.

In LEPC, persistent anthropogenic noise could cause lek attendance to decline, disrupt courtship and breeding activity, and reduce reproductive success. Noise can also cause abandonment of otherwise usable habitat and, as a result, contribute to habitat loss and degradation. There are no data available to quantify the areas of LEPC habitat range-wide that have been affected by noise, but noise is a stressor that is almost entirely associated with anthropogenic features such as roads or energy development which we address in other areas of this report. Therefore, through our accounting for anthropogenic features we may have inherently accounted for all or some of the response of the LEPC to noise produced by those features.

3.3.2.4 *Hunting, and Other Recreational, Educational, and Scientific Use*

In the late 19th century, LEPC were subject to commercial hunting (Jackson and DeArment 1963, p. 733; Fleharty 1995, pp. 38–45; Jensen *et al.* 2000, p. 170). Harvest throughout the species' historical range has been regulated since approximately the turn of the 20th century (Crawford 1980, pp. 3–4). Currently, the LEPC is classified as a game species in Kansas, New Mexico, Oklahoma, and Texas, although authorized harvest is no longer allowed in any of the states. The LEPC has been listed as a State-threatened species in Colorado, eliminating harvest of the species under the State's Nongame and Endangered or Threatened Species Conservation Act, since 1973. In March of 2009, Texas adopted a temporary, indefinite suspension of their previous 2-day season until LEPC populations could recover to harvestable levels. This suspension is still in effect. The hunting season for LEPC in Oklahoma has been closed since 1998, with harvest estimated to have peaked at near 16,000 birds in 1970, followed by a drastic decrease to less than a 1,000 by 1975, then rebounding to an annual estimated harvest ranging from 6,000–12,000 through the 1980s (Haukos *et al*. 2016, pp. 138−139). In New Mexico, the LEPC was legally hunted until 1996 (Hunt 2004, p. 39). The annual harvest in the 1960s averaged about 1,000 birds, but harvest declined to only 130 birds in 1979. Harvest rebounded a few years later, peaking in 1987 and 1988 when average harvest was about 4,000 birds (Hunt 2004, p. 39). Harvest subsequently declined through the early 1990s. In Kansas, LEPC could legally be hunted up until 2014. The bag limit was one LEPC daily south of Interstate 70, and two LEPC north of Interstate 70. For additional information on harvest of LEPC refer to Haukos *et al*. (2016, pp. 133–144).

A growing recreational activity that has the potential to negatively affect individual breeding aggregations of LEPC is the occurrence of public and guided bird watching tours of leks during the breeding season. The site-specific impact of recreational observations of LEPC at leks is currently unknown, but daily human disturbance could reduce mating activities, possibly leading to a reduction in total production. However, disturbance effects are likely to be minimal at the population level if disturbance is avoided by observers remaining in vehicles or blinds until LEPC naturally disperse from the lek and if observations are confined to a limited number of days and leks. Solitary leks comprising fewer than 10 males are most likely to be affected by repeated recreational disturbance. Suminski (1977, p. 70) strongly encouraged avoidance of activities that could disrupt nesting activities.

Research and monitoring activities such as roadside surveys, aerial surveys, and lek and flush counts that tend to rely on passive sampling rather than active handling of the birds are not likely to substantially impact the LEPC at the population level, although brief flushing of adults from nests can expose eggs and chicks to predation and extreme temperatures. Aerial surveys, as currently executed, have been shown to result in birds briefly abandoning leks, but it is not expected to be a substantial effect (McRoberts *et al*. 2011a, p. 30). When birds are flushed, some increased energy expenditure or exposure to predation may occur, but the impacts are anticipated to be minor and of short duration that do not rise to measurable effects at the population level. Studies that involve handling of adults, chicks, and eggs, particularly those involving the use of radio transmitters, also may cause increased energy expenditure, predation exposure, or otherwise impact individual birds. However, such studies typically: occur at a relatively small, localized scale; are of short duration, during the lekking rather than nesting season, last no more than a few years; and are not likely to cause an impact to LEPC populations.

3.3.2.5 *Collision Mortality from Fences*

Fencing is a fundamental tool of livestock management and is often essential for proper herd and grazing management. Fencing is used to confine livestock and prevent them from grazing areas such as public roads, agricultural fields, lands intended for hay production, outside of property boundaries, and those lands enrolled in some types of conservation programs. However, fencing, particularly at higher densities, can contribute to fragmentation of the landscape and hinder efforts to conserve grasslands on a landscape scale (Samson *et al.* 2004, p. 11–12). Fencing can be particularly detrimental to the LEPC in areas, such as Western Oklahoma, where initial settlement patterns favored larger numbers of smaller parcels for individual settlers (Patten *et al.* 2005b, p. 245). Fencing large numbers of small parcels increases the density of fences on the landscape, increasing the potential for LEPC to encounter fences during flight. In addition to direct mortality of LEPC through collisions during flight, fencing can also indirectly lead to mortality by creating hunting perches used by raptors and by facilitating corridors that may enhance movements of mammalian predators (Wolfe *et al.* 2007, pp. 96–97, 101). Wolfe *et al.* (2007, p. 101) and Patten *et al.* (2005b, p. 241) found high proportions of mortality to fence collisions in Oklahoma; however, the majority of studies range-wide have found little evidence that fence collisions are a large contribution to direct mortality of LEPC (Hagen *et al.* 2007, p. 524; Grisham and Boal 2015, p., 6; Kukal 2010, p. 54; Pirius 2011, p. 24; Robinson *et al*. 2016, entire). Therefore, in most areas where the landscapes have not been fenced as intensively as in Oklahoma, fence collision risk is not as high and not likely to result in population level effects.

3.3.2.6 *Predation*

Predation is a naturally occurring process and generally does not independently pose a substantial risk to wildlife populations, including the LEPC. Natural predation can be confounding cause for species declines when populations are extremely small, when habitat conditions have been altered to create increased predatory opportunities or increased effectiveness for predators, or when the species has an abnormal level of vulnerability to predation. The LEPC's cryptic plumage and behavioral adaptations allow the species to persist under normal predation pressures. LEPC predation varies seasonally during different life stages, with higher predation during the breeding season compared to the nonbreeding season (Boal 2016, p. 145). Although all age classes of LEPC may experience relatively constant, year-round risk from mammals, higher predation risk is seen during LEPC breeding season in the spring and summer from ravens (*Corvus corax*) and from various species of snakes preying on eggs and young, and during raptor migration seasons in the fall and spring from raptors preying on juveniles and adults (Boal 2016, p. 147). Adults may be most susceptible to predation while on the lek when birds are more conspicuous. Both Patten *et al.* (2005b, p. 240) and Wolfe *et al.* (2007, p. 100) reported that raptor predation increased with lek attendance. Patten *et al.* (2005b, p. 240) stated that male LEPC are more vulnerable to predation when exposed during lek displays than they are at other times of the year and that male LEPC mortality was chiefly associated with predation. However, during 650 hours of lek observations in Texas, raptor predation at leks was considered to be uncommon and an unlikely reason for declines in LEPC populations (Behney *et al.* 2011, pp. 336–337). Behney *et al.* (2012, p. 294) further observed that the timing of lekking activities in their study area corresponded with the lowest observed densities of raptors and that LEPC contend with a more abundant and diverse assemblage of raptors in other seasons.

Rates of predation on LEPC likely are influenced by certain aspects of habitat quality such as fragmentation or other forms of habitat degradation (Robb and Schroeder 2005, p. 36). As habitat fragmentation increases, usable habitat becomes more spatially restricted and the effects of terrestrial nest predators on grouse populations may increase (Braun *et al.*1978, p. 316). Nest predators typically have a positive response (e.g., increased abundance, increased activity, and increased species richness) to habitat fragmentation, although the effects are expressed primarily at the landscape scale (Stephens *et al.* 2003, p. 4). Similarly, as habitat quality decreases through reduction in vegetative cover, predation of LEPC nests, juveniles, and adults are all expected to increase. For this reason, ensuring adequate vegetative cover and removing raptor perches such as trees, power poles, and fence posts may lower predation more than any conventional predator removal methods (Wolfe *et al.* 2007, p. 101). As discussed within this document, existing trees, power poles, transmission lines, fences, and other vertical structures have either contributed to additional predation on LEPC through increase of perches for avian predators, provided movement areas and hunting corridors for other predators, or caused areas of usable habitat to be abandoned by LEPC due to avoidance behavior (Hovick *et al*. 2014a, p. 1685). While we reviewed all the available information regarding the effects of predation on the LEPC, the data necessary to calculate the total effect of predation on the LEPC do not exist.

3.3.2.7 *Parasites and Diseases*

Although parasites and diseases have the potential to influence LEPC population dynamics, little is known regarding the consequences of parasites or diseases at the LEPC population level (Peterson 2016, p. 173). Past adverse impacts to LEPC populations have not been observed, although diseases and parasites have been found in LEPC (Peterson 2016, p. 173). Some degree of impact from parasites and disease is a naturally occurring phenomenon for most wildlife species and is one element of compensatory mortality (the phenomenon that various causes of mortality in wildlife tend to balance each other, allowing the total mortality rate to remain constant) that operates among many species. However, there is no information that indicates parasites or disease have caused, or contributed to, the decline of any LEPC populations, and, at this time, we have no basis for concluding that disease or parasite loads are a concern to any LEPC populations. For a more detailed discussion of parasites and diseases of the LEPC, please refer to Peterson (2016, pp. 159–183).

3.3.2.8 *Fire*

Fire, or its absence, is understood to be one of three major ecological drivers of grasslands in the Southern Great Plains, with the remaining two being climate and grazing (Anderson 2006, entire; Koerner and Collins 2014, entire; Wright and Bailey 1982, pp. 80–137). Fire is an ecological process important to maintaining grasslands by itself and in coupled interaction with grazing and climate. The interaction of these ecological processes results in increasing heterogeneity on grasslands through the creation of temporal and spatial diversity in plant community composition and structure and concomitant response of wildlife (Fuhlendorf and Engle 2001, entire; Fuhlendorf and Engle 2004, entire; Fuhlendorf *et al*. 2017a, pp. 169–196). Some landowners working in these landscapes use fire as one of many tools to manage livestock behavior, forage quantity and quality and to increase performance of livestock (Fuhlendorf *et al*. 2017a, pp. 169–196). Acknowledging the role and importance of fire, grassland conservation recommendations often promote prescribed fire use and provide incentives to landowners' use of fire through conservation program efforts such as training and education, cost share, and planning assistance.

In general, following settlement of the Great Plains, fire management emphasized fire prevention and suppression, and often knowingly coupled with purposeful grazing pressures that significantly reduce and remove fine fuels (Sayre 2017, pp. 61–70). This approach, occurring in concert with settlement and ownership patterns that occurred in most of the Southern Great Plains, meant that the scale of management was relegated to smaller parcels than historically were affected. Smaller parcels intensively grazed and typically precluded from fire to the maximum extent resulted in landscapes generally transforming from dynamic heterogeneous configurations to largely static and homogenous plant communities. This simplification of vegetative pattern due to decoupling fire and grazing (Starns *et al.* 2019, pp. 1–3) is now seen as part of the contribution to changes in the number and size of wildfires and ultimately declines in biodiversity in the affected systems (Fuhlendorf and Engle 2001, entire). Changes in patterns of occurrence and size of wildfire in the Great Plains have been noted in recent years (Donovan *et al*. 2017, entire). While these landscapes have a long history of wildfire, large wildfires (greater than 1,000 ac [400 ha]) typically did not occur in recent past decades. But an increase in the Southern Great Plains of megafires (greater than 100,000 ac (400 km^2) has been documented since the mid-1990s (Lindley *et al.* 2019, pp. 164). Donovan *et al.* (2017, pp. 5990) report changes throughout all or portions of the Great Plains in the number of large wildfires, season of fire occurrence, increased area burned by wildfire, or increasing probability of large wildfires. Furthermore, Donovan *et al.* (2020a, pp.11) documented Great Plains land cover dominated by woody or woody/grassland combined vegetation as disproportionately more likely to host large wildfire, showing both the greatest increase in number of fires and area burned. Fire behavior has also been affected such that these increasingly large wildfires are burning under weather conditions (Lindley *et al.* 2019, entire) that result in greater burned extent and intensity. These shifts in fire parameters and their outcomes have potential consequences for LEPC, including: (1) larger areas of complete loss of nesting habitat as compared to formerly patchy mosaicked burns; and (2) large scale reduction in the spatial and temporal variation in vegetation structure and composition affecting nesting and brood rearing habitat, thermoregulatory cover, and predator escape cover.

Effects from fire are expected to be relatively short-term (Donovan *et al.* 2020b, entire, Starns *et al.* 2020, entire) with plant community recovery time largely predictable and influenced by pre-fire condition, post fire weather, and types of management. Some effects from fire, however, such as the response to changing plant communities in the range of the LEPC, will vary based on location within the range and available precipitation. One example of potential fire effects to LEPC occurring in the eastern extent of the distribution of sand shinnery oak that occurs in the Mixed-Grass Ecoregion indicates potential negative effects to some aspects of the LEPC habitat for two years (Boyd and Bidwell 2001, pp. 945–946), but the authors caution that these effects could be longer in duration dependent upon precipitation patterns. Effects from fire on LEPC in this study varied based on fire break preparation, season of burn, and type of habitat. Positive fire effects include improved brood habitat through increased forb and grasshopper abundance for food, but these can be countered by short-term (two years) negative effects to quality and availability of nesting habitat and a reduction in food sources (Boyd and Bidwell 2001, p. 945−946). Cannon and Knopf (1979, entire) reported movement of birds into recently burned landscapes of western Oklahoma for lek courtship displays because of the reduction in structure from formerly dense vegetation. More recently, research evaluating indirect effects (Elmore *et al*. 2017, entire) concluded that prescribe fire and managed grazing following the patch-burn or pyric herbivory approach will benefit LEPC through increases in forbs; invertebrates; and the quality, amount, and juxtaposition of brood habitat to available nesting habitat. The importance of temporal and spatial heterogeneity derived from pyric herbivory is apparent in the female LEPC use of all patch types in the patch-burn grazing mosaic, including greater than 2 years post-fire for nesting, 2-year post fire during spring lekking, 1 and 2 year post-fire during summer brooding, and 1-year post-fire during nonbreeding season (Lautenbach 2017, pp. 20–22). While the use of prescribed fire as a tool for managing grasslands throughout the LEPC range is encouraged, current use is at a temporal frequency and spatial extent insufficient to support large amount of LEPC habitat. These fire management efforts are limited to a small number of fire-minded landowners, resulting in effects to a small percentage of the LEPC range.

While LEPC evolved in a fire adapted landscape, little research (Thacker and Twidwell 2014, entire) has been conducted on response of LEPC to altered fire regimes. Research completed to date has focused on site-specific responses and consequences. Human suppression of wildfire and the limited extent of fire use (i.e., prescribed fire) for management over the past century has altered the frequency, scale, and intensity of fire occurrence in LEPC habitat. These changes in fire parameters have happened simultaneously with habitat loss and fragmentation, resulting in patchy distribution of LEPC throughout their range. An increase of larger and more intense or severe wildfires as compared to historical occurrences results in increased vulnerability of isolated, smaller LEPC populations. Both woody plant encroachment and drought are additive factors that increase risk of negative consequences of wildfire ignition, as well as extended post-fire LEPC habitat effects. The extent of these negative impacts can be significantly altered by precipitation patterns following the occurrence of the fire (dry periods will inhibit or extend plant community response).

Historically, fire served an important role in maintenance and quality of habitat for the LEPC. Currently, due to a significant shift in fire regimes in the LEPC range, fire use for management of grasslands plays a locally important but overall limited role in most LEPC habitat. Concurrently, wildfire has increased as a threat, due to compounding influences of increased size and severity of wildfires and the potential consequences to remaining isolated and fragmented LEPC populations.

3.3.2.9 *Insecticides*

Concerns over pesticides affecting vertebrate wildlife populations have recently focused on systemic products which exert broad-spectrum toxicity (Gibbons *et al*. 2014. p. 104). Recent studies have shown that neonicotinoid insecticides (a class of insecticides that share a common mode of action that targets the central nervous system of insects), which are used within the range of the LEPC, have adverse effects on non-target invertebrate species (Hallmann *et al*. 2014, p. 341). Invertebrates constitute a substantial part of the diet of many bird species, including LEPC, during the breeding season and are vital for raising offspring (Hallmann *et al*. 2014, p. 341). Although this has not been investigated specifically in relation to LEPC, Hallmann *et al*. (2014, entire) illustrated that local bird populations in the Netherlands declined by 3.5% annually in areas where there was a higher concentration of the neonicotinoid imidacloprid, and this spatial pattern of decline appeared only after the introduction of imidacloprid in the mid-1990s (even after accounting for spatial differences in land use changes). Use of imidacloprid and clothianidin (two neonicotinoid insecticides) as seed treatments on some crops also poses risks to small birds, and ingestion of even a few treated seeds could cause mortality or reproductive impairment to sensitive bird species (Gibbons *et al*. 2014, p. 103). Despite these concerns, we currently have no information that indicates insecticides are influencing LEPC populations.

3.3.2.10 *Nest Parasitism and Competition from Exotic Species*

Nonnative ring-necked pheasants (*Phasianus colchicus*) have been documented to lay eggs in the nests of several bird species, including lesser prairie-chicken and greater prairie-chicken (Hagen *et al*. 2002, pp. 522–524; Vance and Westemeier 1979, p. 223; Kimmel 1987, p. 257; Westemeier *et al*. 1989, pp. 640–641; Westemeier *et al*. 1998, pp.857–858). Consequences of nest parasitism vary, and may include abandonment of the host nest, reduction in number of host eggs, lower hatching success, and parasitic broods (Kimmel 1987, p. 255). Nests of greater prairie-chickens parasitized by pheasants have been shown to have lower egg success and higher abandonment than unparasitized nests, suggesting that recruitment and abundance may be impacted (Westemeier *et al*. 1998, pp. 860–861). Predation rates also may increase with incidence of nest parasitism (Vance and Westemeier 1979, p. 224). Male pheasants have also been observed disrupting the breeding behavior of greater prairie-chickens on leks (Sharp 1957, pp. 242–243; Follen 1966, pp. 16–17; Vance and Westemeier 1979, p. 222; Holt *et al*. 2010 entire). In addition, pheasant displays toward female prairie-chickens almost always cause the female to leave the lek (Vance and Westemeier 1979, p. 222). Thus, an attempt by a male pheasant to display on a prairie-chicken lek could disrupt the normal courtship activities of prairie-chickens.

Westemeier *et al*. (1998, p. 858) documented statistically that for a small, isolated population of greater prairie-chickens in Illinois, nest parasitism by pheasants significantly reduced the hatchability of nests. They concluded that, in areas with high pheasant populations, the survival of isolated, remnant flocks of prairie-chicken may be enhanced by management intervention to reduce nest parasitism by pheasants (Westemeier *et al*. 1998, p. 861). While Hagen *et al*. (2002, p. 523) documented a rate of only 4 percent parasitism (3 of 75 nests) of lesser prairie-chicken nests in Kansas, the sample size was small and may not reflect actual impacts across larger time and geographic scales, and precipitation gradients. Competition with and parasitism by pheasants may be a potential factor that could negatively affect vulnerable lesser prairie-chicken populations at the local level, particularly if remaining native rangelands become increasingly fragmented (Hagen *et al*. 2002, p. 524). More research is needed, but at this time we do not find that effects of pheasants on lesser prairie-chicken populations are acting on an ecoregional and range wide scale.

3.3.3 Extreme Weather Events

Weather-related events such as drought, snow, and hailstorms can influence habitat quality or result in direct mortality of LEPC. Although hailstorms typically only have a localized effect, the effects of snowstorms and drought can often be more wide-spread and can affect considerable portions of the LEPC range. Drought is considered a universal ecological driver across the Great Plains (Knopf 1996, p. 147). Annual precipitation within the Great Plains is highly variable (Wiens 1974, p. 391), with prolonged drought capable of causing local extinctions of annual forbs and grasses within stands of perennial species, and recolonization is often slow (Tilman and El Haddi 1992, p. 263). Grassland bird species are impacted by climate extremes such as extended drought, which acts as a bottleneck that allows only a limited number of individuals to survive through the relatively harsh conditions (Wiens 1974, pp. 388, 397; Zimmerman 1992, p. 92). Drought also interacts with many of the other factors addressed in this report, such as amplifying the effects of incompatible grazing and predation.

Although the LEPC has adapted to drought as a component of its environment, drought and the accompanying harsh, fluctuating conditions (high temperatures and low food and cover availability) have influenced LEPC populations. Widespread periods of drought commonly result in "bust years" of recruitment as discussed in Section 2.6.2. Following extreme droughts of the 1930s, 1950s, 1970s, and 1990s, LEPC population levels declined and a decrease in their overall range was observed (Lee 1950, p. 475; Ligon 1953, p. 1; Schwilling 1955, pp. 5–6; Hamerstrom and Hamerstrom 1961, p. 289; Copelin 1963, p. 49; Crawford 1980, pp. 2–5; Massey 2001, pp. 5, 12; Hagen and Giesen 2005, unpaginated). Additionally, LEPC populations reached near record lows during and after the more recent drought of 2011 to 2013 (McDonald *et al*. 2017, p. 12; Fritts *et al.* 2018, entire).

Drought impacts prairie grouse, such as LEPC, through several mechanisms. Drought affects seasonal growth of vegetation necessary to provide suitable nesting and roosting cover, food, and opportunity for escape from predators (Copelin 1963, pp. 37, 42; Merchant 1982, pp. 19, 25, 51; Applegate and Riley 1998, p. 15; Peterson and Silvy 1994, p. 228; Morrow *et al*. 1996, pp. 596–597; Ross *et al.* 2016a, entire). Lesser prairie-chicken home ranges will temporarily expand during drought years (Copelin 1963, p. 37; Merchant 1982, p. 39) to compensate for scarcity in available resources. During these periods, the adult birds expend more energy searching for food and tend to move into areas with limited cover in order to forage, leaving them more vulnerable to predation and heat stress (Merchant 1982, pp. 34–35; Flanders-Wanner *et al*. 2004, p. 31). Chick survival and recruitment may also be depressed by drought (Merchant 1982, pp. 43–48; Morrow *et al*. 1996, p. 597; Giesen 1998, p. 11; Massey 2001, p. 12), which likely affects population trends more than annual changes in adult survival (Hagen 2003, pp. 176–177). Drought-induced mechanisms affecting recruitment include decreased physiological condition of breeding females (Merchant 1982, p. 45); heat stress and water loss of chicks (Merchant 1982, p. 46); and effects to hatch success and juvenile survival due to changes in microclimate, temperature, and humidity (Patten *et al*. 2005a, pp. 1274–1275; Bell 2005, pp. 20–21; Boal *et al*. 2010, p. 11). Precipitation, or lack thereof, appears to affect LEPC adult population trends with a potential lag effect (Giesen 2000, p. 145; Ross *et al.* 2016a, pp. 6–8). That is, rain levels in one year promote more vegetative cover for eggs and chicks in the following year, which influences survival and reproduction.

Although LEPC have persisted through droughts in the past, the effects of such droughts are exacerbated by human land use practices such as incompatible grazing and land cultivation (Merchant 1982, p. 51; Hamerstrom and Hamerstrom 1961, pp. 288–289; Davis *et al*. 1979, p. 122; Taylor and Guthery 1980a, p. 2; Ross *et al*. 2016b, pp. 183–186) as well as the other factors that have affected the current condition and have altered and fragmented the landscape and decreased population abundances (Fuhlendorf *et al*. 2002, p. 617; Rodgers 2016, pp. 15−19). In past decades, fragmentation of LEPC habitat was less extensive than it is today, and connectivity between occupied areas was more prevalent and populations were larger, allowing populations to recover more quickly; in other words, LEPC populations were more resilient to the effects of stochastic events such as drought. As LEPC population abundances decline and usable habitat declines and becomes more fragmented, their ability to rebound from prolonged drought is diminished.

Hailstorms are known to cause mortality of prairie grouse, particularly during the spring nesting season. Fleharty (1995, p. 241) provides an excerpt from the May 1879 Stockton News that describes a large hailstorm near Kirwin, Kansas, as responsible for killing prairie-chickens (likely greater prairie-chicken) and other birds by the hundreds. Although such phenomena are likely rare, the effects can be significant, particularly if they occur during the nesting period and result in significant loss of eggs or chicks. Severe winter storms can also result in localized impacts to LEPC populations. For example, a severe winter storm in 2006 was reported to reduce LEPC numbers in Colorado by 75% from 2006 to 2007, from 296 birds observed to only 74. Active leks also declined from 34 leks in 2006 to 18 leks in 2007 (Verquer 2007, p. 2).

We are not able to quantify the impact that severe weather has had on the LEPC populations, but as discussed above, these events have shaped recent history and influenced the current condition for the LEPC.

3.4 Current Conservation Efforts

3.4.1 Range-wide Conservation Efforts

In the following sections, we summarize the LEPC conservation programs that are in place across the species' range. Because the vast majority of LEPC and their habitat occurs on private lands, most of these programs are targeted toward voluntary, incentive-based actions in cooperation with private landowners. Some programs are implemented across the species' range and others are implemented at the state or local level. Below we summarize the current participation in these programs based on the most up-to-date information available, although many of these programs are implemented with fluctuating levels of participation.

3.4.1.1 *Lesser Prairie-Chicken Range-wide Conservation Plan (WAFWA)*

The Lesser Prairie-Chicken Interstate Working Group was formed in 1996 and is composed of state agency biologists under the oversight of WAFWA's Grassland Coordinator. In 2012–2013, the Interstate Working Group and WAFWA developed the RWP in response to concerns about threats to LEPC habitat and resulting effects to LEPC populations (Van Pelt *et al*. 2013, entire). In October 2013, the Service announced its endorsement of the RWP as a comprehensive conservation program that reflects a sound conservation design and strategy that, when fully implemented, should provide a net conservation benefit to the LEPC.

The RWP established biological goals and objectives as well as a conservation targeting strategy which aims to unify conservation efforts towards common goals. Additionally, the RWP establishes a mitigation framework administered by WAFWA that allows plan participants the opportunity to mitigate unavoidable impacts of a particular activity on the LEPC by enrolling in a WAFWA Conservation Agreement (WCA) and provides financial incentives to landowners who voluntarily participate to provide conservation to offset impacts. The mitigation framework is designed to incentivize avoidance and minimization of impacts to LEPC habitat from various development activities and to mitigate impacts when avoidance is not possible. Development activities included in the RWP include oil and gas development (seismic and land surveying, construction, drilling, completion, workovers, operations and maintenance, and remediation and restorations activities), agricultural activities (brush management, building and maintaining fences and livestock structures, grazing, water/windmills, disturbance practices, and crop production), wind energy, cell and radio towers, power line activities (construction, operations and maintenance, and decommissioning and remediation), road activities (construction, operation and maintenance, and decommissioning and remediation), and general activities (hunting, off-highway vehicle (OHV) activity, general construction, and other land management). After approval of the RWP, WAFWA developed a companion oil and gas CCAA was developed which adopted the mitigation framework contained within the RWP that was approved in 2014.

The RWP and CCAA uses a decision support tool[20] that identifies focal areas and connectivity zones where LEPC conservation actions will be emphasized. Within the established mitigation framework, impacts and offsets are quantified by calculating "units" which are dependent upon the extent of the impact, the location of the impact, and the quality of the habitat being impacted. Impacts are mitigated, based upon units, at a ratio of 2:1 to ensure offset units are greater than units impacted. Mitigation dollars are offered to landowners for implementing conservation practices to benefit the species based on the landowner's acreage, location, and habitat quality.

As of August 1, 2020, WAFWA had 22 sites totaling 128,230 unimpacted ac (51,893 ha) under conservation contracts to provide offset for industry impacts which have occurred through the RWP and CCAA (Moore 2020, p. 9). Of those sites, 35,635 unimpacted ac (14,421 ha) are permanently protected range-wide: 2,880 ac (1,165 ha) in the Short-Grass/CRP Ecoregion, 28,840 ac (11,671 ha) in the Sand Sagebrush Ecoregion, 2,708 ac (1096 ha) in the Mixed-Grass Ecoregion, and 1,208 ac (489 ha) in the Shinnery Oak Ecoregion (Moore 2020, p. 11). In 10-year term agreements, 92,595 unimpacted ac (37,472 ha) are being managed under term agreements: 8,772 ac (3,561 ha) in the Short-Grass Prairie Ecoregion, 8,799 ac (3,561 ha) in the Sand Sagebrush Ecoregion, 62,315 ac (25,218 ha) in the Mixed-Grass Ecoregion, and 12,709 ac (5143 ha) in the Shinnery Oak Ecoregion (Moore 2020, p. 10). On these enrolled conservation properties, WAFWA completed approximately 9,330 ac (3,776 ha) of restoration[21] (Moore 2020, p 11). Most of these acres are in the Shinnery Oak and Mixed-Grass Ecoregions and have undergone brush management. These areas are enrolled under RWP conservation contracts that will provide mitigation for 1,538 projects which impacted 48,743 ac (19,726 ha) (WAFWA 2020, table 32, unpaginated). These projects occur on properties enrolled in the CCAA through Certificates of Inclusion or the WCA through Certificates of Participation. When enrolling a property in the CCAA or the WCA, enrollees agree to minimize impacts from projects to LEPC habitat and mitigate for all remaining impacts on the enrolled property. At the end of 2019 in the CCAA, there were 111 active contracts (Certificates of Inclusion) with 6,228,136 ac (2,520,437 ha) enrolled (Moore 2020, p 4), and in the WCA there were 52 active WCA contracts (Certificates of Participation) with 599,626 ac (242,660 ha) enrolled (WAFWA 2020, Table 5 unpaginated).

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[20] https://www.sgpchat.org/

[21] These acres do not include the 8,272 ac (3,348 ha) that WAFWA reports as restoration via chemical suppression of sand shinnery oak as these spaces are already LEPC habitat and the purpose of chemical suppression is to increase the % of grasses and forbs to increase habitat quality. The Service only considers restoration actions to be those which convert space that is not usable to the LEPC to habitat for the LEPC.

A recent audit of the mitigation program associated with the RWP and CCAA identified several key issues to be resolved within the program to ensure financial stability and effective conservation outcomes (Moore 2020, Appendix E). WAFWA hired a consultant who worked with stakeholders, including the USFWS, to consider available options to address the identified issues to ensure long-term durability of the strategy. After close consideration the consultant produced a report which outlines their findings and recommendations to WAFWA regarding the potential changes to the program (ICF 2020, Entire). A range of potential changes are outlined in the report, including the possible termination of a portion of the enrolled term contracts reported above and potential liquidation of assets, including the 28,000-ac (11,300-ha) property owned by WAFWA within the Sand Sagebrush Ecoregion, reported above as part of the permanent conservation properties. If those types of corrective actions were chosen by WAFWA, the acreages associated with the current conservation efforts would change. The Service will coordinate closely with WAFWA to ensure we are aware of any changes to the program.

3.4.1.2 *Lesser Prairie-Chicken Initiative (USDA-NRCS)*

In 2010, the USDA-NRCS began implementation of the Lesser Prairie-Chicken Initiative (LPCI). The LPCI provides conservation assistance, both technical and financial, to landowners throughout the LPCI's administrative boundary (NRCS 2017a, p.1). The LPCI focuses on maintenance and enhancement of LEPC habitat while benefiting agricultural producers by maintaining the farming and ranching operations throughout the region. The Environmental Quality Incentives Program and the Conservation Stewardship Program, the primary programs used to provide funding for conservation through the LPCI, are voluntary programs that provide financial and technical assistance to agricultural producers through contracts up to a maximum term of 10 years in length. These contracts provide financial assistance to help plan and implement conservation practices that address natural resource concerns and provide opportunities to improve soil, water, plant, animal, air, and related resources on agricultural land. An additional program available through LPCI, the Agricultural Conservation Easement Program, provides technical and financial assistance up to 50% the cost of an easement to conserve agricultural land perpetually through a conservation easement.

In 2019, after annual declines in landowner interest in LPCI, the NRCS made changes in how LPCI will be implemented moving forward and initiated conferencing under Section 7 of the ESA with the Service. Prior to 2019, participating landowners had to address all threats to the LEPC present on their property. In the future, each conservation plan developed under LPCI will only need to include one or more of the core management practices that include prescribed grazing, prescribed burning, brush management, and upland wildlife habitat management. Additional management practices may be incorporated into each conservation plan, as needed, to facilitate meeting the desired objectives. These practices are applied or maintained annually for the life of the practice, typically 1 to 15 years, to treat or manage habitat for LEPC. Further details on the implementation of LPCI and the specifics of each practice are explained in more detail in the Section 7 Conference Report for the Natural Resources Conservation Service's Lesser Prairie-Chicken Initiative and Associated Procedures (Service 2019, entire).

From 2010 through 2019, NRCS worked with 883 private agricultural producers to implement conservation practices on 1.6 million ac (647,497 ha) of working lands within the historical range of the LEPC[22] (NRCS 2020a, p.2). During that time, through LPCI, NRCS implemented prescribed grazing plans on 680,800 ac (275,500 ha) across the range (Griffiths 2020, pers. comm.). This included approximately 22,400 ac (9,100 ha) in the Short-Grass/CRP Ecoregion, 73,000 ac (29,500 ha) in the Sand Sagebrush Ecoregion, 329,500 ac (133,300 ha) in the Mixed-Grass Ecoregion, and 256,000 ac (103,600 ha) in the Shinnery Oak Ecoregion. Through LPCI, NRCS has also removed over 41,000 ac (16,600 ha) of Eastern Red Cedar in the Mixed-Grass Ecoregion and chemically treated approximately 106,000 ac (43,000 ha) of mesquite in the Shinnery Oak Ecoregion[23]. Lastly, NRCS has conducted prescribed burns on approximately 15,000 ac (6,000 ha) during this time.

3.4.1.3 *Conservation Reserve Program (USDA-FSA)*

The CRP is administered by the USDA's FSA and provides short-term protection and conservation benefits on millions of acres within the range of the LEPC. The CRP is a voluntary program that allows eligible landowners to receive annual rental payments and cost-share assistance in exchange for removing cropland and certain marginal pastureland from agricultural production. CRP participants establish vegetative or tree covers and then maintain and manage that cover for the term of the contract (Service 2014b). CRP contract terms are for 10 to 15 years. CRP enrollment fluctuates over time as contracts expire and new land is enrolled. Interested owners and operators of cropland are encouraged to make offers for participation in CRP during designated general signup periods. Land to be converted to a conserving cover tend to be enrolled through a competitive process known as general CRP signup. Practices that address more specific, critical needs—such as wetlands and riparian forest buffers, have the opportunity to enroll on a first come, first served basis throughout the year via continuous CRP signup.

The CRP Grasslands program is a working lands program utilizing 10 or 15-year voluntary contracts. Owners and operators participating in CRP Grasslands establish or maintain approved vegetation to support multiple benefits while receiving an annual payment, receiving opportunities for practice cost share, and being allowed to manage the land through seed harvest, haying, grazing and related management practices.

The total amount of land which can be enrolled in the CRP is capped nationally by the Food Security Act of 1985, as amended (the 2018 Farm Bill) at 27 million ac (10.93 million ha), of which 2 million ac (810,000 ha) are reserved for CRP Grasslands. Further, continuous CRP signup practices must account for approximately 30% of CRP enrollment. The amount and dispersion of land enrolled in the CRP fluctuates as contracts expire and new lands are enrolled (FSA 2016a, p. 22). All five states within the range of the LEPC have lands enrolled in the CRP, primarily general CRP signup practices. The 2018 Farm Bill maintains the acreage limitation

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[22] With the exception of the first few years of the program all efforts have been targeted at the EOR plus a 10-mile buffer for the LEPC.

[23] It is worth noting that for mesquite, NRCS is focused on treatment via herbicide application and are currently not removing the dead standing skeletons. As documented by Boggie *et al*. (2017, entire) LEPC avoid both leafed and leafless mesquite and thus the benefits of mesquite treatment are not realized until the dead standing skeletons are removed.

that not more than 25% of the cropland in any county can be enrolled in CRP, with specific conditions under which a waiver to this restriction can be provided for lands enrolled under Conservation Reserve Enhancement Program (CREP) (84 FR 66813).

Recent research in Kansas has shown that participation in the CRP can mitigate losses of grasslands (Spencer *et al.* 2017, pp. 32–36). As identified by many authors (Ross *et al.* 2016a, entire; Hagen and Elmore 2016, entire; Spencer *et al.* 2017, entire; Sullins *et al.* 2019, entire) maintaining grassland in large blocks (<10% cropland) is vital to conservation of the species, and grassland restoration programs such as the CRP can be used to support this conservation approach.

The overall CRP benefit to LEPC is affected by the number of enrolled acres in the region. The spatial extent of CRP varies from year-to-year and depends on the program's statutory authority and prevailing economic conditions. CRP cover quality also affects benefits. With the exception of Kansas and Colorado, most of the early CRP conservation covers used nonnative grasses as the predominant cover type established on enrolled lands. As the program evolved since its inception in 1985, use of native grasses as the predominant cover type has been encouraged, resulting in even greater benefit for LEPC (FSA 2016a, p. 18). Use of native grasses in the CRP potentially creates suitable nesting and brood rearing habitat for the LEPC depending on subsequent management activity and larger landscape characteristics. In addition to what type of cover is established on CRP enrollments, maintenance of that cover (e.g., preventing encroachment of eastern red cedar and mesquite) is critical and has been of some concern.

Lesser prairie-chicken preferences for other available habitat is another element that influences the magnitude of CRP benefits. On one hand, as recently shown in the northern extent of the LEPC range, areas enrolled in CRP were 7 times more likely to be used by LEPC in landscapes receiving 22 in (55 cm) of average annual precipitation as compared to 28 in (70 cm) (Sullins 2017, p. 196). This finding indicates areas where CRP enrollment should be targeted, and it also indicates that during times of below average precipitation, some landscapes rely heavily on the existence of CRP lands to sustain LEPC.

On the other hand, while overall nest density of marked LEPC was approximately 2 times greater in CRP enrolled lands than in grasslands, nest density in CRP enrolled lands varied between 40% and 10% in 2014 and 2015, respectively (Sullins 2017, p. 198). While CRP enrolled land made up 17.3% of available grasslands in 3.1-mi (5-km) areas around leks, LEPC strongly preferred other habitat during brooding (Sullins 2017, p. 199), suggesting that CRP does not support LEPC over all stages of the species' life cycle. Also, recent work in the Shinnery Oak Ecoregion suggests that LEPC used CRP lands, primarily composed of exotic grasses with limited forbs, less than would be expected based upon availability on the landscape and exhibited a strong selection for sites with sand shinnery oak present (Meyers 2016, p. 42), which suggests regional differences and landscape characteristics may drive the relative value of CRP to the LEPC. Other work in the Shinnery Oak Ecoregion has found that LEPC select for all CRP cover types over row crop and native range at the home range scale and for native CRP cover over non-native CRP, row crop, and native range at the point-location scale in a cropland-dominated landscape in Texas (Harryman *et al.* 2019, pp. 130–131).

Over time, CRP enrollment fluctuates both nationally and locally. Within the counties that intersect the EOR+10-mile buffer, acres enrolled in CRP have declined annually since 2007 (with the exception of one minor increase from 2010 to 2011) from nearly 6 million ac (2.4 million ha) enrolled to current enrollment levels of approximately 4.25 million ac (1.7 million ha) (FSA 2020a, unpublished data). More specific to our analysis area, current acreage of CRP enrollment is approximately 1,822,000 ac (737,000 ha) within our analysis area, with approximately 479,000 ac (194,000 ha) in the Short-Grass/CRP Ecoregion, 409,000 ac (166,000 ha) in the Sand Sagebrush Ecoregion, 435,000 ac (176,000) in the Mixed-Grass Ecoregion, and 500,000 ac (202,000 ha) in the Shinnery Oak Ecoregion (FSA 2020b, unpublished data). Of those currently enrolled acres there are approximately 120,000 ac (49,000 ha) of introduced grasses and legumes dispersed primarily within the Mixed-Grass and Shinnery Oak Ecoregions (FSA 2020b, unpublished data).

3.4.1.4 *Conservation Banks*

The Service has approved a range-wide programmatic conservation banking agreement for the LEPC. This agreement outlines the process by which proposed conservation parcels will be submitted to the Service for consideration for the Service's review. The Service has approved four parcels under this agreement. To date, there have been no credit transactions on one of the parcels; thus, the terms and conditions are currently non-binding. At the point of which a credit transaction is imminent and the easement is recorded, this parcel will then be permanently conserved and the management terms and conditions will be required. The other three parcels have easements recorded on portions of the property, the management plans are being implemented, and they have had credit transactions. One of these parcels is in the Mixed Grass Ecoregion and consists of approximately 20,000 ac (8,100 ha) and was approved in 2014. Another parcel in the Shinnery Oak Ecoregion and consists of 2,737 ac (1,108 ha) approved in 2015. Finally, the last parcel consists of 10,500 ac (4,249 ha) in the Shinnery Oak Ecoregion and was approved in 2018.

3.4.1.5 *Southern Plains Grassland Program*

The National Fish and Wildlife Foundation and several partners have established the Southern Plains Grassland Program. This program seeks to work closely with nonprofit and government partners and the ranching community to bring important financial and technical resources to address the health and resilience of the grasslands of the Southern Great Plains. These actions will provide benefits to wildlife and to rural, ranching-based communities. The program will target funds across portions of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, and Texas.

The program aims to improve grassland health and resilience through improved grazing practices, control of invasive species that reduce available forage for livestock and habitat for wildlife, restore formerly converted lands back to grassland, protect existing high-quality grassland parcels, invest in community level grassland collaborative conservation efforts, and explore innovations in conservation, including grass banks, other community cooperative grazing arrangements, and innovations in fencing, water delivery, and recreation.

The Southern Plains Grassland Program seeks to make more than $10 million in grants over the next five years, building upon the contributions from Cargill and Sysco with additional public and private conservation funding. The first request for proposals closed in November of 2021 with initial awards expected in 2022. The actual benefits of this program to the lesser prairie-chicken will depend upon what projects are ultimately funded and where those projects occur on the landscape.

3.4.2 State-Specific Conservation Efforts

3.4.2.1 *Kansas*

The Kansas Department of Wildlife and Parks (KDWP) has targeted LEPC habitat improvements on private lands by leveraging landowner cost share contributions, industry and non-governmental organizations' cash contributions, and agency funds toward several federally funded grant programs. These programs include grant funds from the Landowner Incentive Program (LIP; 2008–2011), State Wildlife Grants (SWG; 2011–2014), and the Wildlife and Sportfish Restoration Program (WSFR, 2012–present). These programs provide direct technical and financial cost share assistance to private landowners interested in voluntarily implementing conservation management practices to benefit species of greatest conservation need—including the LEPC.

The LIP improved 22,531 ac (9,118 ha) through planting of native grasses, tree and brush management, and implementation of prescribed fire. The SWG private landowner program improved a total of 18,855 ac (7,630 ha) through the implementation of tree and brush management, prescribed burning, and fencing of expired CRP lands to encourage landowners to maintain fields as grasslands for livestock production and habitat for LEPC.

In 2014, the KDWP rebranded the Kansas State Wildlife Habitat Incentives Program (Kansas WHIP) to the Habitat First program, allowing for KDWP to leverage the previous State funds (used for Kansas WHIP) to additional funding available through the WSFR grant program. The Habitat First program includes the implementation of habitat management practices that include native grass/forb plantings, CRP disking, planting cover crops, tree and brush management, prescribed fire, and use exclusion (livestock exclusion). The Habitat First program has improved about 12,000 ac (4,856 ha) in the LEPC range since 2014. Prior to 2014, the Kansas WHIP program had improved 30,284 ac (12,255 ha) in LEPC range.

In addition, KDWP was provided an opportunity through contributions from the Comanche Pool Prairie Resource Foundation to leverage additional WSFR funds in 2016. These funds were matched with voluntary cost share contributions from landowners to implement management practices that include tree and brush removal (pre- and post-wildfire), prescribed fire, and native grass planting within the Red Hills Ecoregion. The Kansas Prescribed Fire Council and USFWS Kansas Partners for Fish and Wildlife (PFW) program collaborated with KDWP staff to engage landowners in ongoing conservation delivery efforts. Since implementation in 2016, contracts are currently obligated to complete the direct implementation of 19,655 ac (7,954 ha) with additional funding to be obligated to additional projects soon.

KDWP implements a Walk-In Hunting Access program that was initiated in 1995 to enhance the hunting tradition in Kansas. The program provides recreational game and waterfowl hunters' access to private property, including many lands enrolled in the CRP. By 2004, more than 1 million ac (404,000 ha) had been enrolled in the walk-in hunting program. Landowners receive a payment in exchange for allowing public hunting access to enrolled lands. Payments vary by the number of acres enrolled and length of contract period. Such incentives encourage landowners to provide habitat for resident wildlife species, including the LEPC.

The Nature Conservancy in Kansas is working to expand conservation for LEPC with the 18,060- ac (7,309-ha) Smoky Valley Ranch (SVR) at its core. Through the LEPC Range-Wide Plan, TNC acquired a 3,681-ac (1,490-ha) conservation easement complex near SVR, and another 30,303-ac (12,262-ha) conservation easement in the Sand Sagebrush Ecoregion; both properties include lesser prairie-chicken management plans that run parallel with permanent conservation easements. The Nature Conservancy is also assisting nearby landowners with conservation easements, prescribed fire and grazing, and CRP re-enrollment and reversion to grazing land. In the Red Hills, efforts for protection and enhancement of LEPC habitat, including funds from an NRCS Regional Conservation Partnership Program, have resulted in nearly 50,000 ac (20,000 ha) on three ranches either with secured or in-process conservation easements. Efforts also include continued and direct assistance with prescribed burn associations, including equipment and outreach, to encourage more rancher participation. The Nature Conservancy has recently applied for a NFWF grant to focus and strengthen brush control efforts in the Red Hills and to target highest priority CRP lands for enrollment and reversion to grazing land in southwest Kansas.

The PFW program has contributed financial and technical assistance for restoration and enhancement activities that benefit the LEPC in Kansas. Primary activities include control of invasive, woody plant species such as eastern red cedar; grazing management; and enhanced use of prescribed fire to improve habitat conditions in native grasslands. The PFW program has executed 95 private lands agreements with direct and indirect improvements on about 173,000 ac (70,011 ha) of private lands benefitting conservation of the LEPC in Kansas.

3.4.2.2 *Colorado*

In 2009, TNC and the Colorado Department of Transportation (CDOT) completed the Shortgrass Prairie Initiative, a seven-year project protecting prairie habitat to mitigate for CDOT projects in areas not directly impacted by highways. This project includes a 4,200 ac (1,700 ha) conservation easement managed as viable habitat for LEPC (CDOT 2009, entire). The Nature Conservancy also holds permanent conservation easements on multiple ranches that make up the Big Sandy complex. Totaling approximately 48,940 ac (19,805 ha), this complex is managed with LEPC as a conservation objective and perpetually protects intact sand sagebrush and short-grass prairie communities. Colorado Parks and Wildlife (CPW) provides funding for the Colorado Wildlife Habitat Protection Program (CWHPP), a statewide program offering funding opportunities for private landowners who wish to voluntarily protect important wildlife habitat, and/or, provide sustainable wildlife-related recreational access to the public. To date, CWHPP has not been used for LEPC habitat conservation; however, a request for proposal process provides opportunity for interested landowners with LEPC habitat.

In 2009, CPW initiated its LEPC Habitat Improvement Program (LPCHIP) that provides cost-sharing to private landowners who participate in practices such as deferred grazing around active leks, enhancement of fields enrolled in CRP and cropland to grassland habitat conversion. The LPCHIP improves and restores habitat on private lands for LEPC and other midgrass and sand sagebrush dependent wildlife found in occupied LEPC range in Southeast Colorado. Since program inception, CPW has completed 37,051 ac (14,995 ha) of habitat treatments. Of these, 14,438 ac (5,843 ha) were CRP enhancements, 12,100 ac (4,897 ha) were grazing exclusions around leks, and 10,513 ac (4,254 ha) were habitat establishment on previously cropped acres (Rossi 2020, pers. comm.). CPW leadership has committed long-term funding for this program with an annual budget of $150,000.

The U.S. Forest Service currently manage the Comanche Lesser Prairie-Chicken Habitat Zoological Area, as part of the Comanche and Cimarron National Grasslands, established in 1984, which encompasses an area of 10,177 ac (4,118 ha) in Colorado that is managed to benefit the LEPC (USFS 2014, p. 9). The 2014 Lesser Prairie-Chicken Management Plan – Cimarron and Comanche National Grasslands, provides a framework for managing LEPC habitat on the Cimarron and Comanche National Grasslands (USFS 2014, entire). The plan includes conservation measures to avoid, minimize, and mitigate existing threats in the Comanche Lesser Prairie-Chicken Habitat Zoological Area, connectivity zones outlined in Van Pelt *et al*. (2013, pp. 49–50, 78), and areas within 2 mi (3.2 km) of any existing or historical lek dating back to 2003 (USFS 2014, pp. 20–23). Specifically, this plan limits habitat loss and fragmentation in LEPC habitat in these areas from road construction, wind energy development, and oil and gas development and sets grazing management and prescribed fire guidelines to meet LEPC-specific habitat goals (USFS 2014).

In 2016, CPW and KDWP partnered with Kansas State University and USFS to initiate a three-year translocation project to restore LEPC to the Comanche National Grasslands (Colorado) and Cimarron National Grasslands (Kansas). The translocation goals were to secure the long-term persistence, resiliency, and distribution of lesser prairie-chicken populations within the Sand Sagebrush Ecoregion by restoring core populations, and to assess the feasibility of translocating lesser prairie-chickens as a tool to restore population abundance and habitat occupancy. Beginning in the fall of 2016 and concluding with the 2019 spring lekking season, the partnership trapped and translocated 411 lesser prairie-chickens from the Short-Grass/CRP Ecoregion in Kansas to the Sand Sagebrush Ecoregion. During April and May 2020 lek counts, Colorado and Kansas biologists and technicians found 115 male birds on 20 active leks in the landscape around the Comanche and Cimarron National Grasslands (Rossi 2020, pers. comm.). During lek counts in 2021, 65 males on 15 leks were documented in the release area (CPW 2021, p. 3).

CPW completes annual ground counts of all currently known LEPC lek locations, historical lek locations, and in other suitable habitat in Colorado. In 2017, CPW counted 37 males on seven active leks; however, in 2020, CPW counted 141 males on 24 leks. Six of these leks are in the translocation area and are directly attributed to translocated birds and their offspring. The 14 other leks in Prowers and Cheyenne Counties, Colorado, are outside the translocation area. Habitat conditions have been favorable for LEPC over the past several years (Rossi 2020, pers. comm.). Ground based counts conducted in 2021 by CPW counted 92 males on 22 leks (CPW 2021, p. 3).

The Colorado Oil and Gas Conservation Commission (COGCC) explicitly considers wildlife resources in oil and gas permitting. On April 16, 2019, Colorado Governor Polis signed SB19-181, which changed the mandate of the COGCC from fostering oil and gas development to regulating oil and gas development “in a reasonable manner to protect and minimize adverse impacts to public health, safety, and welfare, the environment and wildlife resources.” §34-60-

106(2.5)(a), C.R.S. Lesser prairie-chicken habitats are included in the list of High Priority Habitats for which actions must be taken to avoid, minimize, and mitigate for impacts to wildlife resources. In November 2020, COGCC approved new regulations to finalize the wildlife rules included in the 1200 Series. The 1200 Series rules include several actions pertaining to LEPC habitats including focal areas, connectivity areas, and lek sites (https://cogcc.state.co.us/#/home).

The Colorado State Land Board (CSLB) manages surface and mineral estate resources for the benefit of public education and public institutions, of which approximately 84,250 ac (34,094 ha) of surface and 170,300 ac (68,918 ha) of mineral estate are within the LEPC EOR. The CSLB is committed to conserving LEPC habitat and has developed a Lesser Prairie-Chicken Stewardship Action Plan (https://www.colorado.gov/statelandboard/stewardship-action-plans). The LEPC Stewardship Action Plan provides guidance to conserve LEPC habitat from leasing actions including, conversion to cropland, oil and gas minerals, wind, solar, solid minerals, and rights-of-way.

3.4.2.3 *Oklahoma*

In January 2013, the Oklahoma Department of Wildlife Conservation (ODWC) was issued a 25-year enhancement of survival permit pursuant to section 10(a)(1)(A) of the ESA that included an umbrella CCAA between the Service and ODWC for the LEPC in 14 Oklahoma counties (77 FR 37917). In 2014, ODWC began enrollment of private lands. As of 2019, there were 84 participants with a total of 399,225 ac (161,659 ha) enrolled in the ODWC CCAA, with 357,654 ac (144,837 ha) enrolled as conservation acres (ODWC 2020). Through this CCAA, ODWC works with participating cooperators who voluntarily commit to implementing or funding specific conservation actions, such as prescribed grazing management, removal of unnecessary fencing, brush management and tree removal, prescribed fire, and windmill removal from livestock watering facilities, in an effort to reduce or eliminate threats to LEPC. In conjunction with funding by various programs (such as NRCS, FSA, and PFW), many enrolled properties have participated in a number of LEPC conservation actions: fencing has been removed along a total of 10.9 mi (17.5 km), eastern red cedar has been removed on a total 23,337 ac (9,444 ha), prescribed burns were conducted on a total of 32,003 ac (12,951 ha), and 83 windmills were removed and replaced with solar pumps (ODWC 2020). Enrollment in this CCAA was capped at 400,000 ac (162,000 ha), but a recently approved amendment to this agreement increased the enrollment cap to 1,000,000 ac (405,000 ha) to allow additional enrollment in this agreement.

The ODWC owns six wildlife management areas (WMA) in the range of the LEPC, though only a portion of each WMA can be considered as conservation acres for LEPC (some are near roads, have trees in riparian areas, are near transmission lines, wind farms, etc.): (1) Cimarron Bluff Wildlife Management Area encompasses 3,430 ac (1,388 ha) in northeastern Harper County; (2) Cimarron Hills Wildlife Management Area encompasses 3,770 ac (1,526 ha) in northwestern Woods County; (3) Beaver River Wildlife Management Area and McFarland Management Unit encompasses 26,749 ac (10,825 ha) in Beaver County; (4) Packsaddle Wildlife Management Area encompasses 20,512 ac (8,301 ha) in Ellis County; (5) Hal and Fern Cooper Wildlife Management Area encompasses 16,080 ac (6,507 ha) in Harper and Woodward Counties; and (6) Ellis County Wildlife Management Area encompasses 4,800 ac (1,942 ha) in Ellis County.

The Service's PFW program also has contributed financial and technical assistance for restoration and enhancement activities that benefit the LEPC in Oklahoma. Important measures include control of eastern red cedar, native grass planting, and fence marking and removal to minimize collision mortality. The PFW program has funded a shared position with ODWC for six years to conduct CCAA monitoring and, in addition, has provided funding for on-the-ground-work in the LEPC range. Since 2017, the Oklahoma PFW program has implemented 51 private lands agreements on about 10,603 ac (4,291 ha) for the benefit of the LEPC in Oklahoma.

The Nature Conservancy of Oklahoma manages the 4,050 ac (1,640 ha) Four Canyon Preserve in Ellis County for ecological health to benefit numerous short-grass prairie species, including the LEPC. Management focuses on the removal of invasive species, sustainable grazing practices, woody species removal, and prescribed fire, when appropriate. In 2017, TNC acquired a conservation easement on 1,784 ac (722 ha) in Woods County. The Conservancy is seeking to permanently protect additional acreage in the region through the acquisition of conservation easements. Two easements in Woods and Harper Counties, totaling over 2,440 ac (987 ha), are currently being pursued. The Conservancy also assists local landowners with habitat management consultation, recommendations, and assistance (i.e., the application of prescribed fire), when appropriate.

3.4.2.4 *Texas*

Texas Parks and Wildlife Department (TPWD) worked with the Service and landowners to develop the first state-wide umbrella CCAA for the LEPC in Texas which was finalized in 2006. The conservation goal of the Texas CCAA is to encourage conservation and improvement of LEPC habitat on non-Federal lands by offering private landowners incentives to implement voluntary conservation measures through available funding mechanisms and by providing technical assistance and regulatory assurances concerning land use restrictions that might otherwise apply, should the LEPC become listed under the ESA. The conservation measures would generally consist of prescribed grazing; prescribed burning; brush management; cropland and residue management; range seeding and enrollment in various Farm Bill programs such as the CRP, the Grassland Reserve Program, and State Acres for Wildlife Enhancement program; and wildlife habitat treatments through the Environmental Quality Incentives Program. The Texas CCAA covers 50 counties, largely encompassing the Texas Panhandle and South Plains regions. This CCAA covers the lands currently occupied by LEPC in Texas plus those lands that are unoccupied and have potential habitat and those lands that could contain potential habitat should the LEPC population in Texas increase. Total landowner participation by the close of January 2020 is 91 properties totaling approximately 657,038 ac (265,894 ha) enrolled in 15 counties (TPWD 2020, entire).

The Service's PFW program and the TPWD have actively collaborated on range management programs designed to provide cost-sharing for implementation of habitat improvements for LEPC. The Service provided funding to TPWD to support a Landscape Conservation Coordinator position for the Panhandle and Southern High Plains region, as well as funding to support LIP projects targeting LEPC habitat improvements (brush control and grazing management) in this region. More than $200,000 of Service funds were committed in 2010, and an additional $100,000 was committed in 2011. Since 2008, Texas has addressed LEPC conservation on 14,068 ac (5,693 ha) under the LIP. Typical conservation measures include native plant restoration, control of exotic vegetation, prescribed burning, selective brush management, and prescribed grazing. The PFW program in Texas has executed 66 private lands agreements on about 131,190 ac (53,091 ha) of privately owned lands for the benefit of the LEPC in Texas.

In 2007, TNC of Texas acquired approximately 6,000 ac (2,428 ha) of private ranchland in Yoakum and Terry Counties for the purpose of conserving and restoring LEPC habitat. This acquisition helped secure a geographically important LEPC population. Since the original acquisition, an additional 4,635 ac (1,876 ha) were acquired, totaling 10,635 ac (4,303 ha) in Yoakum Dunes Preserve in Cochran, Terry and Yoakum Counties. In 2014, TNC donated this land to TPWD. The TPWD acquired an additional 3,402 ac (1,377 ha) contiguous to the Yoakum Dunes Preserve creating the 14,037 ac (5,681 ha) Yoakum Dunes Wildlife Management Area. In 2015, through the RWP process, WAFWA acquired an additional 1,604 ac (649 ha) in Cochran County, nearly 3 mi (5 km) west of the Yoakum Dunes Wildlife Management Area. The land was deeded to TPWD soon after acquisition. In 2016, an additional 320 ac (129 ha) was purchased by TPWD bordering the WAFWA acquired tract creating an additional 1,924 ac (779 ha) property that is being managed as part of the Yoakum Dunes Wildlife Management Area, now at 15,961 ac (6,459 ha).

3.4.2.5 *New Mexico*

An LEPC working group composed of local, State, and Federal officials, along with private and commercial stakeholders, published the Collaborative Conservation Strategies for the Lesser Prairie-Chicken and Sand Dune Lizard in New Mexico in August 2005. This document provides guidance in the development of the BLM's Special Status Species Resource Management Plan Amendment (RMPA) and the development of the CCA and CCAA for the LEPC and dunes sagebrush lizard (*Sceloporus arenicolus*) (DSL) in New Mexico.

The RMPA, which was approved in April 2008, addressed the concerns and future management of LEPC and DSL habitats on BLM lands and established the Lesser Prairie-Chicken Habitat Preservation Area of Critical Environmental Concern (BLM 2008, entire). Since the RMPA was approved in 2008, BLM has closed approximately 300,000 ac (121,000 ha) to future oil and gas leasing and closed approximately 850,000 ac (344,000 ha) to wind and solar development (BLM 2008, p. 3). From 2008 to 2020, they have reclaimed 3,500 ac (1,416 ha) of abandoned well pads and associated roads and required burial of power lines within 2 mi (3.2 km) of LEPC leks. Additionally, BLM has implemented control efforts for mesquite on 832,104 ac (336,740 ha) and has plans to do so on an additional 30,000 ac (12,141 ha) annually. In 2010, BLM acquired 7,440 ac (3,010 ha) of land east of Roswell, New Mexico, to complete the 54,000 ac (21,853 ha) Area of Critical Environmental Concern for LEPC which is managed to protect key habitat.

Following approval of the RMPA, a CCA was drafted by a team including the Service, BLM, Center of Excellence for Hazardous Material Management (CEHMM), and participating cooperators to address the conservation needs of the LEPC and DSL on BLM lands in New Mexico by undertaking habitat restoration and enhancement activities and minimizing habitat degradation. A CCAA was also developed in association with the CCA to facilitate conservation actions for the LEPC and DSL on private and State lands in southeastern New Mexico. Through this CCA and CCAA, CEHMM works to: protect and enhance existing populations and habitat; restore degraded habitat; create new habitat; augment existing populations of LEPC; restore populations; fund research studies; undertake other activities on private lands and Federal leases or allotments to improve the status of the LEPC; and minimize surface disturbances or relocate projects to avoid disturbance to LEPC or DSL (CEHMM 2016, pp. 1–2).

Since the CCA and CCAA were finalized in 2008, 43 oil and gas companies have enrolled a total of 1,964,163 ac (794,868 ha) in the historical range of the LEPC. In addition, 72 ranchers in New Mexico and the New Mexico Department of Game and Fish have enrolled a total of 2,055,461 ac (831,815 ha). The New Mexico State Land Office has enrolled a total of 406,673 ac (164,575 ha) in the historical range of the LEPC. The CCA and CCAA have treated 79,297 ac (32,090 ha) of mesquite and reclaimed 154 abandoned well pads and associated roads. CEHMM has also removed 7,564 ac (3,061 ha) of dead, standing mesquite, and has another 12,000 ac (5,000 ha) scheduled in the upcoming two years.

A National Fish and Wildlife Foundation grant funded in 2011 awarded $971,600 to assist landowners with grazing management deferment planning, monitoring lek sites, surveying for leks, conducting vegetative transect monitoring to determine habitat condition in response to deferment, and cultural surveys for proposed mesquite mastication projects. In 2019, the LEPC working group proposed to develop a Regional Conservation Partnership Program on identified priority LEPC areas in New Mexico. The New Mexico LEPC working group committed $2,000,000 in leveraged funds and, through a proposal submitted by New Mexico Association of Conservation Districts, was awarded an additional $2,000,000 over a 5-year period from NRCS. This funding will go to remove mesquite from the landscape, creating and restoring LEPC habitat in New Mexico.

Acquisition of land for the protection of LEPC habitat continues in New Mexico. The Nature Conservancy owns and manages the 28,000 ac (11,331 ha) Milnesand Prairie Preserve near Milnesand, New Mexico. Additionally, the New Mexico Department of Game and Fish (NMDGF) has designated 30 Prairie Chicken Areas (PCAs) specifically for management of the LEPC ranging in size from 28 to 7,189 ac (11 to 2,909 ha) and totaling more than 27,262 ac (11,033 ha). More recently, NMDGF purchased an additional 7,417 ac (3,000 ha) property that connects two of the previously owned PCAs that will create 9,817 ac (4,000 ha) contiguous property. These areas are closed to the public annually during the breeding and nesting season (March 1 to July 30) and restrictions are in place to minimize noise and other activities associated with oil and gas drilling. In 2007, the State Game Commission used New Mexico State Land Conservation Appropriation funding to acquire 5,285 ac (2,137 ha) of private ranchland in Roosevelt County. This property, the Sandhills Prairie Conservation Area (formerly the Lewis Ranch), is located east of Milnesand, New Mexico, and adjoins two existing LEPC areas owned by the State Game Commission. In 2015, the NMDGF removed 457 ac (185 ha) of light-medium density mesquite on the Sandhills Prairie Conservation Area west tract. In 2016, 598 ac (242 ha) of light-medium density mesquite was removed on the Claudell PCA. In 2018, an additional 200 ac (81 ha) of mesquite was removed on the Sandhills Prairie Conservation Area. In February 2020, the NMDGF conducted a prescribed burn on 1,084 ac (439 ha) on the Milnesand PCA. This was done in conjunction with a burn on adjacent State land, 551 ac (223 ha) and private land. This prescribed burn was a joint effort by the USFWS-PFW, NMDGF, BLM, New Mexico State Land Office, and the Grasslands Charitable Foundation.

The Service's PFW program in New Mexico has contributed financial and technical assistance for restoration and enhancement activities benefitting the LEPC in New Mexico. In 2016, the PFW program executed a private land agreement on 630 ac (255 ha) for treating invasive species with a prescribed burn. In 2020 the PFW program executed a private land agreement for a prescribed burn on 155 ac (63 ha). This agreement also facilitated the 2020 prescribed burn on NMDGF and New Mexico State Lands Office lands mentioned above. They plan to continue working in Eastern New Mexico to remove invasive species and increase the number of private land agreements in the future.

3.4.3 Regulatory Mechanisms

In Appendix D, we review the existing regulatory mechanisms (such as local, State, and Federal land use regulations or laws) that may be significant to LEPC conservation and that may ameliorate the stressors affecting the species. We conclude that existing regulatory mechanisms have minimal influence on the range-wide trends of LEPC habitat loss and fragmentation because the vast majority of the LEPC analysis area occurs on private lands, and the activities affecting LEPC habitat are largely unregulated land use practices and land development.

3.5 Current LEPC Habitat Conditions and Distribution and Abundance

3.5.1 Range-wide Current Habitat Evaluation

We estimated the current amount and configuration of potential LEPC usable area within the analysis area using the geospatial analysis described in Section 3.2 and Appendix B, Parts 1, 2, and 3, and considering existing impacts as described in Section 3.3. Impacts included in this analysis were those direct and indirect effects of areas converted to cropland, encroached by woody vegetation such as mesquite and eastern red cedar, and developed for roads, petroleum production, wind energy, and transmission lines. We acknowledge that there are other impacts on the landscape that have the ability to affect LEPC habitat. For those impacts there were either no geospatial data available to evaluate or they would have added so much complexity to our geospatial model that the results would have been uninterpretable or not explanatory for our purpose. The total area of all potential usable (land cover that may be consistent with LEPC areas that have the potential to support LEPC use) and potential usable, unimpacted land cover (potential usable land cover not impacted by landscape features) categories in each ecoregion and range-wide is shown in Table 3.2. To account for fragmentation and landscape composition, the current unimpacted potential usable land cover was grouped using potential usable areas with 60% or greater usable land cover within one mi (1.6 km) as described in Section 3.2 (Table 3.2)[24]. The results suggest that current LEPC potential usable unimpacted area with 60% or greater unimpacted potential land cover within one mile (1.6 km) is about 19% of the entire

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[24] There are multiple values reported in the literature about what the needed percent grassland is for the LEPC. As an additional sensitivity analysis to this assumption, we also summarized these data using 70%, 80%, and 90% thresholds. The results of this analysis are presented in Appendix B, Part 1.

analysis area and may range from 12% to 33% within each of the four ecoregions[25]. Maps of these areas are provided in Appendix E, Figures E.8–E.11.

Table 3.2 Results of LEPC geospatial analysis by ecoregion and range-wide estimating total area in acres, potential usable area, potential usable unimpacted area, spaces with 60% or greater potential usable unimpacted area within one mile (1.6 km), and proportion of the total ecoregion of each total for spaces with 60% or greater potential usable unimpacted areas within one mile (1.6 km).

Ecoregion	(All Results in Acres) Ecoregion Total Area	Potential Usable Area	Potential Usable Unimpacted Area	Potential Usable Unimpacted Area (60% within 1 mile)	Percent of Total Area
Short-Grass/CRP	6,298,014	2,961,318	1,985,766	1,023,894	16.3%
Mixed-Grass	8,527,718	6,335,451	2,264,217	994,483	11.7%
Sand Sagebrush	3,153,420	1,815,435	1,358,405	1,028,523	32.6%
Shinnery Oak	3,850,209	2,626,305	1,423,417	1,023,572	26.6%
Range-wide Totals	21,829,361	13,738,509	7,031,805	4,070,472	18.6%

3.5.2 Range-wide Changes in LEPC Distribution and Abundance

Once distributed widely across the Southern Great Plains, the LEPC currently occupies a substantially reduced portion of its presumed historical range (Rodgers 2016, p. 15). There have been several estimates of the potential maximum historical range of the LEPC (e.g., Taylor and Guthery 1980a, p. 1, based on Aldrich 1963, p. 537; Johnsgard 2002, p. 32; Playa Lakes Joint Venture 2007, p. 1) with a wide range of estimates on the order of about 64 to 115 million ac (26 to 47 million ha). The more recent estimate of the LEPC encompasses an area of approximately 115 million ac (47 million ha). Presumably, not all of the area within this historical range was evenly occupied by LEPC, and some of the area may not have been suitable to regularly support LEPC populations (Boal and Haukos 2016, p. 6). However, experts agree that the current range of the LEPC has been significantly reduced from the historical range at the time of European settlement, although there is no consensus on the exact extent of that reduction as estimates vary from greater than 90% reduction (Hagen and Giesen 2005, unpaginated) to approximately 83% reduction (Van Pelt *et al.* 2013, p. 3).

Estimates of population abundance prior to the 1960s are indeterminable and rely almost entirely on anecdotal information (Boal and Haukos 2016, p. 6). While little is known about precise historical population sizes, the LEPC was reported to be quite common throughout its range in the early 20th century (Bent 1932, pp. 280–281, 283; Baker 1953, p. 8; Bailey and Niedrach 1965, p. 51; Sands 1968, p. 454; Fleharty 1995, pp. 38–44; Robb and Schroeder 2005, p. 13). In one example, Litton (1978, p. 1) suggests that prior to 1900, as many as two million birds may have existed in Texas alone. Information regarding population size is available starting in the 1960s as the State fish and wildlife agencies began routine LEPC monitoring efforts. Hagen *et al. (*2017, pp. 6–9*)* calculated historical trends in LEPC abundances from 1965 through 2016 by

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[25] Due to limitations in data availability and accuracy as well as numerous limitations with the methodology and assumptions made for this analysis, this should not be viewed as a precise estimate of the LEPC habitat; it instead provides a generalized baseline to characterize the current condition and by which we can then forecast the effect of future changes.

population reconstruction methods based on historical lek surveys[26]. The results suggest the LEPC range-wide abundance (based on a minimum estimated number of male LEPC) peaked from 1965–1970 at a mean estimate of about 175,000 males (Figure 3.1). The mean population estimates maintained levels of greater than 100,000 males until 1989, after which they steadily declined to a low of 25,000 males in 1997 (Garton *et al*. 2016, p. 68). The mean population estimates following 1997 peaked again at about 92,000 males in 2006, but subsequently declined to 34,440 males in 2012.

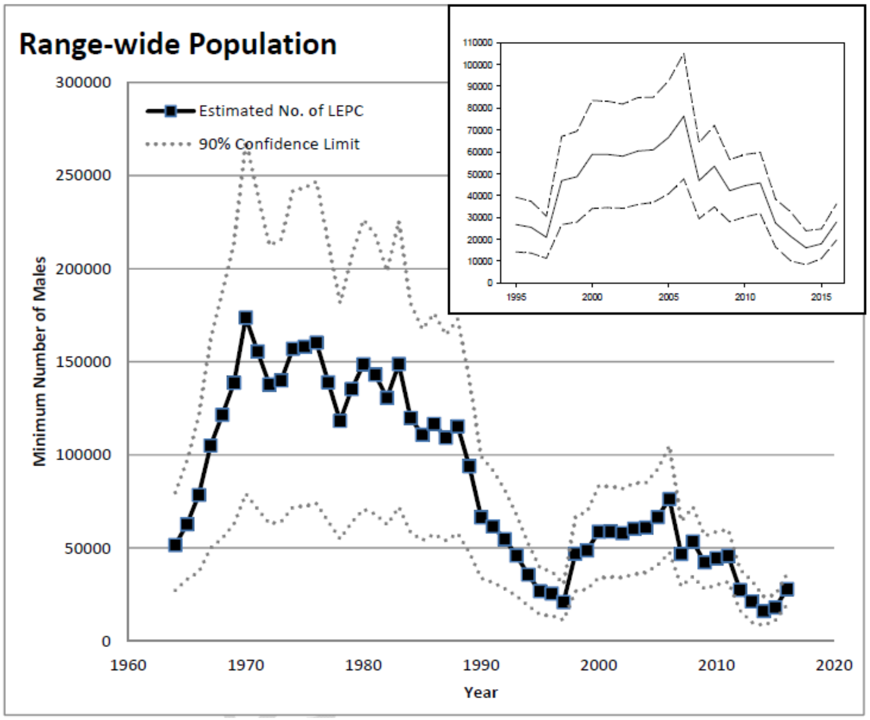

Figure 3.1 Estimated range-wide minimum number of lesser prairie-chickens males attending leks from 1964 to 2016 (90% confidence limit) based on population reconstruction using 2016 aerial survey as the initial population size. The inset map shows detail of population reconstruction from 1995 to 2016. Graph reproduced from Hagen *et al. (*2017, p. 634).

Following development of aerial survey methods (McRoberts *et al*. 2011b, entire), more statistically rigorous estimates of LEPC abundance (both males and females) have been conducted by flying aerial line-transect surveys throughout the range of the LEPC and extrapolating densities from the surveyed area to the rest of the range beginning in 2012

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[26] The Service has identified concerns in the past with some of the methodologies and assumptions made in this analysis which largely still remain, and the challenges of these data are noted in Cummings *et al.* (2017, pp. 29–30) and (Zavaleta and Haukos 2013, p. 545). While these concerns remain, including the very low sample sizes particularly in the 1960s, this work represents the only attempt to compile the extensive historical ground lek count data collected by State agencies to estimate range-wide population sizes.

(Nasman *et al*. 2021, entire)[27]. The aerial survey results from 2012 through 2021 (Figure 3.2) estimated the LEPC population abundance, averaged over the most recent 5 years of surveys (2016-2021, no surveys in 2019), at 29,502 (90% confidence interval: 8,686, 60,617) (Nasman *et al*. 2021, p. 14; Table 3.3).

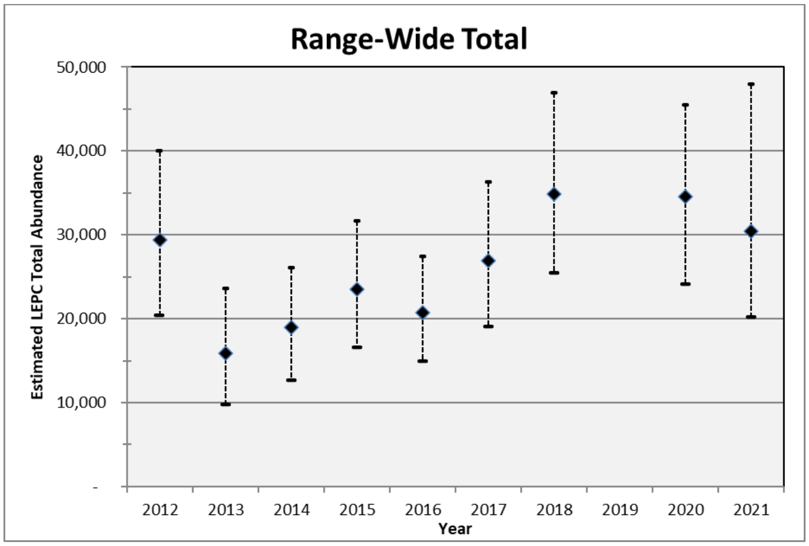

Figure 3.2 Annual estimates of total range-wide population size of lesser prairie-chicken from 2012–2021; bars represent the bootstrapped 90% confidence intervals. Graph produced from results of Nasman *et al*. (2021, p. 14). There were no surveys in 2019.

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[27] The results of these survey efforts should not be taken as precise estimates of the annual LEPC population abundance, as indicated by the large confidence intervals. Thus, we caution the reader not to draw conclusions based upon annual fluctuations but instead we believe the best use of this data is for long-term trend analysis. This is why we report the population estimate for the current condition as the average of the past 5 years of surveys.

Table 3.3 Range-wide and ecoregional estimated LEPC total population sizes averaged from 2014 to 2021, lower and upper 90% confidence intervals (CI) over the 5 years of estimates, and percent of range-wide totals for each ecoregion (from Nasman *et al*. 2021, p. 14). No surveys were conducted in 2019.

Ecoregion	**5-year Average Estimate**	***5-year Minimum Lower CI***	***5-year Maximum Upper CI***	**Percent of Total**
Short-Grass/CRP	**19,870**	*6,521*	*36,329*	67%
Mixed-Grass	**5,202**	*1,662*	*10,441*	18%
Sand Sagebrush	**1,182**	*55*	*4,547*	4%
Shinnery Oak	**3,249**	*630*	*9,300*	11%
Range-wide Totals	**29,502**	*8,868*	*60,617*	100%

3.5.3 Current Habitat and Recent Population Trends by Ecoregion

3.5.3.1 *Short-Grass/CRP Ecoregion*

Prairies of the Short-Grass/CRP Ecoregion have been significantly altered since European settlement of the Great Plains. Much of these prairies have been converted to other land uses such as cultivated agriculture, roads, power lines, petroleum production, wind energy, and transmission lines. Some areas have also been altered due to woody vegetation encroachment. Within this ecoregion, it has been estimated that about 73% of the landscape has been converted to cropland with 7% of the area in CRP (Dahlgren *et al*. 2016, p. 262). Using the geospatial analysis described in Section 3.2, we were able to explicitly account for habitat loss and fragmentation and quantify the current condition of this ecoregion for the LEPC. Of the sources of habitat loss and fragmentation which have occurred, conversion to cropland has had the single largest impact on land cover in this ecoregion (Table 3.4). We estimated approximately 1,023,894 ac (414,355 ha), or 16% of the ecoregion, in potential usable unimpacted areas with 60% or greater potential usable unimpacted land cover within one mile (1.6 km) (Table 3.2).

Table 3.4 Estimated areas of current direct and indirect impacts, by impact source, and the proportion (%) of the total area of the Short-Grass/CRP Ecoregion estimated to be impacted (see Table 3.2 for totals). Impacts are not necessarily cumulative because of overlap of some impacted areas by more than one impact source.

Short-Grass/CRP Ecoregion		
Impact Sources	**Acres**	**% of Ecoregion**
Cropland Conversion	2,333,660	37%
Petroleum Production	248,146	4%
Wind Energy Development	145,963	2%
Transmission Lines	436,650	7%
Woody Vegetation Encroachment	284,175	5%
Roads	1,075,931	17%
Total Ecoregion Area	**6,298,014**	

Prior to the late 1990s, LEPC in this ecoregion were thought to be largely absent (or occurred sporadically in low densities) (Hagen and Giesen 2005, unpaginated; Rodgers 1999, p. 19). We do not know what proportion of the eastern Short-Grass/CRP Ecoregion in Kansas was historically occupied by LEPC (Hagen 2003, pp. 3–4), and surveys in this ecoregion only began in earnest in 1999 (Dahlgren *et al*. 2016, p. 262). Rodgers and Hoffman (2005, p. 120) reported that most CRP lands in Kansas were seeded using warm season native mix, often dominated by little bluestem (*Schizachyrium scoparium*) with significant amounts of sideoats grama (*Bouteloua curtipendula*) and/or switchgrass (*Panimum virgatum*) and lesser amounts of other species. Starting in 1997, the CRP often included seed mixtures that contained introduced and native forbs, and they reported that stands reached 14–32 in (35–80 cm) in height (Rodgers and Hoffman 2005, p. 120). This is largely due to the fact that the CRP is an idle lands program and has contractual limits to the type, frequency, and timing of management activities, such as burning, haying, or grazing. As a result of these factors, CRP often provides the vegetative structure preferentially used by lesser prairie-chickens for nesting. Fields (2004, p. 105) and Fields *et al*. (2006, p. 937) surmised that the availability of CRP lands, especially CRP lands with interseeded or original seed mixture of forbs, in the State of Kansas resulted in the increased population abundance and occupancy of the LEPC in this ecoregion.

The northern section of this ecoregion is the only portion of the LEPC's range where co-occurrence with greater prairie-chicken occurs. Hybridization rates of up to 5% have been reported (Pitman 2013, p. 5), and that rate seemed to be stable across multiple years of KDWP surveys at the time, though sampling is limited where the species co-occur (Pitman 2013, p. 12). Limited additional work has been completed to further assess the rate of hybridization. Dahlgren *et al*. (2016, p. 265) expresses concerns about the implications of genetic introgression (i.e., dilution) of LEPC genes, and the fact that potential effects are poorly understood (2016, p. 276). Subsequent publication by Oyler-McCance *et al*. (2016, pp. 656–657) summarize the evidence of hybridization of greater prairie-chicken and LEPC, including discussion that introgression seems to be occurring through females because of failure of hybrid males to breed due to conflated sexually selected traits between the species (Galla and Johnson 2015, p.10). The apparent female-biased introgression is probably magnified because the majority of breeding at leks is completed by a limited number of males in this lek system (Bain and Farley 2002, p. 686). Unresolved issues include whether hybridization reduces fitness, alters behavior or morphological traits in either a positive or negative way and the historical occurrence and rate of hybridization.

Hagen *et al*. (2017, pp. 8−10), estimated historical trends in LEPC abundance from 2001 to 2016 in the Short-Grass/CRP Ecoregion using population reconstruction methods and aerial survey results from 2016 as the initial population size (Figure 3.3). The mean population estimate increased from a minimum of about 14,000 males in 2001 and peaked at about 21,000 males in 2011.

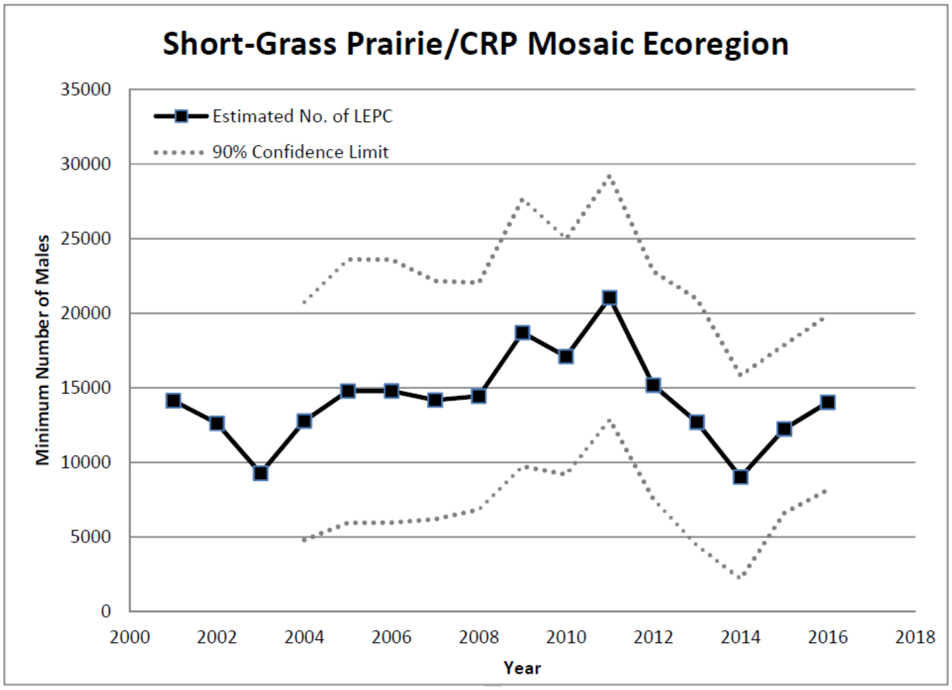

Figure 3.3 Estimated minimum number of male lesser prairie-chickens attending leks from 2001 to 2016 (90% confidence limit) in the Short-Grass Prairie/CRP Mosaic Ecoregion. Graph reproduced from Hagen *et al.* (2017, p. 633).

Aerial surveys have been conducted to estimate LEPC population abundance since 2012 and results indicate that the Short-Grass/CRP Ecoregion (Figure 3.4) has the largest population size (Nasman *et al*. 2021, p. 14) of the four ecoregions. Average estimates from 2016 to 2021 are 19,870 birds (90% confidence intervals (CI): 6,521, 36,329), making up about 67% of the range-wide LEPC total (Table 3.3). Recent years have suggested modest increases. Approximate distribution of lek locations as reported by WAFWA (www.sgpchat.org, accessed in July 2020) observed occupied at least once by LEPC between 2015 and 2019 are shown in Appendix E, Figure E.7.

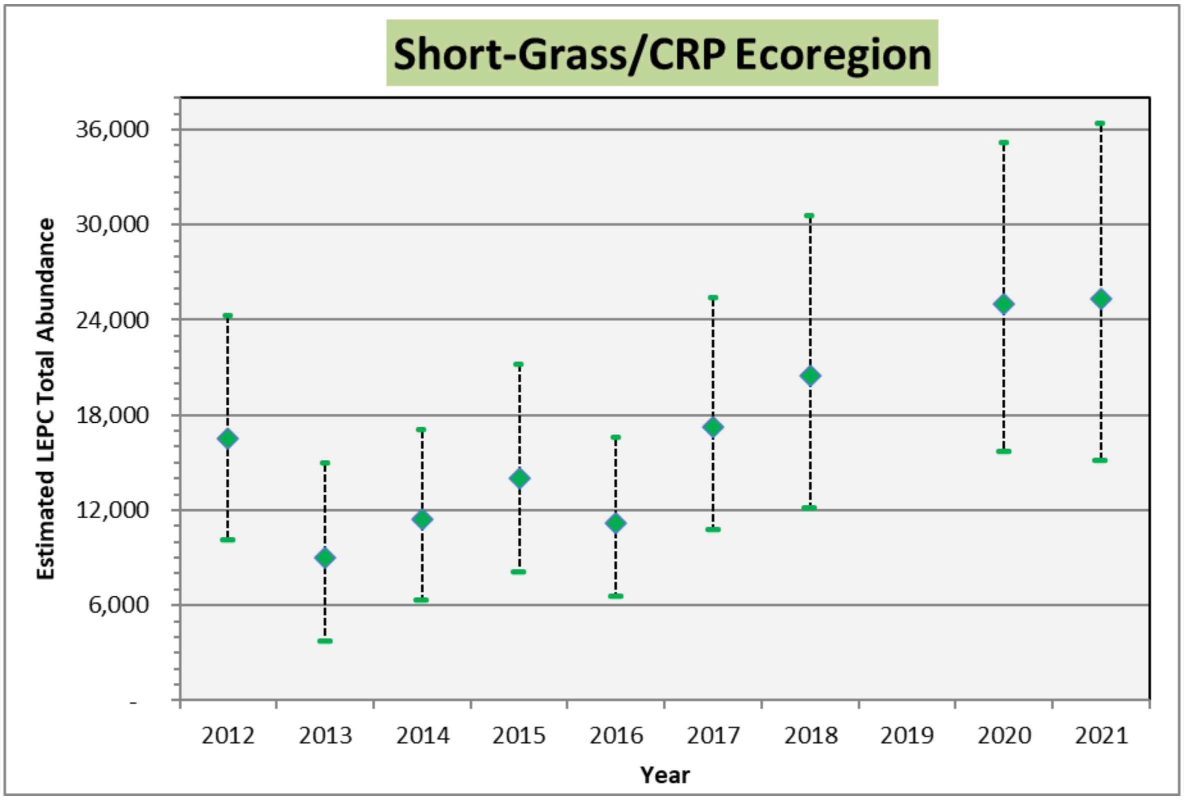

Figure 3.4 Annual estimates of breeding lesser prairie-chicken population sizes in the Short-Grass Prairie/CRP Mosaic Ecoregion from 2012 to 2021. Error bars are bootstrapped 90% confidence intervals. Graph produced from results of Nasman *et al*. (2021, p. 14). No aerial surveys were conducted in 2019.

3.5.3.2 *Mixed-Grass Prairie Ecoregion*

Much of the Mixed-Grass Prairie Ecoregion was severely fragmented originally by homesteading, which subdivided tracts of land into small parcels of 160–320 ac (65–130 ha) in size (Rodgers 2016, p. 17). As a result of these small parcels, road and fence densities are higher compared to other ecoregions and, therefore, increase habitat fragmentation and pose higher risk for collision mortalities than in other ecoregions (Wolfe *et al*. 2016, p. 302). Fragmentation has also occurred due to oil and gas development, wind energy development, transmission lines, highways, and expansion of invasive plants such as eastern red cedar. Conservation Reserve Program fields occupy between 10% and 20% of the Mixed-Grass Ecoregion, and these lands in Oklahoma and Northeastern Panhandle of Texas are dominated by exotic grasses (Wolfe *et al*. 2016, p. 300). A major concern for LEPC populations in this ecoregion is the loss of grassland due to the rapid westward expansion of the eastern red-cedar (NRCS 2016a, p. 16). Oklahoma Forestry Services estimated the average rate of expansion of eastern red-cedar in 2002 to be 762 ac (308 ha) per day (Wolfe *et al*. 2016, p. 302).

Using the geospatial analysis described in Section 3.2, we were able to explicitly account for habitat loss and fragmentation and quantify the current condition of this ecoregion for the LEPC. Of the sources of habitat loss and fragmentation which have occurred, encroachment of woody vegetation had the largest impact, with conversion to cropland, roads, and petroleum production also having significant impacts on land cover in this ecoregion (Table 3.5). We estimated there are approximately 994,483 ac (402,453 ha) or 12% of the ecoregion occur in potential usable unimpacted areas with 60% or greater potential usable unimpacted land cover within one mile (1.6 km) (Table 3.2).

Table 3.5 Estimated areas of current direct and indirect impacts, by impact source, and the proportion (%) of the total area of the Mixed-Grass Ecoregion estimated to be impacted (see Table 3.2 for totals). Impacts are not necessarily cumulative because of overlap of some impacted areas by more than one impact source.

Mixed-Grass Ecoregion		
Impact Sources	**Acres**	**% of Ecoregion**
Cropland Conversion	1,094,688	13%
Petroleum Production	859,929	10%
Wind Energy Development	191,571	2%
Transmission Lines	576,713	7%
Woody Vegetation Encroachment	2,047,510	24%
Roads	1,732,050	20%
Total Ecoregion Area	**8,527,718**	

The Mixed-Grass Ecoregion historically contained the highest LEPC densities (Wolfe *et al.* 2016, p. 299). Hagen *et al.* (2017, pp. 6−7) estimated historical trends in LEPC abundance from 1965–2016 in the Mixed-Grass Ecoregion using population reconstruction methods (Figure 3.5). The mean population estimate was around 30,000 males in the 1970s and 1980s. Population estimates declined in the 1990s and peaked again in the early 2000s at around 25,000 males, before declining and remaining to its lowest levels, <10,000 males in 2012, since the late 2000s.

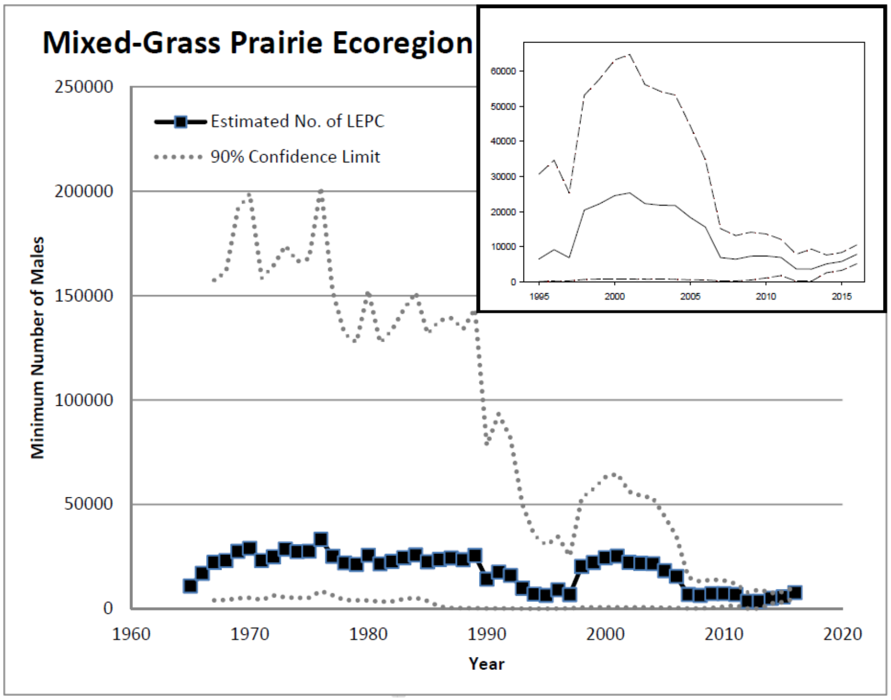

Figure 3.5 Estimated minimum number of lesser prairie-chickens attending leks from 1965 to 2016 (90% confidence limit) in the Mixed-Grass Prairie Ecoregion. Inset shows detail of population reconstruction from 1995 to 2016. Graph reproduced from Hagen *et al.* (2017, p. 630).

Aerial surveys have been conducted to estimate LEPC population abundance since 2012, and results in the Mixed-Grass Prairie Ecoregion from 2012 through 2021 (Figure 3.6) indicate this ecoregion has the second highest population size (Nasman *et al*. 2021, p. 14) of the four ecoregions. Average estimates from 2016 to 2021 are 5,202 birds (90% CI: 1,662, 10,441), representing about 18% of the range-wide total (Table 3.3). Results show minimal variation since surveys began with lower than average estimates in the past two years (Figure 3.6. Approximate distribution of lek locations as reported by WAFWA (www.sgpchat.org, accessed in July 2020) observed occupied at least once by LEPC at least once between 2015 and 2019 are shown in Appendix E, Figure E.7.

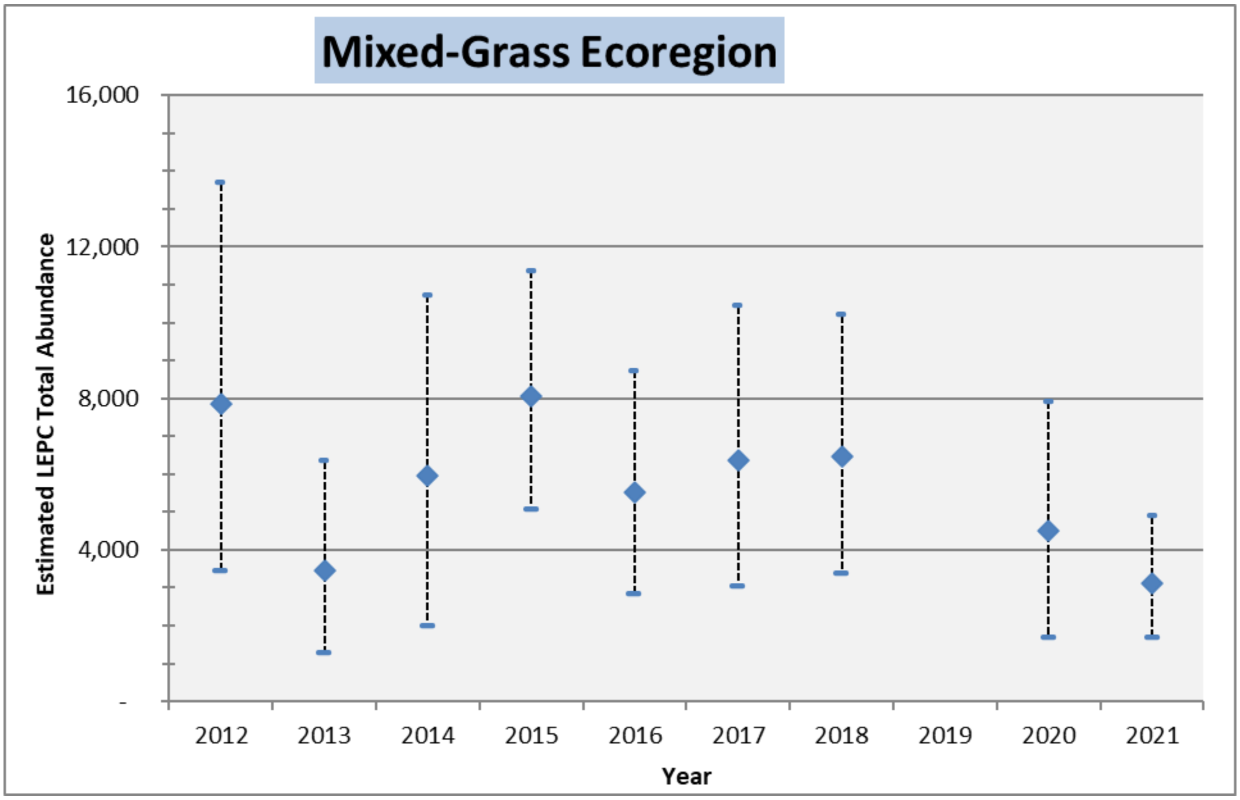

Figure 3.6 Annual estimates of breeding LEPC population sizes in the Mixed-Grass Prairie Ecoregion from 2012 to 2021. Error bars are bootstrapped 90% confidence intervals. Graph produced from results of Nasman *et al.* (2021, p. 14). No aerial surveys were conducted in 2019.

3.5.3.3 *Sand Sagebrush Ecoregion*

Prairies of the Sand Sagebrush Ecoregion have been influenced by a variety of activities since European settlement of the Great Plains. Much of these grasslands have been converted to other land uses such as cultivated agriculture, roads, power lines, petroleum production, wind energy, and transmission lines. Some areas have also been altered due to woody vegetation encroachment. Haukos *et al.* (2016, p. 285) concluded only 26% of historical sand sagebrush prairie is available as potential nesting habitat for LEPC. Using the geospatial analysis described in Section 3.2, we were able to explicitly account for habitat loss and fragmentation and quantify the current condition of this ecoregion for the LEPC. Of the sources of habitat loss and fragmentation that have occurred, conversion to cropland has had the single largest impact on land cover in this ecoregion (Table 3.6). We estimated there are approximately 1,028,523 ac (416,228 ha) or 33% of the ecoregion that occur in potential usable unimpacted areas with 60% or greater potential usable unimpacted land cover within one mile (1.6 km) (Table 3.2). In addition, habitat loss due to the degradation of the rangeland within this ecoregion continues to be a limiting factor for LEPC, and most of the existing birds within this ecoregion persist primarily on CRP lands.

Table 3.6 Estimated areas of current direct and indirect impacts, by impact source, and the proportion (%) of the total area of the Sand Sagebrush Ecoregion estimated to be impacted (see Table 3.2 for totals). Impacts are not necessarily cumulative because of overlap of some impacted areas by more than one impact source.

Sand Sagebrush Ecoregion		
Impact Sources	**Acres**	**% of Ecoregion**
Cropland Conversion	994,733	32%
Petroleum Production	163,704	5%
Wind Energy Development	0	0%
Transmission Lines	167,240	5%
Woody Vegetation Encroachment	68,147	2%
Roads	446,316	14%
Total Ecoregion Area	**3,153,420**	

This region supported large numbers of LEPC in the past, with a single flock detected in Seward County, Kansas, estimated to potentially contain more than 15,000 birds (Bent 1932, p. 281). The estimated population size is believed to have peaked at over 85,000 males in the 1970s (Garton *et al*. 2016, p. 62). This population has been in decline since the late 1970s. Most of the decline has been attributed to habitat deterioration and conversion of sand sagebrush to intensive row crop agriculture due to an increase in center pivot irrigation innovations (Jensen *et al*. 2000, p. 172).

Environmental conditions in this ecoregion can be extreme, with stochastic events impacting LEPC populations. As an example, during an extreme blizzard event in Prowers County, Colorado, during 2006–2007, it was estimated that about 80% of the LEPC died overwinter and there was about a 75% reduction of LEPC population in the Colorado portion of the ecoregion (Haukos *et al*. 2016, p. 285). Drought conditions from 2011–2014 have expedited population decline (Haukos *et al*. 2016, p. 285).

Hagen *et al*. (2017, pp. 6−8) estimated historical trends in LEPC abundance from 1965 to 2016 in the Sand Sagebrush Ecoregion using population reconstruction methods (Figure 3.5). The mean population estimate peaked at >90,000 males from 1970 to 1975 and declined to its lowest level of fewer than 1,000 males in recent years.

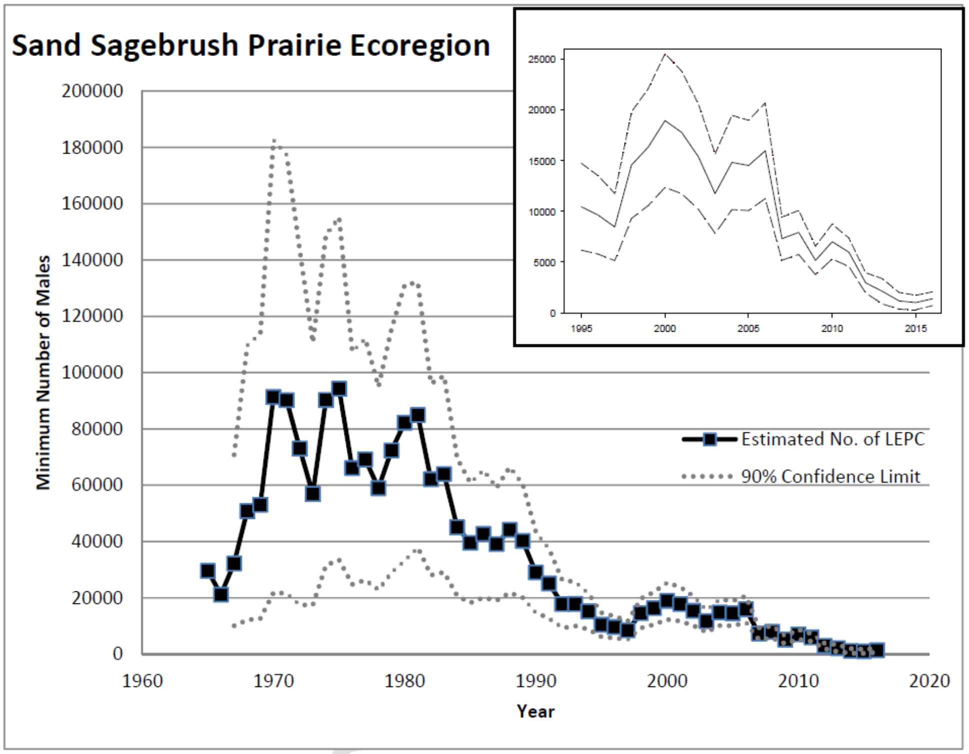

Figure 3.7 Estimated minimum number of lesser prairie-chickens attending leks 1964 to 2016 (90% confidence limit) in the Sand Sagebrush Prairie Ecoregion. Inset shows detail of population reconstruction from 1995 to 2016. Graph reproduced from Hagen *et al.* (2017, p. 631).

Aerial surveys have been conducted to estimate LEPC population abundance since 2012 and results in the Sand Sagebrush Prairie Ecoregion from 2012 through 2021 (Figure 3.8) indicate that this ecoregion has the lowest population size (Nasman *et al.* 2021, p. 14) of the four ecoregions. Average estimates from 2016 to 2021 are 1,182 birds (90% CI: 55, 4,547) representing about 4% of the range-wide LEPC total (Table 3.3). Recent results have been highly variable, with 2020 being the lowest estimate reported. Although the aerial survey results show 171 birds in this ecoregion in 2020 (without confidence intervals because the number of detections were too low for statistical analysis), ground surveys in this ecoregion in Colorado and Kansas detected 406 birds, so we know the current population is actually larger than indicated by the aerial survey results (Rossi and Fricke, pers. comm. 2020, entire). The 2021 results estimated 440 birds (CI: 55, 963) (Figure 3.8). Approximate distribution of lek locations as reported by WAFWA (www.sgpchat.org, accessed in July 2020) observed occupied at least once by LEPC at least once between 2015 and 2019 are shown in Appendix E, Figure E.7.

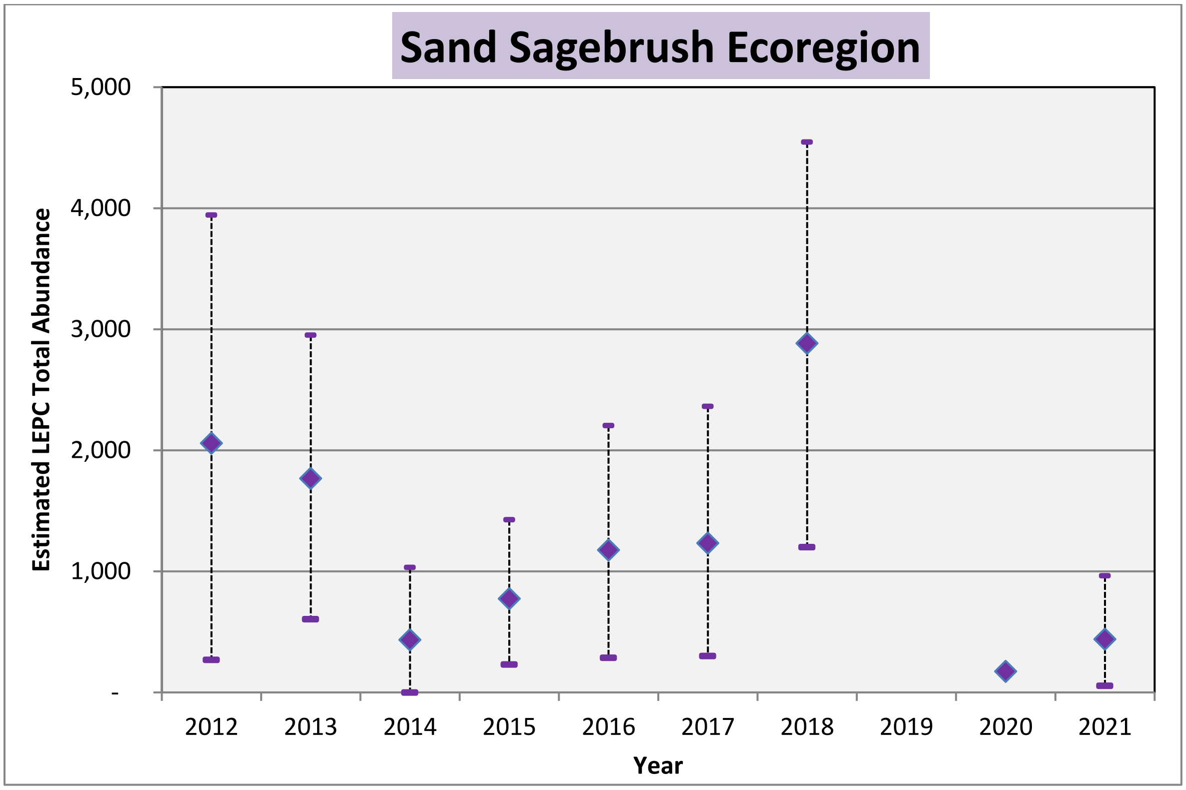

Figure 3.8 Annual estimates of breeding LEPC population sizes in the Sand Sagebrush Prairie Ecoregion from 2012 to 2021. Error bars are bootstrapped 90% confidence intervals. Graph produced from results of Nasman *et al*. (2021, p. 14). No aerial surveys were conducted in 2019, and no confidence intervals were generated in 2020.

3.5.3.4 *Shinnery Oak Prairie Ecoregion*

The Shinnery Oak Ecoregion is geographically disconnected from populations elsewhere in the species distribution. With the exception of LEPC areas owned by the State Game Commission and federally owned BLM lands in New Mexico, the majority of Shinnery Oak Prairie on the Southern High Plains is privately owned (Grisham *et al*. 2016a, p. 315). Nearly all of the area in the Texas portion of the ecoregion is privately owned and managed for agricultural use and petroleum production (Haukos 2011, p. 110). The remaining patches of shinnery oak prairie have become isolated, relict communities because the surrounding grasslands have been converted to row crop agriculture or fragmented by oil and gas exploration and urban development (Peterson and Boyd 1998, p. 22). Additionally, mesquite encroachment within this ecoregion has played a significant role in available space for the LEPC. Prior to the late 1990s, approximately 100,000 ac (40,000 ha) of sand shinnery oak in New Mexico and approximately 1,000,000 ac (405,000 ha) of sand shinnery oak in Texas were lost due to the application of tebuthiuron and other herbicides for agriculture and range improvement (Peterson and Boyd 1998, p. 2). Technological advances in irrigated row crop agriculture have led to recent conversion of shinnery oak prairie habitat to row crops in Eastern New Mexico and West Texas (Grisham *et al*. 2016a, p. 316).

Using the geospatial analysis described in Section 3.2, we were able to explicitly account for habitat loss and fragmentation and quantify the current condition of this ecoregion for the

LEPC[28]. Of the sources of habitat loss and fragmentation which have occurred, cropland conversion, roads, and encroachment of woody vegetation had the largest impacts on land cover in this ecoregion (Table 3.7). We estimated there are approximately 1,023,572 ac (414,225 ha) or 27% of the ecoregion occur in potential usable unimpacted areas with 60% or greater potential usable unimpacted land cover within one mile (1.6 km) (Table 3.2).

Table 3.7 Estimated areas of current direct and indirect impacts, by impact source, and the proportion (%) of the total area of the Shinnery Oak Ecoregion estimated to be impacted (see Table 3.2 for totals). Impacts are not necessarily cumulative because of overlap of some impacted areas by more than one impact source.

Shinnery Oak Ecoregion		
Impact Sources	**Acres**	**% of Ecoregion**
Cropland Conversion	540,120	14%
Petroleum Production	161,652	4%
Wind Energy Development	90,869	2%
Transmission Lines	372,577	10%
Woody Vegetation Encroachment	617,885	16%
Roads	742,060	19%
Total Ecoregion Area	**3,850,209**	

Hagen *et al*. (2017, pp. 6–9) estimated historical trends in LEPC abundance from 1969–2016 in the Shinnery Oak Ecoregion using population reconstruction methods (Figure 3.9). The mean population estimate ranged between about 5,000 to 12,000 males through 1980, increased to 20,000 males in the mid-1980s and declined to ~1,000 males in 1997. The mean population estimate peaked again to ~15,000 males in 2006 and then declined again to fewer than 3,000 males in the mid-2010s.

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[28] Due to lack of spatial information on the extent of sand shinnery oak eradication efforts, we were not able to quantify habitat loss due to this action.

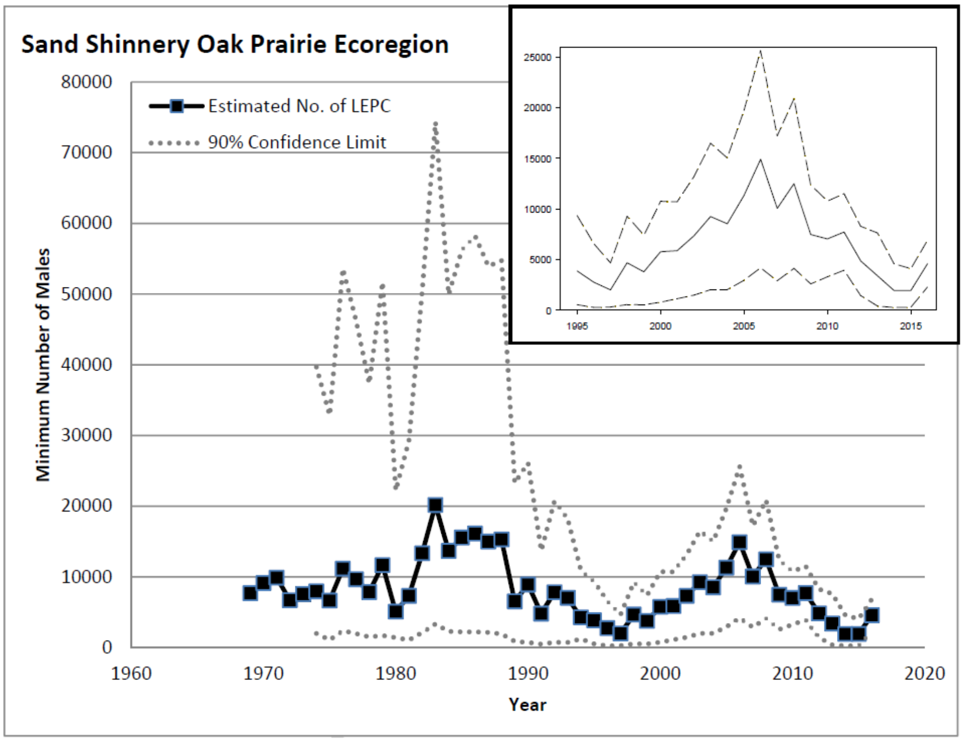

Figure 3.9 Estimated minimum number of lesser prairie-chickens attending leks from 1969 to 2016 (90% confidence limit) in the Sand Shinnery Oak Ecoregion. Inset shows detail of population reconstruction from 1995 to 2016. Graph reproduced from Hagen *et al.* (2017, p. 631).

Aerial surveys have been conducted to estimate LEPC population abundance since 2012, and results in the Shinnery Oak Ecoregion from 2012 through 2021 (Figure 3.10) indicate that this ecoregion has the third highest population size (Nasman *et al*. 2021, p. 14) of the four ecoregions. Average estimates from 2015 to 2021 are 3,249 birds (90% CI: 630, 9,300), representing about 11% of the range-wide total (Table 3.3). Recent estimates have varied between fewer than 1,000 birds in 2015 to more than 5,000 birds in 2020. Approximate distribution of lek locations as reported by WAFWA (www.sgpchat.org, accessed in July 2020) observed occupied at least once by LEPC at least once between 2015 and 2019 are shown in Appendix E, Figure E.7.

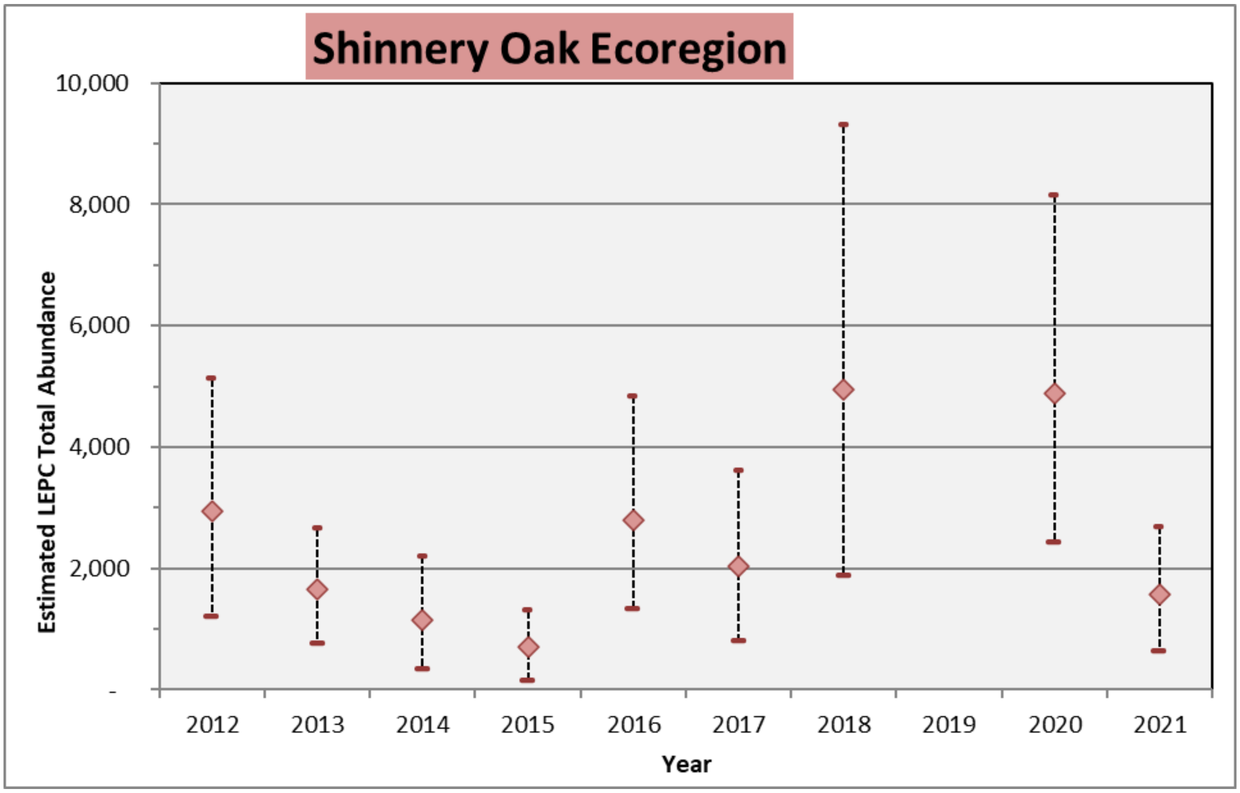

Figure 3.10 Annual estimates of breeding LEPC estimated population sizes in the Shinnery Oak Ecoregion in 2012 to 2021. Error bars are bootstrapped 90% confidence intervals. Graph produced from results of Nasman *et al*. (2021, p. 14). No aerial surveys were conducted in 2019.

4. FUTURE CONDITION

4.1 Summary

We assessed the future condition of the LEPC by considering the potential changes in habitat availability in the future within each of the four ecoregions. For some of the main sources of habitat loss and fragmentation, we used a geospatial model to predict the possible land cover changes based on five plausible future scenarios of differing levels of habitat impacts and habitat restoration. Included in the geospatial model were projections of future impacts related to the conversion of native grassland to cropland, the infrastructure associated with petroleum production and wind energy development, and encroachment of woody vegetation. Using these projections combined with projected conservation efforts in the form of habitat restoration (restoring grasslands from croplands and removal of infrastructure and removal of woody vegetation) resulted in estimates of potential usable area for the LEPC across its range.

We projected the results of our geospatial model for 25 years into the future and found that LEPC areas with 60% or greater potential usable unimpacted land cover within one mile (1.6 km) declines in all but the most optimistic scenario[29]. The optimistic plausible scenario had changes in usable area ranging from a 5% net loss to a 12% net gain in the different ecoregions, and an overall net gain of about 0.5%. The other four scenarios resulted in net usable area range-wide losses ranging from 7% to 26% depending on the different scenarios.

There are other factors that may continue to negatively influence the LEPC into the future but were not explicitly projected into the future as part of the geospatial analysis, including, for example, grazing practices, road construction, power line and transmission construction, and shrub control. In addition, many conservation practices that result in habitat enhancements for LEPC are expected to continue through the multitude of LEPC programs that are working to conserve the species across its range. We projected these enhancement efforts into the future. The enhancement efforts are primarily targeted at improving the quality of existing LEPC habitat.

The effects of climate change were also not included in our geospatial model but are anticipated to have significant influences on future LEPC populations. Climate change in the Southern Great Plains is expected to result in generally warmer and drier weather with more frequent and more intense droughts. These changes are likely to lead to direct impacts on LEPC reproduction and survival rates and possibly cause large scale shifts in the vegetation community. Of greatest concern is the increase in the effects of long-term droughts that place stress on LEPC populations and can put them at high risk of extirpation depending on the intensity and duration of the period with below normal rainfall usually accompanied by above normal temperatures. The impacts of climate change on LEPC populations, which are already relying upon available habitat that has

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[29] As discussed later in this chapter these projections do not account for all potential sources of future habitat loss for the LEPC. Due to data limitations, we were not able to project potential additional habitat loss resulting from construction of new roads, distribution lines, and transmission lines with any degree of certainty. Thus, the projections of habitat loss should be considered a minimum.

been greatly reduced and fragmented, will likely be a significant driver of future LEPC population persistence.

Several calculations of population growth rates have been compiled for the LEPC, primarily using matrix models, resulting in 19 out of the 23 calculated growth rates indicating declining populations. Another evaluation of the future risk of extinction of the LEPC has been conducted using historical ground surveys to assess the risk of quasi-extinction in each of the four ecoregions and range-wide over 30 and 100 years into the future (Hagen *et al.* 2017, pp. 7−14). The results suggest a wide range of risks among the ecoregions depending partially on whether we consider movement between them, but the Sand Sagebrush Ecoregion consistently had the highest risks of quasi-extinction and the Short-Grass/CRP Ecoregion had the lowest. This analysis was based on simulated demographic variability of populations and did not incorporate changing environmental conditions related to habitat or climate.

4.2 Future Analysis Methods: Geospatial Modeling

As discussed in Section 3.2 (and fully detailed in Appendix B, Parts 1 and 2) we conducted a geospatial analysis to characterize the current condition of the landscape for the LEPC by categorizing land cover data (into either potential usable, potential restoration, or non-usable categories), taking into account exclusion areas and impacts to remove non-usable areas. We further refined the analysis to account for connectivity by grouping unimpacted usable areas by joining together areas with greater that 60% potential usable unimpacted land cover within one mi (1.6 km). We then used this geospatial framework to analyze the future condition for each ecoregion. To analyze future habitat changes, we accounted for the effects of both future loss of usable areas and restoration efforts by estimating the rate of change based on future projections (Figure 4.1). Dawson *et al*. 2011 (entire) introduced a similar framework that uses information from different sources to identify vulnerability and support the design of conservation responses.

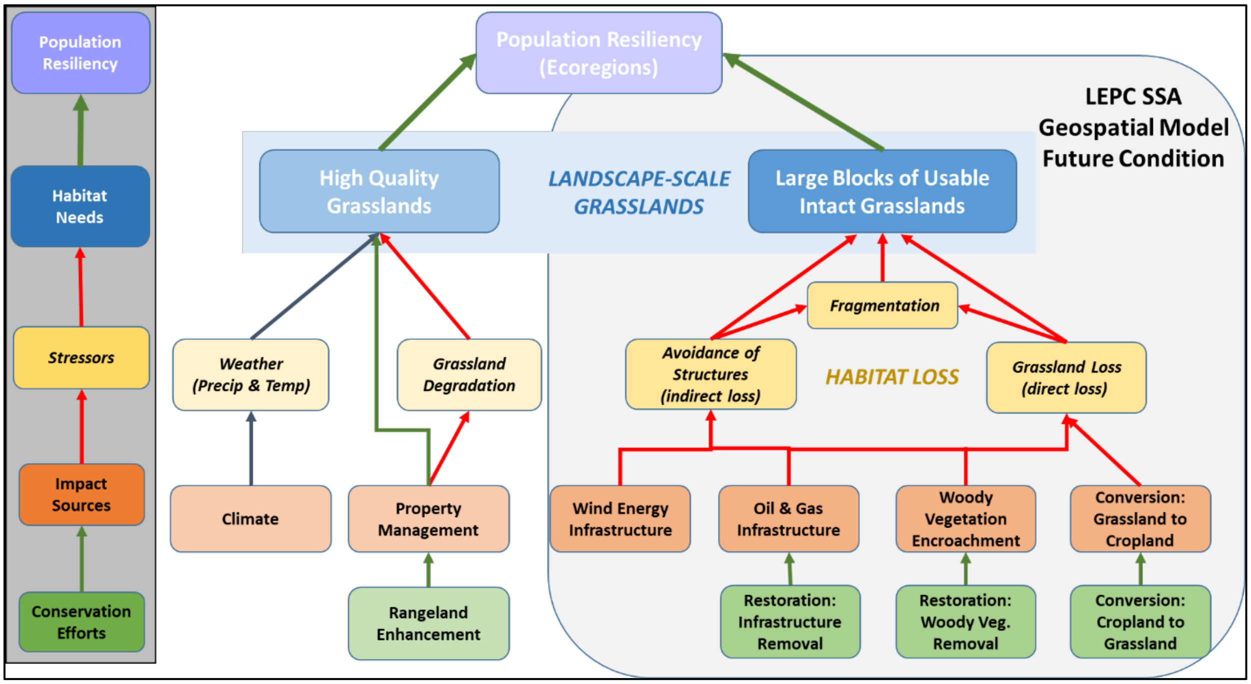

Figure 4.1 Influence diagram outlining the analysis of future conditions for LEPC. Future restoration efforts, impact sources and stressors affecting large blocks of usable intact grassland are captured in the geospatial model. Influences on high-quality grasslands, including enhancement efforts, were evaluated separately from the geospatial model.

Due to uncertainties associated with both future conservation efforts and impacts, it is not possible to precisely quantify the effect of these future actions on the landscape. Instead, we established five future scenarios to represent a range of plausible outcomes based upon three plausible levels of conservation[30] (restoration efforts) and three plausible levels of impacts (Table 4.1). To account for some of the uncertainty in these projections, we combined the levels of impacts into five different scenarios labeled 1 through 5 (Table 4.1). Scenario 1 represents the scenario with low levels of future impacts and high levels of future restoration, and Scenario 5 represents the scenario with high impacts and low restoration. Scenarios 2, 3, and 4 have continuation levels of restoration efforts and vary impacts at low, mid, and high levels, respectively. While these scenarios do not account for all nine possible combinations of the future impacts and restoration[31], they do provide a wide range of potential future outcomes to consider in assessing LEPC habitat conditions.

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[30] Appendix C documents how the Service worked with conservation organizations to develop the actual estimates of future conservation efforts.

[31] The other four possible scenarios combining impacts and restoration efforts all fall within the five selected.

Table 4.1 Schematic of future scenarios considering a range of future impacts and restoration efforts.

Scenario Reference	Levels of Future Changes in Usable Area	
	Restoration	Impacts
1	HIGH	LOW
2	CONTINUATION	LOW
3	CONTINUATION	MID
4	CONTINUATION	HIGH
5	LOW	HIGH

To project the likely future effects of impacts (described below in Section 4.3) and conservation efforts (described below in Section 4.4) to the landscape as described through our land cover model, we quantified the three levels of future habitat restoration and three levels of future impacts within the analysis area by ecoregion on an annual basis. We then extrapolated those results over the next 25 years. We chose 25 years as a period that we had reasonable confidence in projecting these future changes, and the time frame corresponds with some of the long-term planning for the LEPC. Because it is not possible to predict exactly where on the landscape potential impacts and restoration efforts will occur, we used a modeling simulation process to randomly select areas for change within specific geographic constraints established for each impact or restoration effort (see Appendix B). We conducted the simulation 20 times for each of the 5 scenarios for each of the 4 ecoregions. We report the results based on the median simulation result and the additional statistics around all simulation are provided in Appendix E, Table E.1. A complete description of methodology used to quantify projections of impacts and future conservation efforts is provided in Appendix C.

Quantifying future conservation efforts in terms of habitat restoration allows us to account for the positive impact of those efforts within our analysis by converting areas of land cover which were identified as potential habitat in our current condition model to usable land cover in the future projections. By explicitly quantifying three levels of impacts in the future, this allows us to account for the effect of these impacts on the LEPC by converting areas identified as usable land cover in our current condition model to non-usable area that will not be available for use by the LEPC in the future.

As we did for the current condition to assess habitat connectivity, after we characterized the projected effects of conservation and impacts on potential future usable areas, we grouped the areas of potential usable, unimpacted land cover on these new future landscape projections into areas of 60% or greater potential usable unimpacted land cover within one mile (1.6 km) (described in Section 3.2 and Appendix B, Parts 1, 2, and 3). We used this process to determine how much potential usable area is within one mi (1.6 km) of each area identified as potential usable area. Those spaces formed potential usable areas with at least 60% of that area in potential usable area for the LEPC. Also, as done for the current condition (see Section 3.2 and Appendix B, Part 4), we evaluated the frequency of usable area blocks by size. Figure 4.2

reports the results of the frequency distribution of habitat block sizes for the median simulation for each of the five future scenarios in each of the ecoregions.

4.3 Future Risk Factors

4.3.1 Habitat Loss and Fragmentation

As discussed in Section 3.3.1, habitat loss and fragmentation is the primary concern for LEPC viability. This habitat loss and fragmentation has occurred due to a variety of activities on the landscape as discussed in 3.3.1.1–3.3.1.5. We will discuss how each of these activities may contribute to future habitat loss and fragmentation for the LEPC and present the outcomes of the projections outlined in Appendix C.

4.3.1.1 *Conversion of Grassland to Cropland*

Because much of the arable lands (lands capable of being used for row crops) have already been converted to cultivated agriculture, we do not expect future rates of conversion of grassland to cultivated agriculture to reach the level of conversion witnessed historically; however, conversion has continued to occur (Lark 2020, entire). Rates of future conversion of grasslands to cultivated agriculture in the analysis area will be affected by multiple variables including site-specific biotic and abiotic conditions as well as socioeconomic influences such as governmental agriculture programs, commodity prices, and the economic benefits of alternative land use practices.

For the purposes of this SSA, the Service conducted an analysis to project the future rates of conversion of grassland to cropland at three different levels. We used information from Lark (2020, entire) that aggregated remote sensing data from the USDA Cropland Data layer. We clipped this spatial data to only include information within our analysis area and calculated the annual net change in cropland within each of our ecoregions. The annual net change values were reduced to account for user accuracy associated with these data sets. We used the overall average annual conversion, the lowest two consecutive years of average net conversion, and the highest four consecutive year average net conversion to project intermediate, low and high levels of development, respectively (see Appendix C for additional details). Table 4.2 outlines the resulting three levels of projected habitat loss of future conversion of grassland to cultivated agriculture per ecoregion over the next 25 years for the purpose of this SSA.

Table 4.2 Future projection of three levels of impacted acres of potential usable area for the LEPC from conversion of grassland to cropland over the next 25 years in each ecoregion.

Ecoregion	**Projected Impacts (acres)**		
	Low	**Intermediate**	**High**
Short-Grass/CRP	89,675	145,940	185,418
Mixed-Grass	4,220	33,761	50,910
Sand Sagebrush	42,573	95,678	142,438
Shinnery Oak	21,985	51,410	93,946
Total	158,454	326,789	472,712

4.3.1.2 *Petroleum Production*

Given current trends in energy production, we anticipate that oil and gas production across the LEPC range will continue to occur and that rates will vary both temporally and spatially. The rates of development will be dependent upon new exploration, advancements in technology, and socioeconomic dynamics that will influence energy markets in the future.

For the purposes of this SSA, the Service conducted an analysis to project the future rates of petroleum production at three different levels. We compiled state well permitting spatial data from each state within each of the ecoregions. Based upon that information, we summarized the annual number of wells drilled per ecoregion from 2004–2019. Annual numbers were used to produce an average annual number of wells drilled per ecoregion for this 15-year period, which was used as our intermediate level. We then varied the average by one standard deviation to produce low and high levels for our projections. Next, we analyzed existing wells to determine the percentage of wells that would impact potential usable areas and used this information to reduce our three levels of development to only account for those wells, which were likely to impact potential usable areas. Annual number of wells projected to impact potential usable area at the three different levels were converted to a 25-year projection. Finally, we converted the projected number of new wells at the three levels to acres of usable area impacted[32]. Table 4.3 represents the extent of potential usable area impacted we project per ecoregion at the three levels of development per ecoregion over the next 25 years for the purposes of this SSA.

Table 4.3 Future projection of three levels of impacted acres (including both direct and indirect effects) of potential usable area for the LEPC from oil and gas development over the next 25 years in each ecoregion.

	Projected Impacts (acres)		
Ecoregion	**Low**	**Intermediate**	**High**
Short-Grass/CRP	26,848	54,618	82,388
Mixed-Grass	82,716	170,989	259,262
Sand Sagebrush	3,166	9,054	14,942
Shinnery Oak	136,539	190,144	243,749
Total	249,269	424,805	600,342

4.3.1.3 *Wind Energy Development and Transmission Lines*

As discussed in Section 3.3.1.2, the states in the LEPC analysis area have experienced some of the largest growth in wind energy development in the Nation. The entire estimated historical range of the LEPC occurs in areas determined to have average wind speeds exceeding what is necessary for large-scale wind energy development (21.3 ft/second, 6.5 m/second, at 262 ft, 80 m high) (Department of Energy [DOE] National Renewable Energy Laboratory 2010b, p. 1). In 2019, three of the five LEPC states, Colorado, New Mexico, and Kansas, were within the top 10 states nationally for fastest growing states for wind generation in the past year (AWEA 2020a, p.

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[32] This conversion accounts for the indirect impacts as well as potential overlap with other existing impacts. The result was that each new well impacts an estimated 38 ac (15.4 ha) of potential usable area. See appendix C for further detailed explanation.

33). Due to this high wind potential and recent history of wind energy development, we assume that wind energy developers will continue to be interested in new wind projects within the LEPC EOR.

The Southern Great Plains is a region of the United States with significant wind energy resources (AWEA 2016, p.12) that overlaps extensively with the LEPC EOR. Wind energy development in the region is a relatively recent occurrence, starting in the early 2000s, but it has increased as capacity of existing transmission lines have increased and as new transmission line projects are constructed. In light of global climate change influences from fossil fuel energy sources, there are positive benefits of transitioning the world's power generation to low-carbon sources to support climate change mitigation efforts. As with any development type, wind energy developments have the potential to result in site-specific negative direct and indirect effects to wildlife and their habitat. For wind energy, the amount of habitat loss and fragmentation that occurs is directly related to the location and size of the wind energy facility. The intersection of the amount of wind resource potential and increasing transmission capacity, coupled with increasing knowledge of the direct and indirect effects of all types of developments on grassland species, has elevated concerns of potential negative effects of large scale deployment of wind energy developments in the range of the LEPC.

Identification of the actual number of proposed wind energy projects that will be built within the range of the LEPC in any future timeframe is difficult to accurately discern. An analysis of current and potential future wind energy development was conducted by the Service for the purposes of this SSA, and the future development was estimated at three different levels within the analysis area of the LEPC at low, intermediate, and high levels (Appendix C). In general, to project the number of projects, we started with the annual installed capacity within the U.S. and reduced that to only account for the percentage of that capacity which occurs within the LEPC states, further reduced this to only account for the percentage that occurs within our analysis areas (broken out by ecoregion), and finally assumed the megawatts per average project (see appendix C for further detail). Table 4.4 represents the wind development projects projected at three levels of development per ecoregion.

Table 4.4 Projections of future wind energy development projects for the next 25 years at three levels in each LEPC ecoregion and range-wide.

	Projected Wind Developments		
Ecoregion	**Low**	**Intermediate**	**High**
Short-Grass/CRP	7	11	16
Mixed-Grass	10	18	25
Sand Sagebrush	1	2	3
Shinnery Oak	4	7	10
Total	22	38	54

As outlined within Section 3.3.1.2, wind energy development also has indirect impacts on the LEPC. To determine the number of acres impacted by wind energy development in the current condition, we analyzed wind energy facilities recently constructed within and near our analysis area. We applied a 5,900-ft (1,800-m) impact radius to individual turbines to account for indirect impacts and found that the last 5 years show a substantial increase in the relative density of wind energy projects, with the average area for 2003–2012 equaling 19,305 ac (7,813 ha) per project, while the 2014–2019 average area equaled 35,720 ac (14,450 ha) per project (see Appendix C for further details)[33]. This analysis does not mean that all of the impacts occur to otherwise usable LEPC land cover. Instead, it is highly unlikely that all projected impacts will occur in areas which are otherwise usable for the LEPC. Because we cannot predict the precise location of future developments and to simplify and facilitate modeling the locations for future projections for wind development, we created a potential wind energy development grid that was laid over the analysis area with each grid cell encompassing approximately 35,000 ac (14,200 ha), which is the average size of a wind facility as discussed above. The amount of LEPC suitable land cover occurring within any given grid was variable based on the location of the grid cell. Model runs used randomly selected wind development grid cells to project wind development to the future landscape (see Appendix B, Part 2, for additional explanation of the modeling methods and assumptions). The results of this random placement of future wind energy development within the grid we created is that the amount of potential usable land cover impacted depends on the amount of potential usable land cover in the affected grid cells. The resulting projected impacts in 25 years using the median iteration for each of the range of future scenarios (Scenarios 1 and 5, see Table 4.1) are shown in Table 4.5. The range-wide projections range from 66,400 ha (164,100 ac) to 133,000 ha (328,000 ac).

Table 4.5 Range of projections of future wind energy development impacts (including both direct and indirect effects) in acres for the next 25 years for Scenarios 1 and 5 each LEPC ecoregion and range-wide.

	Projected Wind Development Impacts (acres)	
Ecoregion	**Scenario 1**	**Scenario 5**
Short-Grass/CRP	68,300	134,200
Mixed-Grass	50,200	106,000
Sand Sagebrush	3,900	21,300
Shinnery Oak	41,700	66,500
Total	164,100	328,000

Electrical transmission capacity represents a major limitation on wind energy development in the Great Plains. Additional transmission lines will be required to transport future electricity production to markets; thus, we expect an expansion of the current transmission capacity in the Great Plains. As this expansion occurs, these transmission lines will, depending on their location, result in habitat loss as well as further fragmentation and could also be the catalyst for additional wind development affecting the LEPC. While we were able to analyze the current impacts of transmission lines on the LEPC, due to the lack of information available to project the

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[33] The State biologists that participated in the development of this SSA recommended that the Service consider adopting the impact radii outlined with the LEPC Range-Wide Conservation Plan (Van Pelt *et al.* 2013, p. 94). There was particular concern over the impact radius used for wind turbines because the difference between what is included as part of the Range-Wide Plan (667 m) is considerable smaller than what the Service used (1,800 m). To evaluate the implications of wind development impact radii, we conducted a sensitivity analysis to estimate the difference in the output of our spatial model using the smaller, 667 m impact radii. See Appendix B, Part 6 for further details and results of this analysis.

location (and thus effects to LEPC habitat), we could not quantify the future potential effect of habitat loss and fragmentation on the LEPC which could be caused by transmission line development. However, we do acknowledge potential habitat loss and fragmentation from transmission lines is likely to continue depending upon their location.

4.3.1.4 *Woody Vegetation Encroachment*

In Section 3.3.1.4, we outlined the effects of woody vegetation encroachment on habitat availability of the LEPC. Numerous studies have documented the continued increase in woody vegetation into grassland ecosystems (Ansley *et al.* 2001, pp. 172–176; Briggs *et al.* 2002a, pp. 578; Briggs *et al.* 2000b, p. 287; Asner *et al*. 2003, p. 323; Barger *et al*. 2011 p. 8; Wang *et al*. 2017 p. 241). Due to the past encroachment trends and continued suppression of fire across the range of the LEPC, we expect this encroachment of woody vegetation into grasslands to continue, which will result in further loss of LEPC habitat. The degree of future habitat impacts will depend on land management practices and the level of conservation efforts for woody vegetation removal.

To describe the potential future effects of encroachment of woody vegetation, we used available information regarding rates of increases in eastern red cedar and mesquite encroachment and applied this rate of change (over the next 25 years) to the amount of existing woody vegetation per ecoregion within the analysis area (Appendix C). The estimated current condition analysis described in Section 3.3.1.4 provides the baseline of woody vegetation encroachment, and rates derived from the literature were applied to this baseline to project new acres of encroachment. We then adjusted the projected number of new acres of encroachment using relative density calculations specific to each ecoregion to account for indirect effects. Additionally, due to assumed differences in encroachment rates and tree densities we provide two projections for each the Short-Grass/CRP and Mixed-Grass Ecoregions (East and West portions), largely based on current tree distribution and precipitation gradient. We projected the extent of expected habitat loss due to encroachment of woody vegetation at low, intermediate, and high levels of encroachment (see Appendix C for rationale behind assumed rates of change). Table 4.6 outlines the three levels of this projected habitat loss by ecoregion caused by future encroachment of woody vegetation over the next 25 years for the purpose of this SSA.

Table 4.6 Projection of impacts from woody vegetation encroachment (including both direct and indirect effects) at three levels at year 25 in the LEPC ecoregions.

	Projected Impacts (acres)		
Ecoregion	**Low**	**Intermediate**	**High**
Short-Grass/CRP - East	38,830	64,489	93,877
Short-Grass/CRP - West	1,390	3,598	5,963
Mixed-Grass - East	311,768	517,784	753,739
Mixed-Grass - West	874	2,261	3,748
Sand Sagebrush	7,650	12,706	18,496
Shinnery Oak	11,548	81,660	170,653
Total	372,060	682,498	1,046,476

4.3.1.5 *Roads and Electrical Distribution Lines*

As discussed in Section 3.3.1.5, roads and electrical distribution lines are another important source of habitat loss and fragmentation. In our current condition analysis, we were able to quantify the area affected by roads, but no data were available to quantify the potential independent impacts of distribution lines on habitat loss and fragmentation. We acknowledge that some additional habitat loss and fragmentation will occur in the future due to construction of new roads and power lines, but we do not have data available to inform projections on how much and where any potential new development would occur. Therefore, we did not quantify potential future habitat loss and fragmentation which could be caused by construction of new roads and power lines.

4.3.2 Climate Change

Future climate projections for this region of the United States indicate general trends of increasing temperatures and increasing precipitation extremes over the 21st century (Karl *et al.* 2009, pp. 123–128; Kunkel *et al.* 2013, pp. 73–75; Shafer *et al*. 2014, pp. 442–445; Easterling *et al.* 2017, pp. 216−222; Vose *et al.* 2017, pp. 194−199). The Fourth National Climate Assessment found the average temperature has already increased between the first half of the last century (1901–1960) and present day (1986–2016), with observed regional average temperatures within the Southern Great Plains[34] increasing by 0.4°C (0.8°F) and within the Southwest increasing 1.6°F (0.9°C) (Vose *et al.* 2017, p. 187). By mid-century (2036–2065), regional average temperatures compared to near-present times (1976–2005) are projected to increase by 3.6 to 4.6°F (2.0 to 2.6°C) in the Southern Great Plains, and by 3.7 to 4.8°F (2.1 to 2.7°C) in the Southwest, depending on future emissions projections. By late-century (2071–2100), regional average temperatures are projected to rise in the Southern Great Plans by 4.8°F to 8.4°F (2.7 to 4.7°C), and by 4.9 to 8.7 °F (2.7 to 4.8°C) in the Southwest (Vose *et al*. 2017, p. 197). Annual extreme temperatures are also consistently projected to rise faster than annual averages with future changes in "very rare" extremes increasing; by late century, current 1-in-20 year maximums are projected to occur every year, while current 1-in-20 year minimums are not expected to occur at all (Vose *et al*. 2017, pp. 197−198).

Projecting patterns of changes in average precipitation across these regions of the United States results in a range of increasing and decreasing precipitation with high uncertainty in overall averages, although parts of the Southwest are projected to receive less precipitation in the winter and spring (Easterling *et al.* 2017, pp. 216−218; Wuebbles *et al.* 2017, p. 12). However, extreme precipitation events are projected to increase in frequency in both the Southern Great Plains and the Southwest (Easterling *et al.* 2017, pp.218−221). Other extreme weather events such as heat waves and long duration droughts (Cook *et al.* 2016, entire), as well as heavy precipitation, are expected to become more frequent (Karl *et al*. 2009, pp. 124–125; Shafer *et al*. 2014, p. 445; Walsh *et al*. 2014, pp. 28–40). Seager *et al*. (2007, pp. 1181, 1183–1184) suggest that the devastating 'dust bowl' conditions of the 1930s could become more common in the American Southwest, with future droughts being much more extreme than most droughts on record. Other modeling also projects change in precipitation in North American through the end of this

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[34] For the National Climate Assessment, Southern Great Plains includes the states of Kansas, Oklahoma, and Texas; Southwest includes California, Nevada, Utah, Arizona, Colorado, and New Mexico (USGCRP 2017, p. 4).

century, including an increase in dry conditions throughout the Central Great Plains (Swain and Hayhoe 2015, entire). Further, the combination of increasing temperature and drought, referred to as "hot drought," results in greater impacts on various ecological conditions (e.g., water availability, soil moisture) than increased in temperature or drought alone (Luo *et al*. 2017, entire). The recent National Climate Assessment concludes that the human effect on droughts is complicated, and there is little evidence for a human influence on observed precipitation deficits (Wehner *et al.* 2017, p. 231). However, there is much evidence for a human influence on surface soil moisture deficits due to increased evapotranspiration caused by higher temperatures. In addition, future decreases in surface (top 4 in (10 cm)) soil moisture from anthropogenic forcing over most of the United States are likely as the climate warms under higher scenarios (Wehner *et al.* 2017, p. 231).

Grasslands are critically endangered globally and an irreplaceable ecoregion in North America, and climate change is an emerging threat to grassland birds (Wilsey *et al.* 2019). Grisham *et al.* (2016, entire) reviewed the potential effects of ongoing climate change on the Southern Great Plains and on the LEPC. Their analysis provides season by season projected changes in temperature and precipitation for each ecoregion in 2050 and 2080 (Grisham *et al.* 2016b, pp. 222−227). The results suggest increases in temperatures throughout the LEPC range and possible increases in average precipitation in the northern part of the range but decreasing precipitation in the southern portion of its range (Grisham *et al.* 2016b, pp. 222−227). Weather changes associated with climate change can have direct effects on the LEPC, leading to reduced survival of eggs, chicks, or adults, and indirect effects on LEPC are likely to occur through a variety of means including long-term (by mid and late twenty-first century) changes in grassland habitat. Other indirect effects may include more secondary causes such as increases in predation pressure or susceptibility to parasites or diseases. We have little information to describe future grassland conditions resulting from long-term climate changes, although warmer and drier conditions would most likely reduce overall habitat quality for LEPC in much of its range. In general, the vulnerability of LEPC to the effects of climate change depends on the degree to which it is susceptible to, and unable to cope with, adverse environmental changes due to long-term weather trends and more extreme weather events.

One area of vulnerability for the LEPC is the need for specific thermal profiles in the microhabitats they use for nesting and rearing of broods. Warmer air and surface soil temperatures and the related decreased soil moisture near nest sites have been correlated with lower survival and recruitment in the LEPC (Bell 2005, pp. 16, 21). On average, LEPC avoid sites for nesting that are hotter, drier, and more exposed to the wind (Patten *et al*. 2005a, p. 1275). Grisham *et al.* (2016c, p. 737) confirmed microclimate thresholds for nest survival across the species range and concluded that nest survival probability decreased by 10% every half-hour when temperature was great than 34°C (93.2°F) and vapor pressure deficit was less than -23 mmHg during the day. Grisham *et al*. (2013, p. 8) discuss thermal profiles from nests in some cases exceeding 54.4°C (130°F) and humidity below 10% at nests in Texas and New Mexico in 2011, which are beyond the threshold for nest survival. Boal *et al*. (2010, p. 4) suggests that increased temperatures in the late spring as projected by climate models may lead to egg death or nest abandonment of LEPC. Furthermore, the researchers suggest that if LEPC shift timing of reproduction (to later in the year) to compensate for lower precipitation, then impacts from higher summer temperatures could be exacerbated. A study which modelled the impacts of climate change on a variety of species of concern suggested that by 2070 (under Representative

Concentration Pathway (RCP) 8.5, high future carbon emissions) the LEPC could have a net loss of more than 50% of its range due to unsuitable climate variables (Salas *et al*. 2017, p. 370)[35]. In a study of greater prairie-chickens, Hovick *et al*. (2014b, p. 1-5) showed that heterogeneous grasslands have high thermal variability with a range of measured operative temperatures spanning 41 °F (23 °Celsius) with air temperatures >86 °F (30 °Celsius). In this setting, females selected nest sites that were as much as 14.4 °F (8 °Celsius) cooler than the surrounding landscape.

Although the entire LEPC range is likely to experience effects from ongoing climate changes, the southern portion of the range in the Shinnery Oak Ecoregion may be particularly vulnerable to warming and drying weather trends, as this portion of the range is already warmer and drier than northern portions and is projected to continue that trend (Grisham *et al*. 2013, entire; Grisham *et al.* 2016c, p. 742). Research in the Shinnery Oak Ecoregion relating projections in weather parameters in 2050 and 2080 to nest survival suggested with high certainty that the negative effects on future nest survival estimates are significant, and the resulting survival rates are too low for population sustainability in the Southern Great Plains in the absence of other offsetting influences (Grisham *et al*. 2013, pp. 6–7). As late spring and summer daily high temperatures rise, the ability for LEPC to find appropriate nest sites and successfully rear broods is expected to decline. Lower rates of successful reproduction and recruitment lead to further overall declines in population abundance and resiliency to withstand stochastic events such as extreme weather events.

Extreme weather effects such as drought, heat waves, and storms can also directly affect LEPC survival and reproduction and can result in population crashes due to species responses including direct mortality from thermal stress, increased predation due to larger foraging areas, or decreased fitness when food resources are scarce. Like other wildlife species in arid and semiarid grasslands, LEPC on the Southern High Plains have adaptations that increase resilience to extreme environments and fluctuating weather patterns; however, environmental conditions expected from climate change may be outside of their adaptive potential, particularly in the time frame weather changes are expected to occur (Fritts *et al.* 2018, p. 9556). Extreme weather events and periods of drying of soil surface moisture are projected to increase across the LEPC range (Easterling *et al.* 2017, pp. 218−222; Wehner *et al.* 2017, pp. 237−239). In Kansas, researchers used Bayesian hierarchical models to quantify the effects of extreme weather events on changes in abundance of LEPC counted during ground based surveys conducted between 1981 and 2014 (Ross *et al*. 2016a, entire). The findings indicate that extreme drought events in the summer had a significant impact on LEPC abundance recorded at leks; thus, they predicted increases in drought frequency and intensity could have negative consequences for the LEPC (Ross *et al*. 2016a, pp. 6–7). Recent efforts in Oklahoma to investigate the influence of seasonal weather patterns and climate on the LEPC using LEPC data collected from 1999 to 2009

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[35] There are important limitations to the application of this study; it did not consider other non-climatic variables that influence LEPC distribution, but only modeled temperature and precipitation. The results suggest range loss in the northern portion of the range where LEPC populations appear to currently be expanding, so the results are not consistent with current observations (Salas *et al*. 2017, p. 378–379).

suggests that even mild increases in drought had significant impacts on the likelihood of population extirpation (De Angelis 2017, p. 15).

Drought is a particularly important factor in considering LEPC population changes. LEPC is considered a "boom-bust" species, meaning that there is a high degree of annual variation in population size due to variation in rates of successful reproduction and recruitment. These variations are largely driven by seasonal precipitation patterns (Grisham *et al*. 2013, pp. 6–7). Periods of below normal precipitation and higher spring/summer temperatures result in less appropriate grassland vegetation cover and less food sources, resulting in decreased reproductive output (bust periods). Periods with favorable climatic conditions (above normal precipitation and cooler spring/summer temperatures) will support favorable LEPC habitat conditions and result in high reproductive success (boom periods). Fritts *et al*. (2018, pp. 9556–9557), using a 12-year population model, estimated the LEPC population failed to rebound for at least four years following the 2011 drought. This suggests the extreme environmental conditions during 2011 may have been beyond which the LEPC is adapted or that the return period following the 2008/2009 dry period, and ensuing low population numbers in 2010, was too short for the population to recover enough to be resilient to the 2011 drought. The resilience and resistance of species and ecosystems to changing environmental conditions depend on many circumstances (Fritts *et al.* 2018, entire). As climatic conditions shift to more frequent and intense drought cycles, this is expected to result in more frequent and extreme bust years for the LEPC and fewer boom years. As the frequency and intensity of droughts increase in the Southern Great Plains region, there will be diminishing opportunity for boom years with above-average precipitation. Overall, this may lessen the intensity of boom-and-bust LEPC population cycles in the future (Ross *et al.* 2018, entire). These changes will reduce the overall resiliency of LEPC populations and exacerbate the effects of habitat loss and fragmentation (as discussed in Section 3.3.1 above). Because LEPC carrying capacities have already been much reduced, if isolated populations are extirpated due to seasonal weather conditions, they cannot be repopulated due to the lack of nearby populations.

Although climate change is expected to alter the vegetation community across the LEPC range (Grisham *et al.* 2016b, pp. 228−231), we did not account for the future effects of climate change in our geospatial habitat model, as we did not have information to inform specific land cover changes predicted to result from future climate change. We acknowledge the increasing availability of literature and data that could possibly be used to support assessing changes to land use and land cover in the LEPC range related to socioeconomics, climate change and others (e.g., Drummond *et al*. 2012, entire; Sohl *et al*. 2012, entire; Sohl *et al*. 2016, entire). The structure and scope of our spatial habitat model did not provide opportunity for exploration of all possible factors potentially affecting future habitat conditions. We expect opportunities will exist for future analyses addressing these other factors.

The best available information supports that climate change projections of increased temperatures, increased precipitation extremes, increased soil drying, and an increase of severe events such as drought and storms within the Southern Great Plains are likely to have significant influences on the future resiliency of LEPC populations by mid to late 21st century. These trends are expected to exacerbate the challenges related to past and ongoing habitat loss and fragmentation, making it less likely for populations to withstand extreme weather events that are likely to increase in frequency and severity.

4.3.3 Other Factors

4.3.3.1 *Livestock Grazing*

We are relatively certain that grazing will continue to be a primary land use on the remaining areas of grassland within the range of the LEPC in the future, and grazing has the ability to drastically influence habitat suitability for the LEPC (Diffendorfer *et al*. 2015, p. 1). When managed to produce habitat conditions which are required by the LEPC, grazing is an invaluable tool for maintaining healthy prairie ecosystems. However, if grazing is managed in a way that is focused on maximizing short-term cattle production, resulting in rangeland that is over utilized, this could have significant negative effects on the LEPC. Grazing management varies both spatially and temporally across the landscape. Additionally, grazing management could become more difficult in the face of a changing climate with more frequent and intense droughts (as discussed in Section 4.3.2). Our geospatial model does not account for impacts to habitat quality and data do not exist to quantify range wide extent of grazing practices and their effects on habitat. We acknowledge livestock grazing will influence LEPC populations in the future.

4.3.3.2 *Shrub Control and Eradication*

The removal of native shrubs such as sand shinnery oak is an ongoing concern to LEPC habitat availability throughout large portions of the EOR, particularly in New Mexico, Oklahoma, and Texas. Suitable LEPC habitat historically included shrubs, and the permanently removal of shrubs may result in habitat that fails to meet the basic needs of the species, such as foraging, nesting, predator avoidance, and thermoregulation. In this portion of the range, nesting habitat primarily consists of low-growing shrubs and native grasses. In a few instances, herbicide use may aid in the restoration of LEPC habitat by allowing native grasses to increase where dense monocultures of sand shinnery oak exist.

While relatively wide scale shrub eradication has occurred in the past, we do not have geospatial data to evaluate the extent to which shrub eradication has contributed to habitat loss and fragmentation for the LEPC. While some Federal agencies such as BLM limit this practice in LEPC habitat, the practice still occurs through some Federal programs and on private lands. We do not have data available to project the potential scale of habitat loss likely to occur in the future due to shrub eradication.

4.3.3.3 *Hunting, and Other Recreational, Educational, and Scientific Use*

The LEPC is currently not hunted in any state, and thus we do not expect hunting to affect the LEPC in the future. Additionally, while other recreational, educational, and scientific uses have the potential to have some localized impacts, there is no evidence to suggest that these impacts will have a detectable effect on the LEPC population in the future as measured within this SSA.

4.3.3.4 *Collision Mortality from Fences*

As discussed in Section 3.3.3.4, mortality due to fence collision could have an impact on the LEPC but appears to be a function of fence density. Areas with lower fence densities (for example, New Mexico) likely have less of an impact than areas with higher fence densities (for example, Oklahoma). We do not expect fencing to have a major influence on LEPC populations in the future except for localized effects in areas with high densities of fences.

4.3.3.5 *Influence of Anthropogenic Noise*

While we expect anthropogenic noise to be an ongoing influence on the LEPC, information does not exist to allow us to explicitly quantify the effects of anthropogenic noise on the LEPC. Most noise within the range of the LEPC is caused by anthropogenic features; thus, through our accounting for the effects of those features, we may have also accounted for all or some of the response of the LEPC to the noise produced. However, no data currently exist to allow us to explicitly project the effects of anthropogenic noise on LEPC beyond the implications that are likely accounted for by the inclusion of the influence of the features included in this analysis.

4.3.3.6 *Predation*

Predation is a natural part of wildlife population dynamics and usually only becomes a concern when predation rates become elevated above natural levels. Predation on LEPC is primarily tied to habitat quality; thus, the factors in this report which we discuss that are likely to influence habitat quality or influence predators in a way that increases predation risk for the LEPC could have an influence on the LEPC in the future. For the purposes of this SSA, we do not quantify any of these potential future effects and acknowledge that this could influence the LEPC in the future.

4.3.3.7 *Parasites and Diseases*

Currently, no information exists to support parasites or diseases playing a significant role in the population trends for the LEPC. As populations decrease in size due to other factors, the risk of parasites or disease becoming more of an influence in LEPC population trends is increased.

4.3.3.8 *Fire*

The current lack of prescribed fire use in the range of the LEPC is contributing to woody plant encroachment and degradation of grassland quality due to its decoupling from the grazing and fire interaction that is the foundation for plant community diversity in structure and composition, which in turn supports the diverse habitat needs of LEPC. Evidence suggests that these cascading effects are contributing to greater wildfire risk, and concerns exist regarding the changing patterns of wildfires (scale, intensity, and frequency) and their consequences for remaining LEPC populations and habitat that are increasingly fragmented. As the effects of fire suppression continue to manifest throughout the Great Plains, the future impacts of wildfires on the LEPC are difficult to predict. If recent patterns continue with wildfires occurring at increasingly larger scales with less frequency and higher intensities than historical fire occurrence, there is an increasing potential of greater negative impacts on LEPC. Additionally, as climate change projections are indicating the possibility of longer and more severe droughts across the range of the LEPC, this could alter the vegetation response to fire both temporally and spatially. A vigorous and expansive adoption of prescribed fire in management of remaining grasslands would be expected to have a moderating effect on risk of wildfires, and concurrently reduce woody plant encroachment and increase habitat quality and diversity. We are not able to quantify these impacts on the future condition of the landscape in our analysis, but we acknowledge that fire (both prescribed fires and wildfire), or its absence, will continue to be an ecological driver across the range of the LEPC in the future with potentially positive and negative effects across both short-term and long-term timelines.

4.3.3.9 *Insecticides*

Since we currently have no information that insecticides are influencing LEPC populations, we did not attempt to predict any future effects of insecticides.

4.3.3.10 *Nest Parasitism and Competition from Exotic Species*

While ring-necked pheasants have been documented to parasitize nest of the LEPC and to disrupt breeding behavior, these occurrences have only been documented to occur at low rates which may have localized impacts. These impacts are likely the greatest in areas which are fragmented and support high densities of ring-necked pheasants. Because the LEPC largely select for intact landscapes we do not expect nest parasitism and breeding disruption from ring-necked pheasants to result in ecoregional or range-wide population level effects to viability.

4.4 Future Conservation Efforts

4.4.1 Ongoing Conservation Efforts

As discussed in Section 3.4, there are multiple ongoing conservation efforts benefiting the LEPC including the RWP, the LPCI, CCAAs, and other Federal and State programs. Below, we will quantify the potential benefits of those programs for the LEPC in the future. To be explicit and quantitative in characterizing the potential future conservation benefits of the various conservation efforts, we worked with the primary conservation entities delivering LEPC conservation programs to develop estimated plausible rates of future conservation efforts. We asked the entities to provide us with information to project three levels of conservation: low, continuation, and high. We asked that the conservation entities not to provide aspirational goals for a given program but to instead use past performance, funding expectations, and expert opinion to provide rates for given conservation practices. We then used this information to estimate future conservation efforts over the next 25 years for the LEPC.

We characterize two general types of conservation efforts. The first are restoration efforts, which are those actions which convert otherwise non-usable area for the LEPC to usable space (examples: conversion of cropland to grassland, removal of energy infrastructure, and removal of woody vegetation). The second are enhancement efforts, which are those actions intended to maintain or enhance the quality of existing LEPC habitat (example: grazing management, prescribed fire, and inter-seeding) (Figure 4.1). For restoration efforts, we incorporated the outcome of those efforts into our geospatial model to characterize the future condition as discussed in Section 4.2. Because data are unavailable at the appropriate scale and resolution to evaluate habitat quality range wide for the LEPC (vegetative structure and composition), our geospatial analysis does not incorporate habitat quality. As a result, habitat enhancement efforts are not included in the spatial model, but they are summarized below and are considered as part of the overall assessment. For additional details regarding the assumptions, specifics for each program, spatial targeting, and the process for the projection of conservation efforts, please see Appendix C. Below we characterize future conservation efforts resulting from restoration and enhancement actions.

4.4.1.1 *Future Restoration Efforts (All Programs)*

For the purpose of this analysis, we define a restoration effort as those actions which will convert non-usable area to space which is suitable LEPC habitat. In general, for the LEPC there are three primary conservation activities occurring on the landscape that we consider restoration. Those are converting cultivated agriculture to grasslands, removal of energy infrastructure, and removal of woody vegetation encroachment (Figure 4.1). We asked our conservation partners to provide us with plausible rates for conservation efforts occurring within the analysis area of the LEPC by ecoregion[36]. Next, we converted those rates for each program to the total effort at year 25 and combined the efforts from all programs to give us the total conservation effort for each action. Table 4.7 summarizes the three levels of projected future restoration efforts over the next 25 years for each ecoregion.

Table 4.7 Projected changes in land cover (in acres) from restoration efforts over the next 25 years within the LEPC ecoregions.

Restoration Efforts	**Level of Future Effort (Acres)**		
	Low	**Continuation**	**High**
Short-Grass/CRP Ecoregion			
Conversion of Agriculture to Grassland	0	2,500	10,500
Removal of Energy Infrastructure	0	2,500	3,750
Removal of Woody Vegetation	0	98,820	154,818
Mixed-Grass Ecoregion			
Conversion of Agriculture to Grassland	1,269	11,075	23,575
Removal of Energy Infrastructure	0	450	676
Removal of Woody Vegetation	99,103	193,213	406,079
Sand Sagebrush Ecoregion			
Conversion of Agriculture to Grassland	0	10,000	20,500
Removal of Energy Infrastructure	0	550	826
Removal of Woody Vegetation	0	0	1,128
Shinnery Oak			
Conversion of Agriculture to Grassland	0	0	366
Removal of Energy Infrastructure	1,646	51,298	122,898
Removal of Woody Vegetation	65,824	135,803	275,928

4.4.1.2 *Future Enhancement Efforts (All Programs)*

There are several enhancement actions for LEPC being implemented across the analysis area. We asked our conservation partners to provide us with a range of plausible rates for conservation efforts occurring within the LEPC analysis area by ecoregion[37]. Next, we converted those rates for each program and conservation effort to the total effort at year 25. Table 4.8 summarizes the

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[36] Additionally, we requested information regarding spatial targeting of conservation efforts, project life span, and effectiveness. Please refer to Appendix C, Section C.2, for additional details.

[37] We also requested information regarding effectiveness, project life span, and spatial targeting of these efforts. Please refer to Appendix C, Section C.3.4 for additional details.

three projected levels of future habitat enhancement over the next 25 years for each ecoregion. These efforts only represent those above and beyond what is already accounted for within the current condition discussion within Chapter 3. Efforts already reported within Chapter 3 of the report which we had reasonable certainty would continue into the future are not included within this table. Acreage enrolled in CCAAs are assumed to continue to be enrolled in the future, and CCAA projections within this table represent enrollments in addition to existing enrollments. This table also does not include continued management actions on permanently protected properties (such as State-owned wildlife management areas or conservation banks), as it is assumed this management will continue. Additionally, the numbers reported for NRCS grazing plans are acres in addition to the number of acres reported in Section 3.4 that are being managed under prescribed grazing for the LEPC by NRCS, as we assume that as contract acres expire from the program additional acres will be enrolled. While we were not able to explicitly project this, several conservation entities communicated that the ultimate ESA listing decision will have implications on future enrollment; specifically, some conservation entities said they would expect a decrease in enrollment should the LEPC not be listed.

The actual conservation benefit provided to the LEPC by these programs varies greatly and is difficult to summarize because it depends on the location and the specific actions being carried out for each individual agreement. In addition, the level of future voluntary participation in these programs can be highly variable depending on available funding, opportunities for other revenue sources, and many other circumstances.

Table 4.8 Projected amount of habitat enhancement (in acres) over the next 25 years within the four lesser prairie-chicken ecoregions.

	Total Level of Future Effort (Acres) at Year 25		
Enhancement Efforts	**Low**	**Continuation**	**High**
Short-Grass/CRP Ecoregion			
KDWP Enhancement Contract	0	6740	17,500
NRCS LPCI Grazing Plan	0	0	4,000
USFWS PFW Contract	14,000	14,000	20,000
Mixed-Grass Ecoregion			
WAFWA Management Plan	0	0	118,245
KDWP Enhancement Contract	0	120	3,100
ODWC Management	1,400	3,300	6,400
ODWC Additional CCAA Enrollment	0	50,000	100,000
NRCS LPCI Grazing Plan	0	0	58,000
USFWS PFW Contract	50,000	50,000	70,000
TPWD Additional CCAA Enrollment	0	0	50,000
Sand Sagebrush Ecoregion			
KDWP Enhancement Contract	0	720	4,400
CPW Enhancement Contract	0	12,200	37,900
NRCS LPCI Grazing Plan	0	0	13,000
USFWS PFW Contract	0	6,000	18,000
Shinnery Oak Ecoregion			
WAFWA Management Plan	0	0	8,129
NRCS LPCI Grazing Plan	0	0	39,000
BLM Prescribed Fire	0	25,000	100,000
NM CCA/A Prescribed Fire	50,000	100,000	150,000
USFWS PFW Contract	5,000	15,000	50,000
TPWD Additional CCAA Enrollment	0	0	60,000

4.4.1.3 *Conservation Reserve Program*

As discussed in Section 3.4.1.2, the benefits of the CRP vary regionally but are important to the conservation of the LEPC, especially in the Short-Grass/CRP Ecoregion. Predicting changes to the CRP is difficult because of the many aspects of the program that affect participation, including changes to maximum enrolled acres, changes to scoring factors in the Environmental Benefit Index, commodity price fluctuations, and others. For the purposes of our geospatial model, we assume no net change in acreage enrolled in the CRP within the analysis area over the next 25 years. We acknowledge that given the historical trends of CRP acreage caps, realistically the number of CRP acres could remain constant with current levels or decrease as compared against current levels[38]. Dahlgren *et al.* (2016, p. 273) concluded that if LEPC depends on CRP lands in the Short-Grass/CRP Ecoregion, then the habitat availability is in a precarious situation because more than half of all LEPC are in this ecoregion and depend on CRP lands, which is a relatively short-term (10–15 years) program subject to political support and dynamic commodity prices. As outlined within Section 3.4.1.2, CRP acreage enrollment within the counties intersecting the LEPC range have continually declined over the past decade. If CRP enrollment decreases in the future, some of these lands will likely be converted to other land uses including cultivated agriculture.

4.4.2 Other Potential Future Conservation Efforts

The Service has been working with various parties on the development of potential planning efforts that could result in conservation benefits for the LEPC. These efforts include Habitat Conservation Plans, CCAAs, and conservation banks. While these efforts have the potential to result in benefits to the LEPC, there is a significant level of uncertainty regarding whether these efforts will be completed and if so the level of benefit to the LEPC is highly dependent upon the final terms specific to each effort. Because of this uncertainty, these potential future efforts were not factored into our analysis.

4.5 Projected Future Habitat and Abundance

4.5.1 Habitat Projections under Future Scenarios

To forecast the potential changes in future LEPC habitat, we used the projected levels of potential future impacts from conversion to cropland (Section 4.3.1.1), petroleum production (Section 4.3.1.2), wind energy development (Section 4.3.1.3), and woody vegetation encroachment (Section 4.3.1.5), and the potential future habitat restoration efforts (Section 4.4.1). The results of this future geospatial model (described in Section 4.2 and Appendices B and C) using the median simulation output is provided in Table 4.8. Maps showing the simulated configurations of median projections for three of the scenarios (Scenarios 1, 3, and 5)) are shown as examples of spatial results in Appendix E, Figures E.8–E.11. The median results show a very modest increase in areas with 60% or greater potential usable unimpacted land cover under Scenario 1 (assuming high levels of restoration and low levels of impacts) (with an increase for the Shinnery Oak Ecoregion and a decrease for the other three ecoregions) and decreasing amounts of projected declines in areas with 60% or greater potential usable unimpacted land cover under Scenarios 2-5 (Table 4.9). Range-wide changes in areas with 60% or greater potential usable unimpacted land cover range from a 0.5% increase under Scenario 1 to a 26% decrease in Scenario 5. The variance of the geospatial model results within each scenario for the 20 iterations was quite small and is shown in Appendix E, Figure E.12.

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[38] The CRP is funded through the Farm Bill and thus the future benefit provided by the CRP is dependent upon congressional direction and appropriations to that program. Therefore, the future benefits provided by CRP over the next 25 years are dependent upon specifics of future Farm Bills.

Table 4.9 Projected future median acreage of LEPC areas with 60% or greater potential usable unimpacted land cover within one mi (1.6 km) in acres, and showing percent change in acreage from estimated current areas with 60% or greater potential usable unimpacted land cover within one mile (1.6 km), in 25 years.

Ecoregion	(All Results in Acres) Total Area	Current Condition	Scenario 1 Low Impacts High Restoration		Scenario 2 Low Impacts Continuation Restoration		Scenario 3 Moderate Impacts Continuation Restoration		Scenario 4 High Impacts Continuation Restoration		Scenario 5 High Impacts Low Restoration	
			Median	% Change	Median	% Change	Median	% Change	Median	% Change	Median	% Change
Short-Grass/CRP	6,298,014	1,023,894	975,047	**-4.8%**	956,190	**-6.6%**	877,663	**-14.3%**	808,152	**-21.1%**	776,111	**-24.2%**
Mixed-Grass	8,527,718	994,483	974,200	**-2.0%**	864,780	**-13.0%**	742,855	**-25.3%**	649,227	**-34.7%**	630,633	**-36.6%**
Sand Sagebrush	3,153,420	1,028,523	992,632	**-3.5%**	980,302	**-4.7%**	932,477	**-9.3%**	887,224	**-13.7%**	884,851	**-14.0%**
Shinnery Oak	3,850,209	1,023,572	1,149,759	**12.3%**	988,072	**-3.5%**	868,761	**-15.1%**	771,923	**-24.6%**	711,933	**-30.4%**
Range-wide Totals	**21,829,361**	**4,070,473**	**4,091,638**	**0.5%**	**3,789,343**	**-6.9%**	**3,421,756**	**-15.9%**	**3,116,525**	**-23.4%**	**3,003,529**	**-26.2%**

To estimate the projected size of connected blocks of usable area, we evaluated the frequency of occurrence of blocks of various sizes[39]. Figure 4.2 shows that the vast majority of the blocks and the total area within those blocks, both in the current condition and in future scenarios, are less than 12,000 ac (4,856 ha), and very few blocks were greater than 50,000 ac (20,234 ha). The dominance of smaller blocks on the landscape further exhibits that those spaces are highly fragmented, even with the remaining potential usable area for the LEPC totaling approximately 4,000,000 ac (1,600,000 ha) in the current condition, and potentially declining to as low as 3,000,000 ac (1,200,000 ha) under scenario 5 for our future condition projections. High levels of fragmentation, as discussed in Section 3.3.1, do not provide the landscape composition needed for long-term stability of populations. Additionally, in spaces that are highly fragmented, relatively small amounts of additional impacts may have great consequences as landscape composition thresholds for the LEPC are surpassed.

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[39] Note these categories chosen were largely based upon discussions regarding the LEPC required space to support individuals from a single lek as being 12,000 – 50,000 acres. We caution readers to not focus on the absolute values selected for the categories but instead the larger picture of how many acres for each ecoregion consist of smaller vs. larger blocks as an additional relative scale of fragmentation.

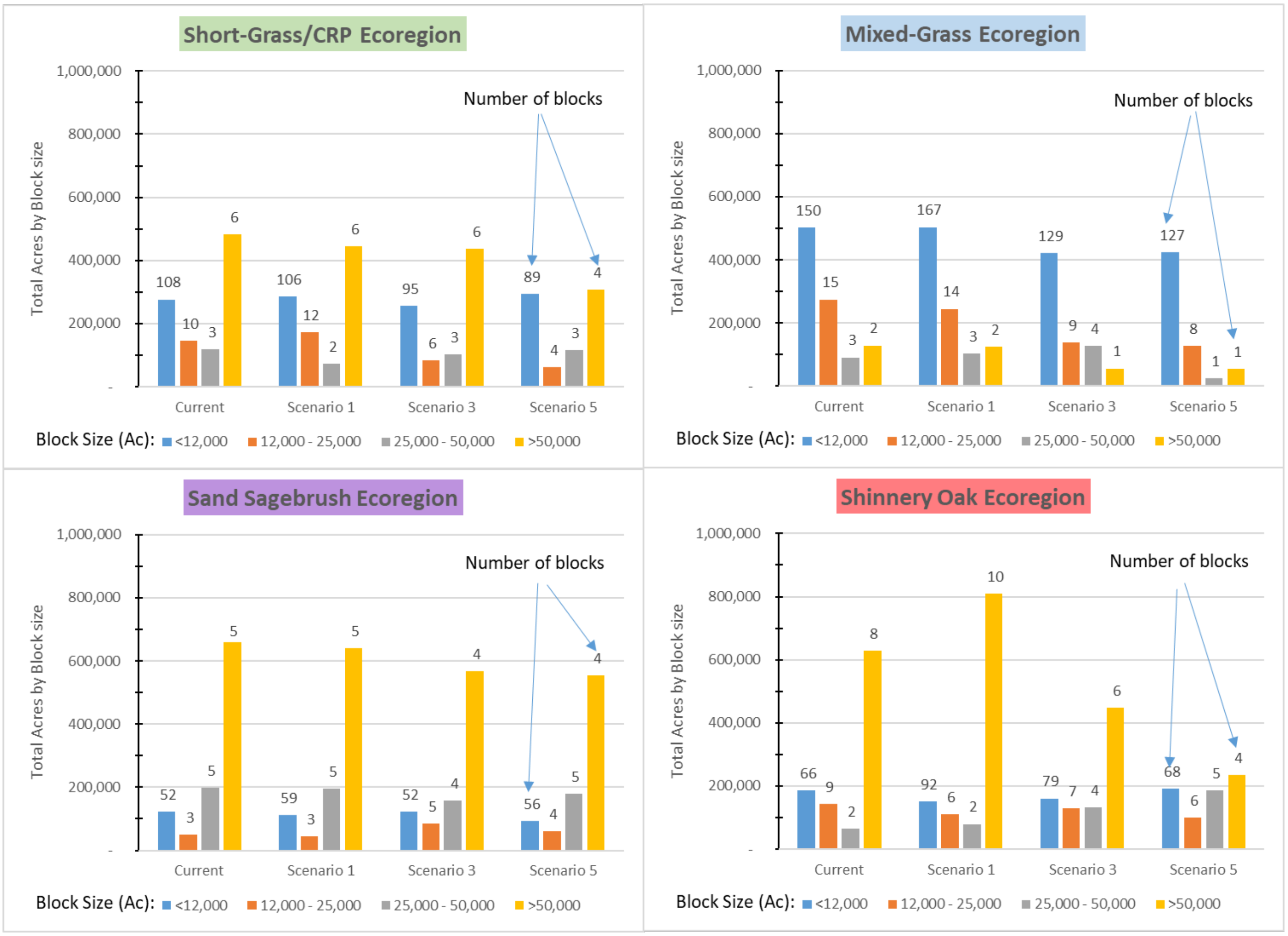

Figure 4.2 Graphs showing the total cumulative acreage of estimated LEPC usable area by block size for the current and projected future conditions (Scenarios 1, 3, and 5). These results are from the geospatial analysis and model. Block sizes were grouped into bins of less than 12,000 ac, 12,000–25,000 ac, 25,000–50,000 ac, and greater than 50,000 ac. Histogram labels indicate the number of usable blocks occurring in each bin.

4.5.2 Future Population Projections

4.5.2.1 *Population Growth Models*

There have been several estimates of LEPC population growth rates based on current conditions for the LEPC, with most derived from demographic matrix models (Fields 2004, pp. 76–83; Hagen *et al*. 2009, entire; Sullins 2017, entire; Cummings *et al.* 2017, entire). The magnitude of actual future declines is unlikely to be as low as some modeling tools indicate; however, most studies suggest declining LEPC populations (Table 4.10). Positive population growth calculations were derived from 2014–2016 (Hagen *et al.* 2017, Supplemental Information; Table 4.10), where estimates indicated populations have increased[40]. Results of population estimates from aerial surveys over the past 10 years have indicated a range-wide fluctuating population beginning with an estimated 28,366 (90% CI: 17,055–40,581) individuals in 2012 to an estimated 30,461 (90% CI: 20,137–41,923) individuals in 2021. Included within this timeframe was a population low of 15,397 (90% CI: 8,145–22,406) individuals in 2013[41].

Table 4.10 Recent LEPC median population growth rate estimates (± standard error) in each ecoregion from multiple sources (adapted from Cummings *et al*. 2017, p. 20). Rates less than 1.0 indicate decreasing population trends, and rates greater than 1.0 (underlined) indicate increasing population trends.

	LEPC Ecoregion			
Information Sources	**Short-Grass**	**Sand Sagebrush**	**Mixed-Grass**	**Shinnery Oak**
Cummings *et al*. 2017, p. 20	0.37 ±0.29	0.69 ±0.24	0.63 ±0.16	0.51 ±0.11
Published matrix models	0.61 (Fields 2004, p. 87) 0.58 ±0.13 (Sullins 2017, p. 57)	0.54 ±0.14 (Hagen *et al*. 2009, p. 1328) 0.74 ±0.19 (Hagen *et al*. 2009, p. 1328) 0.79 ±0.17 (Sullins 2017, p. 57)	0.83 ±0.11 (Sullins 2017, p. 57) 0.79 ±0.13 (Sullins 2017, p. 57)	NA
Lek counts:				
2005-2012, Garton *et al*. 2016, pp. 61–67	1.02 ±0.10	0.88 ±0.10	0.83 ±0.12	0.94 ±0.13
2010-2013, Hagen *et al. 2017,* Supp Info	0.78 ±0.07	0.61 ±0.11	0.76 ±0.44	0.65 ±0.12
2014-2016, Hagen *et al*. 2017, Supp Info	1.07 ±0.33	0.93 ±0.41	1.30 ±0.15	1.35 ±0.92

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[40] We caution that any analysis using growth rates based upon short-term data sets can be problematic as they are very sensitive to the starting and ending points in the estimates. Additionally, these growth rates are accompanied by relatively large margins of error as indicated in the table.

[41] The Service cautions drawing inferences from point estimates based upon these data due to low detection probabilities of the species leading to large confidence intervals. We also caution that trend analyses from short-term data sets are highly sensitive to starting and end population sizes. For example, if you use 2012 as the starting point for a trend analysis it may appear that populations are relatively stable to slightly increasing, but during the years of 2010–2013, the range of the LEPC experienced a severe drought and thus LEPC populations were at historic lows. If the data existed to perform the same analysis using the starting point as 2009, then the results would be very different.

4.5.2.2 *Other viability analysis*

The future risk of extinction of the LEPC has been conducted using historical ground surveys. This analysis used the results of those surveys to project the risk of LEPC quasi-extinction[42] in each of the four ecoregions and range-wide over two time frames, 30 and 100 years into the future. The initial analysis using data collected through 2012 was reported in Garton *et al.* (2016, pp. 60–73), but it has since been updated to include data collected through 2016 (Hagen *et al.* 2017, entire)[43]. Results were reported for each analysis assuming each ecoregion is functioning as an independent population (Table 4.11) and also assuming there is movement of individuals between populations (Table 4.12). The results suggest a wide range of risks among the ecoregions, but the Sand Sagebrush Ecoregion consistently had the highest risks of quasi-extinction, and the Short-Grass/CRP Ecoregion had the lowest. Hagen *et al.* (2017, pp. 10−14) also compared the results of quasi-extinction probability with the early results from data collected through 2012 (Garten *et al.* 2016, pp. 60−73) and found that three of four ecoregions (and range-wide) had a reduced probability of quasi-extinction in the short-term and two of four (and range-wide) in the long-term. This indicates that the probability of persistence had improved following an extreme drought in 2011–2012. These analyses were based only on simulating demographic variability of populations and did not incorporate changing environmental conditions related to habitat or climate.

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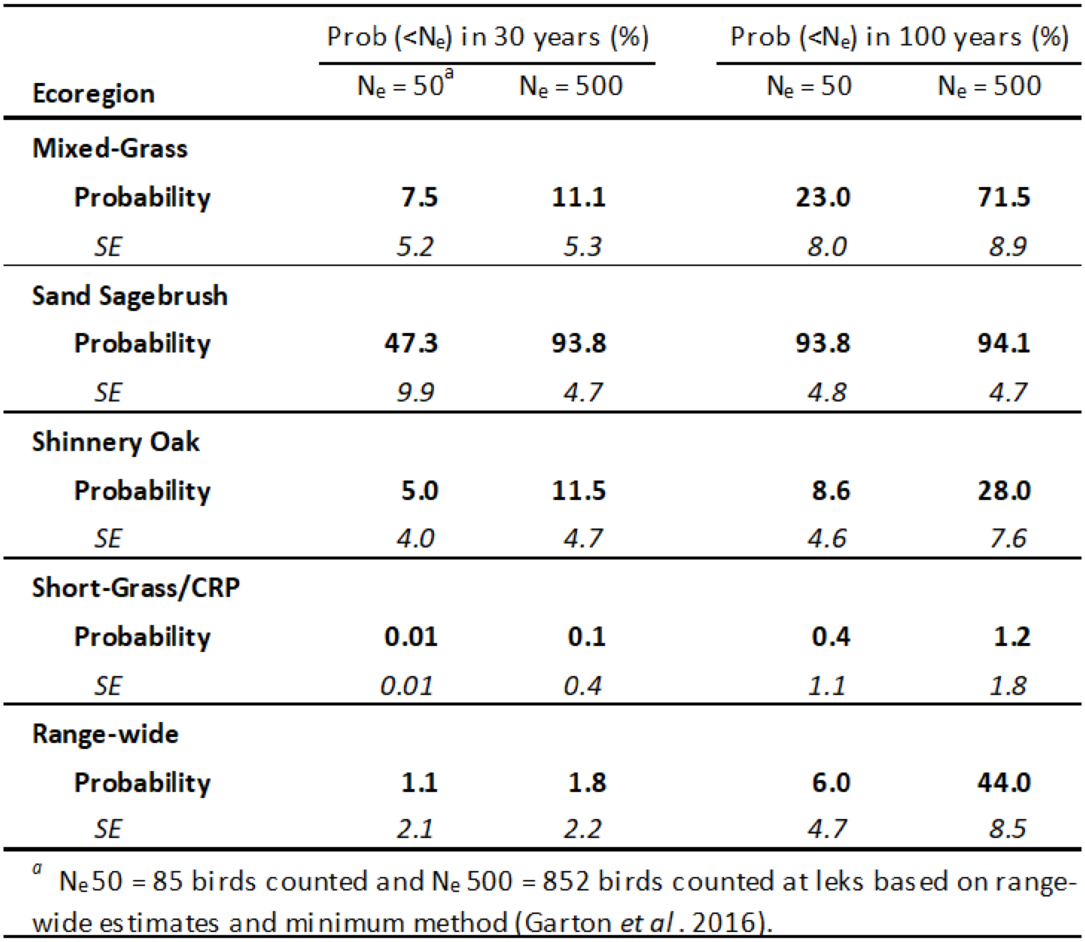
[42] For this analysis, quasi-extinction was set at effective population sizes (demographic N_e) of 50 (populations at short-term extinction risk) and 500 (populations at long-term extinction risk) adult breeding birds, corresponding to an index based on minimum males counted at leks of ≤ 85 and ≤ 852, respectively (Garton *et al. 2016, pp. 59–60)*.

[43] The Service has identified concerns in the past with some of the methodologies and assumptions made in this analysis, and the challenges of these data are noted in Zavaleta and Haukos (2013, p. 545) and Cummings *et al.* (2017, pp. 29–30). While these concerns remain, this work represents one of the few attempts to project risk to the species across its range, and we present it here as part of our overall analysis and recognize any limitations associated with the analysis.

Table 4.11 Multimodel forecasts of probability (weighted mean percentage and standard error, SE) of number of birds attending leks counted in four ecoregions and the range-wide population of lesser prairie-chickens declining to abundances below quasi-extinction levels representing N_e (effective population size) = 50 and N^e = 500 total breeding adults within 30 or 100 years. Reproduced from Hagen *et al.* 2017, p. 630.



	Prob (<N_e) in 30 years (%)		Prob (<N_e) in 100 years (%)	
Ecoregion	N_e = 50[a]	N_e = 500	N_e = 50	N_e = 500
Mixed-Grass				
Probability	**7.5**	**11.1**	**23.0**	**71.5**
SE	*5.2*	*5.3*	*8.0*	*8.9*
Sand Sagebrush				
Probability	**47.3**	**93.8**	**93.8**	**94.1**
SE	*9.9*	*4.7*	*4.8*	*4.7*
Shinnery Oak				
Probability	**5.0**	**11.5**	**8.6**	**28.0**
SE	*4.0*	*4.7*	*4.6*	*7.6*
Short-Grass/CRP				
Probability	**0.01**	**0.1**	**0.4**	**1.2**
SE	*0.01*	*0.4*	*1.1*	*1.8*
Range-wide				
Probability	**1.1**	**1.8**	**6.0**	**44.0**
SE	*2.1*	*2.2*	*4.7*	*8.5*

[a] N_e50 = 85 birds counted and N_e500 = 852 birds counted at leks based on range-wide estimates and minimum method (Garton *et al*. 2016).

Table 4.12 Metapopulation forecasts of probability of number of birds counted attending four sub-populations and the range-wide population of lesser prairie-chickens declining to abundances below quasi-extinction levels (probability and standard error, SE) representing N_e (effective population size) = 50 and N_e = 500 total breeding adults within 30 or 100 years under the best Gompertz density-dependent models with carrying capacities declining through time and correlated rates of change amongst sub-populations (reproduced from Hagen *et al.* 2017, Table 10).

	Prob (<N_e) in 30 years (%)		Prob (<N_e) in 100 years (%)	
Ecoregion	$N_e = 50^a$	$N_e = 500$	$N_e = 50$	$N_e = 500$
Mixed-Grass				
Probability	**3.4**	**23.1**	**32.7**	**100**
SE	*0.1*	*0.2*	*0.3*	*0*
Sand Sagebrush				
Probability	**47.3**	**100**	**100**	**100**
SE	*0.1*	*0*	*0*	*0*
Shinnery Oak				
Probability	**0.2**	**15.8**	**24.5**	**99.9**
SE	*0.1*	*0.3*	*0.1*	*0.1*
Short-Grass/CRP				
Probability	**0.00**	**0**	**24.7**	**88.4**
SE	*0.00*	*0.0*	*0.1*	*0.6*
Range-wide				
Probability	**0.0**	**0.9**	**24.5**	**24.8**
SE	*0.0*	*0*	*0.1*	*0.1*

[a] $N_e 50$ = 85 birds counted and $N_e 500$ = 852 birds counted at leks based on range-wide estimates and minimum method (Garton *et al*. 2016).

5. CONCLUSIONS: VIABILITY AND SPECIES RISK

Throughout the process of conducting this analysis, the Service and our partners discussed many limitations and assumptions associated with this assessment, including inherent uncertainty and accuracy issues associated with spatial data, spatial analysis methods, and future population projections (which are further discussed throughout the document). We draw the following conclusions based upon analyzing the best available information with all of the uncertainty and limitations in mind. The LEPC depends on large continuous expanses of grasslands of the Southern Great Plains to complete its life history and to maintain healthy populations. Over the past century and a half, the Great Plains ecosystems have been greatly altered by human land use practices, primarily for agriculture and energy development. The vast majority of the LEPC range occurs on private lands and public lands that are available for energy development. These land uses resulted in either the direct loss of grassland habitat (largely through conversion to croplands and land development), the indirect loss of grassland habitat (largely through construction of infrastructure for petroleum and wind energy development, roads, power lines and invasion of woody species—all of which the LEPC will avoid), or by degradation of habitat quality due to incompatible grazing or other land management practices. The results of these changes have made the current distribution and abundance of the LEPC much reduced from historical conditions. The remnant grassland has been reduced in both quantity and quality and has been fragmented such that limited appropriate spaces remain to support healthy LEPC populations. The remaining four ecoregions contains a small fraction of the likely overall historical LEPC habitat on the order of 10 to 20% of historical range. And the range-wide abundance of the LEPC has declined from estimates in the hundreds of thousands of birds (or even millions) to most recent 5-year average estimate of about 30,000 birds (90% confidence intervals around estimates over the last 5 years range from 9,000 to 60,000 birds).

In our assessment of the viability of the LEPC, we characterize the biological status of the species in terms of the representation, redundancy, and resiliency, so that we can consider its risk of extinction and, in contrast, its ability to maintain populations into the future. We structured our analysis geographically around the four ecoregions to account for representation, which considers within-species diversity and future adaptive capacity, and redundancy, which considers spreading populations out within ecoregions to reduce the risk of loss of any ecoregions due to catastrophic events. The viability of the LEPC over the next 25 years will primarily depend on the future habitat availability within each of the four ecoregions with the implications of climate change and the quality of existing habitat also impacting the species. Given the already reduced range of the species, an evaluation of the resiliency of populations (ability to withstand stochastic events) within these four ecoregions takes into account the already reduced species' range and associated reduction in redundancy and representation compared to historical conditions.

We used a geospatial analysis of land cover as a basis from which to assess future changes in the amount of potential usable area that could support LEPC populations. We explicitly projected changes in potential usable area over the next 25 years by forecasting both future impacts on habitat and future restoration of habitat. The results (Table 4.9) suggest that, in all but the most optimistic future scenario, future impacts outpace future habitat restoration with range-wide changes as high as a 26% reduction in available habitat in 25 years[44].

One important aspect of LEPC habitat we were not able to explicitly evaluate is the habitat quality of the remaining or future projected grasslands. As the quality of the grassland improves with appropriate vegetative structure to support the life history needs of the species, areas can support higher densities of LEPC. Conversely, as weather and management impact grassland quality in a negative manner, the remaining blocks of LEPC habitat will support lower densities of LEPC. Many conservation efforts have been undertaken in recent years to encourage and incentivize private landowners managing rangeland to promote increased quality of grassland conditions that will be favorable to LEPC populations. The projected future scope for a variety of these land practices is quantified in Table 4.8. Maximizing habitat quality on relatively small areas can potentially temporarily increase the size of local LEPC populations; however, the long term persistence of the LEPC is dependent upon having large blocks of available habitat that are connected to other large habitat blocks to allow them to be sustainable through stochastic events such as drought. The degree to which these habitat enhancement efforts can offset the ongoing loss in overall amount of habitat and ongoing habitat fragmentation is dependent upon several factors. The results from most of these efforts are expected to be temporary, depending on future management, and limited to relatively localized, short-duration increases in bird densities without concomitant efforts for larger-scale habitat restoration. As discussed by Fuhlendorf *et al*. (2017b, pp. 12–13), the benefits of conservation efforts focused on altering site-specific habitat quality for prairie grouse is constrained by higher-level processes of habitat loss and fragmentation. Concentrating conservation efforts on localized management to affect habitat quality, while not addressing the overarching limiting factor of habitat loss and fragmentation, is not addressing the long-term population needs for the LEPC. Therefore, as the amount of habitat decreases and habitat fragmentation increases in the future, the number of LEPC that can be supported by the ecoregions will also decrease. This decline in habitat availability results in long-term population declines with population peaks during years with above average annual precipitation being lower and population lows in following years of poor precipitation continuing to decrease.

Another future influence on LEPC habitat and populations not expressly included in our geospatial model is the effect of future climate change. All of the current climate models and research suggest that the expected environmental changes over the next 30 to 80 years associated with future global climate change are likely to have mostly negative effects on the LEPC through direct impacts on survival of eggs and young and the indirect exacerbating influence of degradation of grassland quality to support LEPC. Weather conditions are critical aspects influencing the temporal fluctuations of LEPC populations that can produce dramatic annual fluctuations in LEPC abundance. Under wet and mild weather conditions, LEPC populations will increase, and under drought or other extreme weather conditions, LEPC populations will decrease. The effects of climate change are presumed to result in more stochastic events

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[44] As discussed in Chapter 4, these projections do not account for all potential sources of future habitat loss for the LEPC. Due to data limitations, we were not able to project potential additional habitat loss resulting from construction of new roads, distribution lines, and transmission lines with any degree of certainty. Thus, the projections of habitat loss should be considered a minimum.

associated with extreme weather conditions, particularly more severe and extended drought conditions that will increase stress on LEPC populations in the future.

A summary of the status of each of the four ecoregions is provided below. Each of the ecoregions contains genetic and ecological diversity that may provide important adaptive capacity for the species.

5.1 Short-Grass Prairie/CRP Mosaic Ecoregion

The Short-Grass Prairie/CRP Mosaic Ecoregion has maintained the largest LEPC population since the early 2000s, with the most recent 5-year average of population estimates approaching 20,000 birds, and it likely represents the most resilient ecoregion compared to the other ecoregions based on the relatively large number of birds present. The genetic structure of the populations in this ecoregion indicates that birds have dispersed into this area primarily from the Mixed-Grass Ecoregion and, to a lesser degree, from the Sand Sagebrush Ecoregion. This is logical as there were very few birds in this area in the 1980s. Evaluations of LEPC population growth trends in this ecoregion have resulted in four of six estimates indicate declining population growth rates, although there is substantial variability around many of the estimates. Quasi-extinction risks calculated from past ground-based surveys for this ecoregion were at or near 0 in the 30-year projections. The risk projections for this ecoregion suggest a lower probability of extirpation compared to other ecoregions because the recent population size and trajectory indicates it is likely reasonably resilient to withstand future stochastic events. However, these projections do not consider potential for future habitat declines.

The projections for changes in future usable area in the Short-Grass/CRP Ecoregion indicate declines ranging from 5 to 24% over the next 25 years. The future of LEPC habitat in this ecoregion will be most influenced by habitat loss and fragmentation from ongoing energy development (oil and gas and wind projects) and future trends in CRP enrollment, as conservation efforts are expected to focus primarily on habitat enhancement programs to manage for high-quality LEPC habitat. While the Short-Grass/CRP Ecoregion is estimated to have the largest population of LEPC, the conditions supporting these populations are reliant upon continued implementation of voluntary, short-term conservation efforts, primarily CRP, to provide available habitat. And future impacts are projected to outpace restoration efforts resulting in a decrease in available habitat over the next 25 years. Climate change is expected to have the least effects in this ecoregion because of projections for generally wetter conditions, although periodic, high-intensity droughts are still of concern.

5.2 Mixed-Grass Prairie Ecoregion

The Mixed-Grass Prairie Ecoregion has experienced substantial declines in the LEPC population, with the most recent 5-year average estimates at around 5,000 birds. The genetic structure of the birds in this ecoregion shows distinct difference in genetic variation compared to the other ecoregions, with the exception that birds from here are moving into the Short-Grass/CRP Ecoregion. Quasi-extinction risks for this ecoregion range from 3 to 23% over 30 years, depending on the effective population size threshold and the model considered. All but one of the population growth rate estimates were below 1, suggesting generally declining populations. Projections for this ecoregion suggest an elevated probability of extirpation as the current population size and trajectory makes it challenging to withstand future stochastic events. And none of these population projections account for future habitat loss.

The projections for future habitat loss in the Mixed-Grass Ecoregion are the largest among the four ecoregions, with results indicating potential usable area declines ranging from 2 to 37% over the next 25 years. This ecoregion also has the highest levels of habitat fragmentation compared to the other ecoregions. The future of LEPC habitat in this ecoregion will be most influenced by habitat loss and fragmentation from ongoing energy development (oil and gas and wind projects) and encroachment by eastern red cedar. Conservation efforts are expected to focus on habitat enhancement programs to manage for high-quality LEPC habitat as well as restoration efforts to remove eastern red cedar.

5.3 Sand Sagebrush Prairie Ecoregion

The Sand Sagebrush Prairie Ecoregion has experienced the most precipitous declines in the LEPC population, with the most recent 5-year average estimates at around 1,200 total birds, and this ecoregion likely has the most reduced resiliency compared to other ecoregions. The genetic structure of the birds in this ecoregion shows distinct difference in genetic variation compared to the other ecoregions, with the exception that birds from here are moving into the Short-Grass/CRP Ecoregion. Evaluations of LEPC population growth trends in this ecoregion have resulted in all seven estimates indicating declining population growth rates. Quasi-extinction risks for this ecoregion range from 47 to 100% over 30 years, depending on the effective population size threshold and the timeframe considered. From 2016-2019 State Wildlife Agencies from Colorado and Kansas translocated LEPC from the Short-Grass/CRP Ecoregion into this ecoregion and have released 411 birds in an attempt to augment the low populations.

While the projections for future habitat loss in the Sand Sagebrush Ecoregion are less than other ecoregions, the results still indicate potential usable area declines ranging from 3 to 14% over the next 25 years. The future of LEPC habitat in this ecoregion will be most influenced by habitat loss and fragmentation from ongoing energy development (oil and gas and wind projects), persistence of planted grasslands (CRP), and conservation efforts are expected to focus on habitat enhancement programs to reduce incompatible grazing and manage for high-quality LEPC habitat.

5.4 Sand Shinnery Oak Prairie Ecoregion

The Sand Shinnery Oak Prairie Ecoregion has experienced substantial declines in the LEPC population, with the most recent 5-year average estimates at around 3,000 birds. The genetic structure of the birds in this ecoregion shows distinct difference in genetic variation compared to the other ecoregions, and this ecoregion is isolated by distance from the other three ecoregions. Quasi-extinction risks for this ecoregion range from 0 to 16%, over the next 30 years depending on the effective population size threshold and the model considered. Three of the four population growth rate estimates were below 1, suggesting generally declining populations. These current projections for this ecoregion suggest an elevated probability of extirpation as the current population size and trajectory makes it challenging to withstand future stochastic events. None of these population projections account for future habitat loss.

The projections for future habitat loss in the Shinnery Oak Ecoregion indicate changes in potential usable area from a 12% increase in Scenario 1 to declines ranging from 3 to 30% in the other scenarios. The future of LEPC habitat in this ecoregion will be most influenced by habitat loss and fragmentation from ongoing energy development (oil and gas and wind projects) and encroachment by mesquite. Conservation efforts are expected to focus on habitat enhancement programs to manage for high-quality LEPC habitat and restoration via the removal of mesquite. Because its southern-most geographic location, this ecoregion is most susceptible to the effects of climate change, as this area is already relatively drier and is projected to experience additional hotter and drier conditions in the future. The potential for population extirpation due to extended drought events is high.

5.5 Summary

As DeYoung and Williford (2016, p. 91) summarized, "…the plight of the LEPC is primarily a problem of habitat loss, both amount and spatial extent. Concerns about habitat loss are paramount because loss of genetic variation, small population size, and amount of habitat, and stochastic events operate in a synergistic, not isolated, manner." If habitat availability continues to decline in the future as projected and the populations supported by that habitat are lost without the necessary connected habitat for recolonization, redundancy within the ecoregions will decline, increasing the risk of losing one or more representative ecoregions. The Sand Sagebrush Ecoregion is already at a very high risk of extirpation. Even as conservation activities continue, all of the ecoregions are at some elevated level of risk of extirpation, depending on the assumptions used to project the future and the timeframe considered. If entire ecoregions are extirpated in the future, then the LEPC will lose broad redundancy, putting it more at risk from species-wide extinction due to catastrophic events such as large-scale, extreme droughts that are predicted to increase in frequency due to climate change. In addition, the loss of ecoregions would be expected to result in the decline in the species' capacity to adapt to future changes in environmental conditions, causing additional risks of species extinction in the future. Over the past 150 years, LEPC populations and their habitats have been drastically reduced. As indicated by our analysis, additional future habitat loss and fragmentation across the range of the LEPC is likely to occur and conservation actions will not be enough to offset those habitat losses. Our analysis finds that the expected conservation efforts are inadequate to prevent continued declines in total habitat availability, much less restore some of what has been lost, and species viability for this species will continue to decline.

Appendix A. Glossary

Anthropogenic–of, relating to, or resulting from the influence of human beings on nature.

Biomass–the amount of living matter in a given habitat, expressed either as the weight of organisms per unit area or as the volume of organisms per unit volume of habitat.

Brood–a number of young produced or hatched at one time.

Climate change–a change in one or more measures of climate that persists over time, whether caused by natural variability, human activity, or both.

Climate–prevailing mean weather conditions and their variability for a given area over a long period of time.

Connectivity (geographical)–a topological property relating to how geographical features are attached to one another functionally and spatially.

Critical habitat–a term defined and used in the Endangered Species Act. It is specific geographic areas that contain features essential to the conservation of an endangered or threatened species and that may require special management and protection.

Cryptic–fitted for concealing; serving to camouflage.

Cumulative effects–when several seemingly separate effects combine to have an effect greater than their individual effects dispersal.

Dimorphic–the condition in which the males and females in a species are morphologically different.

Dispersal (biological)–refers to both the movement of individuals (animals, plants, fungi, bacteria, etc.) from their birth site to their breeding site ('natal dispersal'), as well as the movement from one breeding site to another ('breeding dispersal').

Drought–a prolonged period of abnormally low precipitation. Extreme drought is defined by DE category as "severe fish, plant and wildlife loss reported (U.S. Drought Monitor, https://droughtmonitor.unl.edu/).

Ecological diversity–the variation in the types of environmental settings inhabited by an organism.

Edge effect (ecology)–changes in population or community structures that occur at the boundary of two habitats. Areas with small habitat fragments exhibit especially pronounced edge effects that may extend throughout the range.

Encroachment–to gradually move or go into an area that is beyond the usual or desired limits.

Endemic–the ecological state of a species being unique to a defined geographic location.

Environmental mitigation–environmental mitigation, compensatory mitigation, or mitigation banking are terms used primarily by the United States government and the related environmental industry to describe projects or programs intended to offset known impacts to an existing historical or natural resource such as a stream, wetland, endangered species, archeological site or historic structure. Environmental mitigation is typically a part of an environmental crediting system established by governing bodies which involves allocating debits and credits.

Eradication–the complete destruction of something.

Esophageal–pertaining to the esophagus, the muscular tube that conveys food from the pharynx at the back of the mouth to the stomach.

Exacerbate–make a problem or bad situation worse.

Extinction–the state or process of a species, family, or larger group disappearing from its entire range.

Extirpation–the loss of a population or a species from a particular geographic region.

Forb–an herbaceous flowering plant other than a grass.

Forecast–predict or estimate (a future event or trend).

Fragmentation–the state of being broken into separate parts.

Galliformes–a large and diverse group comprising about 70 genera and more than 250 species of 'gallinaceous birds' (meaning chicken-like) or game birds (as many species are hunted).

Generation time–the average time between two consecutive generations in the lineages of a population.

Genetic diversity (genetic variability)–the genetic measure of a tendency of individual organisms of the same species to differ from one another.

Grassland–Level to rolling landform, composed of predominately herbaceous plants, and sometimes shrubs, but treeless. Includes lands previously tilled or plowed, with a replanted, or grow-back, plant community comprised of native, non-native, introduced, or mixed plants.

Hybridization–act or process of mating organisms of different varieties or species to create a hybrid.

Invasive species–a species that is not native to an ecosystem and which causes, or is likely to cause, economic or environmental harm or harm to human health.

Invertebrates–An animal that has no backbone or spinal column.

Lek–an assembly area where animals (such as the prairie-chicken) carry on display and courtship behavior.

Lekking–activity of male prairie-chicken to assemble in a lek and engage in competitive displays.

Metapopulation–is a group of populations that are separated by space but consist of the same species. These spatially separated populations interact as individual members move from one population to another.

Micro-habitat–a habitat that is of small or limited extent and which differs in character from some surrounding more extensive habitat.

Monte Carlo simulation–or probability simulation; a technique used to understand the impact of risk and uncertainty in different forecasting models.

Morphological–referring to the structure or form of an organism

Native–(of a plant or animal) of indigenous origin or growth.

Opportunistic–(of a plant or animal) able to spread quickly in a previously unexploited habitat.

Patch isolation–when large, contiguous habitat areas are fragmented into a greater number of smaller patches of lower total area that become isolated from each other by a matrix of dissimilar habitats.

Physiological adaptations–internal systematic responses to external stimuli in order to help an organism maintain homeostasis.

Prairie–Level to rolling landform, composed of diverse, predominately- –native, herbaceous plants, and sometimes shrubs, but treeless that has never been tilled or plowed.

Precipitation–rain, snow, sleet, or hail that falls to the ground.

Quasi-extinction–defined as a population collapse that occurs when the population size reaches some given lower density.

Rangeland–Land on which the indigenous vegetation (climax or natural potential) is predominantly grasses, grass-like plants, forbs, or shrubs and is managed as a natural ecosystem. If plants are introduced, they are managed similarly. Grazing is the primary land use and management activity.

Recruitment (ecology)–occurs when juvenile organisms survive to be added to a population, by birth or immigration, usually to an adult or sub-adult stage, whereby the organisms are settled and able to be detected by an observer.

Restoration (ecology)–the practice of renewing and restoring degraded, damaged, or destroyed ecosystems and habitat in the environment by active human intervention and action.

Risk assessment–a systematic process of evaluating the potential risks that may be involved in a projected activity or undertaking.

Scenario–a postulated sequence or development of events.

Site fidelity–the tendency of an organism to stay in or habitually return to a particular area.

Speciation–the formation of new and distinct species in the course of evolution.

Species status assessment (SSA)–the process of analyzing the biological status of a species in terms of future viability.

Species Status Assessment Report (SSA Report)–the resulting documentation of the SSA.

Stochastic events–arising from random processes such as weather, flooding, or fire.

Stressor–any physical, chemical, or biological alteration of the environment that can lead to an adverse response by individuals or populations of a species.

Subspecies–a taxonomic category that ranks below species, usually a fairly permanent geographically isolated race.

Supraorbital–situated above the orbit of the eye.

Taxonomy–the branch of science concerned with classification, especially of organisms; systematics.

Tebuthiuron–A non-selective, broad-spectrum herbicide of the urea class.

Thermal refugia–habitat that provides a reprieve from extreme operative temperatures.

Threats–any action or condition that is known to, or is reasonably likely to, negatively affect individuals of a species.

Vegetative community–association of plant species within a designated geographical unit, which forms a relatively uniform patch, distinguishable from neighboring patches of different vegetation types.

Appendix B. Spatial Analysis of LEPC Usable Area

This Appendix contains all the relevant documentation on the development and application of the lesser prairie-chicken (LEPC) species status assessment (SSA) spatial analysis of usable space for assessment of current condition and projection of future scenarios of conservation and impacts. Included in this report is the information on data sources, spatial modeling methodology, geo-processing techniques, and supplemental analysis and information to evaluate the spatial analysis results. The primary results of the spatial analysis are found within the main body of the LEPC SSA Report.

Contents:

Part 1. Modeling Land Cover Usability and Future Landscape Scenarios using GIS

A. *General Background*

Characterizing the current and likely future condition of the landscape a species depends upon is required to conduct a SSA. For the LEPC SSA, we characterized landscape conditions spatially to analyze the ability of those landscapes to support the biological needs of the LEPC. As described within the main body of the SSA report, the primary concern for the LEPC is habitat loss and fragmentation. We conducted a GIS analysis to analyze the extent of usable land cover changes and fragmentation within the range of the LEPC.

Purpose

1. Create a current condition land cover layer that identifies and ranks land cover classes and landscape features as they relate to LEPC activities. The layer consists of three components (each component is discussed in greater detail later in this document), derived from a variety of spatial data inputs:

a. Potential Usable Land Cover
b. Exclusions
c. Impacts

2. From the Current Condition layer, derive Usable Area Blocks from the un-impacted Potential Usable Area features identified in the Current Condition layer. A raster surface representing a Neighborhood Analysis, Percent Usable Area within one mile was derived and all Usable land cover features which intersected the 60% or greater (usable area within one mile) threshold were selected as Usable Area Blocks (details to follow).

3. Develop future spatial scenarios of the Usable Area Blocks layer to demonstrate how land cover patterns important to LEPC could change and shift based on conservation practices and potential human development over time. Numeric modeling was used for this step. Two other data layers (each layer is discussed in greater detail later in this document) were used in this step:

a. Geographic Constraints
b. Neighborhood Analysis: Percent potential usable area within one mile

All results and summaries from these GIS exercises are discussed in the body of the SSA Report. This supplemental report will only describe and discuss the spatial data and the methods used to achieve these results.

General Limitations

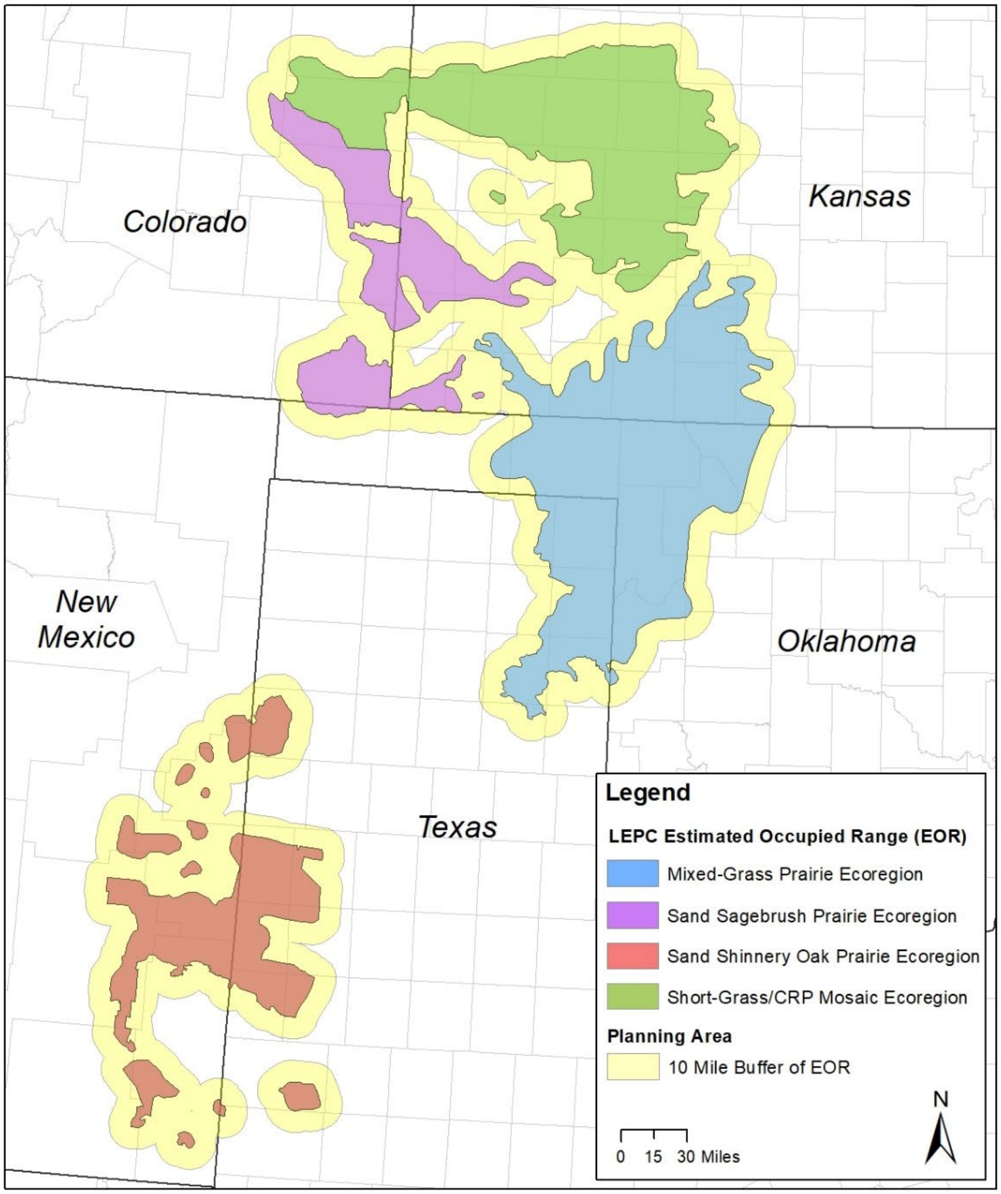
The remotely sensed data products and large national datasets used in this analysis may contain inherent temporal discrepancies and errors of omission and commission. We did not conduct independent accuracy assessments for any of the datasets. Actual on-the-ground condition of mapped cover types is not addressed. All land cover data have a minimum spatial resolution of 30 meters. No field verification or reviews of ancillary datasets/aerial imagery were done to verify the accuracy of the original data used. These data, and all maps/products created from it, are subject to change.

LANDFIRE Existing Vegetation Type (EVT) land cover data were chosen because of its temporal currency and relationship with other spatial datasets used in this study. It should be stated that LANDFIRE data are updated from satellite imagery as well as on-the-ground observations, often at regional or ecoregional scales, resulting in minor inconsistencies across larger landscape scales. The accuracy of all land cover data, including LANDFIRE data, is acknowledged and accepted. Land cover classes with ill-defined or unclear definitions (LANDFIRE/GAP Land Cover Map Unit Descriptions, 2016) were closely examined with aerial imagery (ESRI, Inc. ArcMap on-line data) to determine inclusion/exclusion as a usable class.

The future scenario modeling of spatial data is only a generalized representative view and/or outlook of landscape conditions based on generalized criteria and treatments applied to the input features. The model cannot definitively identify where specific areas of LEPC habitat currently occur or will occur in the future but do show the *variability* of how different landscape configurations may affect LEPC usable area.

Analysis Area

All data, results, and analysis information are reported range-wide and by ecoregion within the LEPC analysis area. The analysis area is based on a revised version (Fricke 2020, pers. comm.) of the LEPC Estimated Occupied Range (EOR) (Van Pelt *et al*. 2013, p. 3). Figure B.1 shows the analysis area and the EOR+10. The EOR+10 is a 10-mile buffer of the EOR often referenced in LEPC planning efforts; it was included in the extent at which input data were collected and processed for our analyses. All analyses, however, were conducted within the revised EOR as the analysis area.



DRAFT The USFWS makes no warranty for use of this map and is not responsible for actions based on this map.

Figure B.1. Analysis area for lesser prairie-chicken ecoregions.

Spatial Data Sources

All source data sets (excluding the National Wetlands Inventory-NWI) were created by entities outside the U.S. Fish and Wildlife Service (Service). All data sets are publicly available or available through licensing agreements. Alterations to these data sets (reclassification, resampling, creating buffer distances, etc.) were done through careful consideration of published literature and expert opinions. For a list of all datasets used, see Table B.1.

Terminology/Nomenclature

GIS Data

Descriptions of terminology used to describe in a more common language the relationship of spatial data used to characterize LEPC usable area:

Land Use / Land Cover Reclassification

Potential Usable Area – Land cover classes (grass and grass/shrub cover types) that may support LEPC use/activities at some point in their life cycle.

Potential Woody Cover Restoration Area – Land cover classes (predominantly forest/shrub cover types) that currently would not support LEPC activities but could be restored to grassland/shrubland in the future by removal of woody vegetation.

Potential Land Use Conversion Area – Land cover classes (various types of agriculture) that currently would not support LEPC activities but could be converted to grassland/shrubland in the future by converting cropland to a vegetative landcover type that could support the life history needs of the LEPC.

Non-Usable Area – Land cover classes and landscape features that do not support LEPC (impervious cover: urban/developed areas and structures, paved roads, certain wetland/riparian areas, steep canyon break topography).

Patch – A spatially explicit polygon with only one land cover classification. A single patch may or may not be of sufficient size by itself to support LEPC activities.

Block – Relationship between more than one patch of potential usable area that falls within a spatially defined proximity of other patches. Proximity will be defined by its relationship to a neighborhood analysis (percent usable area features within one mile of one and other usable polygons).

Impact Feature – Features that result in habitat loss and/or fragment habitat or impede LEPC activities (roads, O&G wells/power transmission/wind turbines/other towers and structures/trees).

Impact Radius – The specified distance (in one direction) from a feature that affect LEPC activities. See Table B.3 for all impact radii used for this analysis.

Geoprocessing Tools and Routines[1]

Clip – Clips one or more data sets to the extent of another (like the project boundary).

Buffer – Adds an outer boundary to a feature, at a user-specified distance.

Convert Raster to Vector – Converts raster image data to vector data format.

Merge – Combines multiple features or layers into one.

Dissolve – Removes boundaries between like features, based on a data table field.

Eliminate – Eliminates polygons by merging them with neighboring polygons that have the largest area.

Erase – Removes data from a source layer using selected features from another layer. Area removed is identical to selected feature.

Union – Geometrically combining multiple layers into one, but maintains attribution for each layer.

Reclassify (raster) – Assigns a new value to a pixel.

Resample (raster) – Alters the size of the pixels.

Extract by Mask/Attribute – These tools to extract data from raster data sources. Extract by Mask works like a “clip” in vector. Selecting and extracting features that are within another data layer. Extract by Attribute extracts data by the cell value or other designated attributes in the data table.

Cell Statistics (raster) – Similar to a vector union, mathematically combines the cell values of two or more raster layers “overlaying” each other into a new raster layer with a new cell value.

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[1] All of these tools and routines can be found in ArcToolbox, primarily Spatial Analyst (license required) and run through ModelBuilder.

Snap Raster (raster) – Snaps pixels from overlaying raster layers so they align on top of each other perfectly (as long as the pixel size is the same or a multiple of the source pixel's size).
Nearest Neighbor – A (spatial) algorithm to find the closest subset of input samples to a query point and apply weights to them based on proportionate areas to interpolate a value (ESRI, Inc. ArcGIS 10.6).

Projections and Transformations

All data were projected in NAD 1983 Albers. This was the USGS LANDFIRE data source projection. All non-Albers data were projected into this system. This projection maintains a perfect 30m x 30m pixel size and allows all of the raster layers to overlay exactly. Projection details can be found in the properties of the spatial data layers.

Basic GIS & Geoprocessing Methods

Since this study area covers a vast geographical landscape, most of the geoprocessing will be performed in the raster data format. This is an image-based format with data comprised of pixels, each containing a value. The ArcGIS software accesses the raster data according to its cell value(s), providing a cell count for each value so that there may be millions of pixels in a layer but only a few values to deal with. This makes the geoprocessing run much faster than the vector (point/line) data. Raster data also neatly "stacks" on top of one and other (as long as the pixel size is the same or a multiple of the source pixel size), making the layers easy to combine (cell statistics function) and reclassify. Source data that are acquired in vector format may have some processing done in the vector environment (like buffering) but then will be converted to raster to be combined with the other layers for the analysis.

For this study, all raster data will have a 30-meter by 30-meter pixel size. This is a standard size for large landscape datasets (such as LANDFIRE, NLCD, etc.). All layers will be "snapped" to the LANDFIRE source layer. This will assure proper alignment of all data layers, avoiding the slivers and gaps that occur in vector data. With proper classification and attribution each layer can maintain its unique cell value identifying the spatial relationship between different overlaying/intersecting layers (described later in this section).

For the final part of the spatial analysis, evaluating potential scenarios in a future condition analysis (described later in this section), all of the data layers will be converted into a vector format. The geoprocessing selection programming scripts used for the future condition analysis only work in that format.

B. Current Condition: Identifying Usable Land Cover, Exclusion and Impact Features

Spatial Data Inputs

The current condition GIS analysis consists of three primary layers (as mentioned above). Through geoprocessing, these layers were overlaid and mathematically intersected (cell statistics), providing a direct spatial relationship between the cell values in all of the layers (Figure B.2).

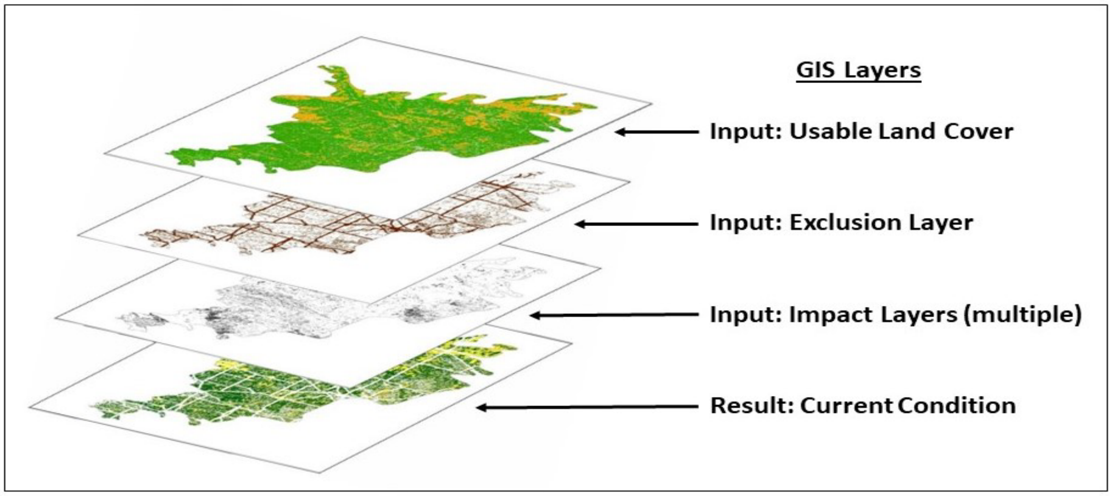

Figure B.2. Representation of various GIS layers developed for the Current Condition.

1. Reclassified Land Cover Layer

Developed from LANDFIRE EVT 2016 Remap data, this layer was reclassified and resampled to identify potential usable, potential restoration, and non-habitat as it relates to LEPC (see previous definitions). This served as the primary input layer for the current condition and the future scenario modeling.

Original data source: 2016 USGS LANDFIRE Existing Vegetation Type (EVT)
a. Data are downloaded from USGS LANDFIRE website (https://www.landfire.gov/)
b. Data are extracted/clipped to ecoregion boundaries
c. All original LANDFIRE individual land cover types/classes are reclassified by giving them a LEPC "usability value" (this is done by expert elicitation by USFWS Biologists with review and input provided by LEPC SSA State partners):

- ***Potential Usable Area***
- ***Potential Woody Cover Restoration Area***
- ***Potential Land Use Conversion Area***
- ***Non-Usable Area***

LEPC Reclassifications (as defined above) for all LandFire EVT land cover classes are detailed in Table B.2.

To aid in the decision process and to attempt to compensate for inherent classification errors, many aspects of each LANDFIRE classification were scrutinized to provide context beyond just the class name. Factors used during expert elicitation as considerations for reclassifying land cover classes:

- Review of aerial photography
- Geographic location/landscape position
- Pixel count
- Proximity to (buffered) lek locations
- Multiple attribute fields within the dataset, and their associated descriptions (LANDFIRE/GAP Land Cover Map Units Description, 2016)

2. Exclusions

Features which are not, nor will not likely be, usable LEPC areas during the analysis time period (25 years) were excluded from any acreage calculations or future scenario modeling. Details on data sources and impact radii can be found in Table B.3.

The following features/layers comprise the exclusion layer;

Roads/Railroads (U.S. Census TIGER)
Urban footprints/Airports (NLCD, TIGER, ESRI, Inc.)
Building Footprints (Microsoft, Inc. through USGS Sciencebase)
Tall structures (not including wind turbines) (FAA Digital Obstacle File and USGS Wind Turbine Database)
Power transmission line corridors (Platts)
Wetlands (large/riparian) (LANDFIRE EVT/NWI)
High slope terrain (25% or greater) (USGS LANDFIRE Slope Dataset, 2016)

3. Impacts:

Areas around features of current impact on the landscape that may affect LEPC were buffered with a feature-specific impact radius. The impact radius applied to any feature and was based on values identified by the Service (USFWS 2014a)[2] .

a. Oil & Gas wells: all selected active surface wells identified in IHS dataset within the analysis area. Impact radius applied was 300 meters.

b. Wind Turbines: all wind turbines identified in FAA and USGS datasets within the analysis area. Impact radius applied was 1,800 meters.

c. Trees: three data sources were used to capture the current tree impact:

1. LANDFIRE EVT tree land cover classes (not including any wetland/riparian classes) were extracted from the original (pre-reclassified and resampled) dataset.
2. National Land Cover Dataset (NLCD) forested classes were extracted.
3. From the SGP CHAT website, the Percent Canopy Cover of Conifer and Mesquite was used. For the Short-Grass/CRP, Mixed-Grass, and Sand Sagebrush Ecoregions, all classes greater than or equal to 1% were used. For the Shinnery Oak Ecoregion, classes greater than or equal to 5% were used. Then all the data were merged and dissolved with the EVT and NLCD data, and buffered accordingly;

Short-Grass/CRP, Mixed-Grass, and Sand Sagebrush tree layer impact radius was 329 meters.

Shinnery Oak tree layer impact radius was 224 meters.

Further rationale and cited literature is referenced in main SSA Report and in Appendix C.

Data Processing (Combining/Intersecting Raster Layers with Cell Statistics Tool)

All of the Usable Land Cover, Impact, and Exclusion raster layers were mathematically combined/intersected using the cell statistics tool. Combining the different layers in this way created one output layer from all of the input layers, while still maintaining the data from each of the input layers. In this way, direct relationships (where the features overlap/intersect) can be calculated (Figure B.3).

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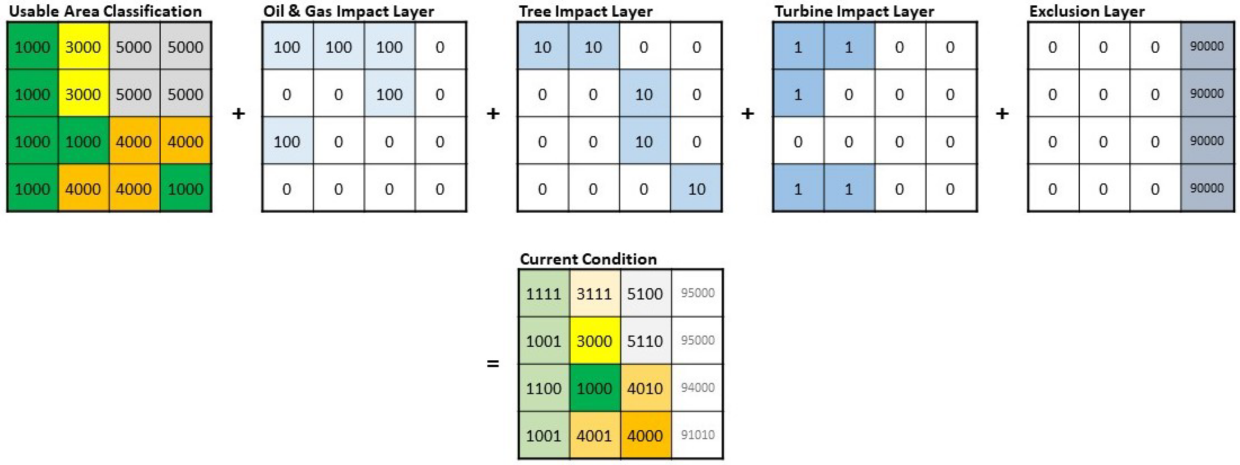
[2] Note that these impact radius distances are those prescribed and used by the U.S. Fish and Wildlife Service, and do not necessarily reflect the opinion or position of state biologists who assisted on the LEPC SSA.



Usable Area Classification

1000	3000	5000	5000
1000	3000	5000	5000
1000	1000	4000	4000
1000	4000	4000	1000

+

Oil & Gas Impact Layer

100	100	100	0
0	0	100	0
100	0	0	0
0	0	0	0

+

Tree Impact Layer

10	10	0	0
0	0	10	0
0	0	10	0
0	0	0	10

+

Turbine Impact Layer

1	1	0	0
1	0	0	0
0	0	0	0
1	1	0	0

+

Exclusion Layer

0	0	0	90000
0	0	0	90000
0	0	0	90000
0	0	0	90000

=

Current Condition

1111	3111	5100	95000
1001	3000	5110	95000
1100	1000	4010	94000
1001	4001	4000	91010

Figure B.3. Schematic of raster cell statistic tool process. Each cell from each layer is coded to total up to a Current Condition cell value, which indicates the impacts affecting each Usable Area cell.

Current Condition Cell Statistics Descriptions (Figure B.3)

LEPC Classification
1000 – Potential Usable Area.
3000 – Potential Woody Cover Restoration Area.
4000 – Potential Land Use Conversion Area.
5000 – Non-Habitat Area

Oil & Gas Impact Layer
100 – Cell is within Oil & Gas impact buffer.
0 – No impact.

Tree Impact Layer
10 – Cell is within Tree impact buffer.
0 – No impact.

Turbine Impact Layer
100 – Cell is within Wind Turbine impact buffer.
0 – No impact.

Exclusion Layer
90000 – Cell is within Exclusion buffer.
0 – Cell is outside of Exclusion buffer.

Example Current Condition Potential Usable Area
1000 – Un-impacted Usable Area.
1100 – Usable Area with Oil & Gas impact.
1010 – Usable Area with Tree impact.
1011 – Usable Area with Tree and Turbine impact.
1111 – Usable Area with Oil & Gas, Tree, and Turbine impacts.
91000 – Usable Area within Exclusion buffer.

The Current Condition layer data table contains all cell values, whether overlaying with other layers or not (as demonstrated above). Each cell value has a pixel count. Acreages can be obtained for each value by multiplying the pixel count by 0.222395 (each 30-m x 30-m pixel equates to 0.222395 acres).

Current Condition Results

All acreage calculations and conclusions from the GIS analysis are summarized in the main body of the LEPC SSA Report. The current condition processing produced four final union/spatial data outputs, one for each ecoregion. These four output datasets were considered the starting point (Year 0) for the following future scenario analysis. All acreage calculations will be derived from these final raster unions (Feature Classes in the next phase). The primary outputs from this effort were the un-impacted usable area features: 1000 = Usable land cover types, with no impacts.

C. Usable Area Blocks: Identifying Usable Land Cover Features that are within a Certain Proximity of One Another

With the land cover suitability, impact effects, and exclusion features determined, we analyzed the relative proximity of all the un-impacted usable area features within each ecoregion. To achieve this, a Neighborhood Analysis was applied on the un-impacted usable area features . The Neighborhood Analysis is a raster surface created (using the nearest neighbor algorithm) by examining the percent of usable area features that are within one mile of each other. The resulting raster will have cell values which will be calculated from 0–100%. This was accomplished using the following techniques in ArcMap (ArcGIS/Toolbox/Spatial Analyst/Neighborhood/Focal Statistics):

Basic Procedures

a. All 1000 cells were reclassified to a value of “1”. This is done so that the output will go from 0 (no cells in the neighborhood) to 11,499 (every cell in the neighborhood—see below).
b. Focal Statistics (Neighborhood Analysis) were run with the following parameters;

Value	1 (1000)	(Un-Impacted Usable Area)
Data	30-m pixel sixe	
Neighborhood	Rectangle	
Settings	3218x3218*	
Units	Map (meters)*	
Stat. Type	SUM	

*1609 meters = 1 mile
One mile from a central point = 1609+1609=3218m
Neighborhood = 3218m x 3218m

Maximum number of 30-m x 30-m cells that can fall within a neighborhood is 11,449.

Cell values from 6869 to 11,449 (represents 60%–100% within one-mile values) were selected, extracted, and converted to a vector layer (ArcGIS/Toolbox/Conversion/From Raster/ Raster to Polygon).

The original un-impacted vector output was then intersected with this new layer. Any original polygon that intersected the new layer is now considered a *Usable Area Block.*

These Usable Area Blocks are the output defining the Current Condition.

Contemporary LEPC research has shown that higher thresholds (percent habitat within one mile greater than 60%) may be needed for LEPC viability. To account for this, acreage calculations were done at a 60%, 70%, 80%, and 90% usable area within one mile (results of this analysis are provided in the **Future Condition Results** section below). This provided an assessment of the consequences if lower levels of fragmentation are needed to support LEPC populations. For further discussion of the basis for this approach, these results are presented and detailed in the SSA Report (Section 4.5.1).

D. Future Scenarios: Modeling Potential Effects of Conservation and Development Actions

Purpose

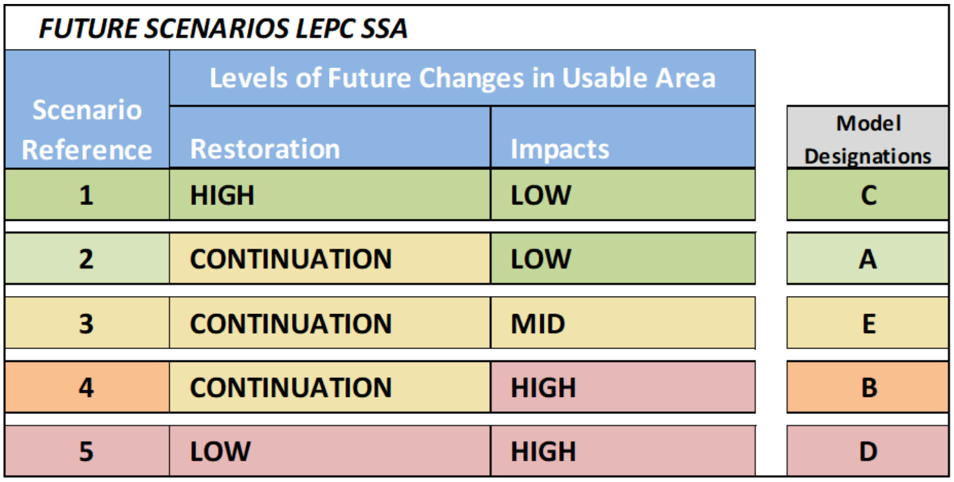
The purpose of this model is to take the Current Condition layer and project how varying rates of LEPC conservation efforts (e.g., removal of woody plant encroachment in grasslands) and impacts (e.g., woody plant encroachment) to LEPC potential usable area may affect land cover types, amounts and configurations 25 years into the future under five scenarios. The final processing step in the Future Scenario projections uses the same neighborhood analysis threshold as the Current Condition to identify usable area patches that relate, together, as Potential Usable Area Blocks.

Development

The future scenarios were developed to examine how a range of future conservation efforts and impacts could affect LEPC potential usable area. These actions may appear as increases or decreases in acreage. The temporal duration of the future scenarios for projecting land cover change via conservation and impacts was set at 25 years. The model design (looking at which impact features to model, and possible increases/decreases of future acreages) was developed by the Service for the purposes of the LEPC SSA. A detailed account of the development effort and descriptions of each scenario is outlined in the main body of the LEPC SSA Report.

Modeling Change on the Landscape from Conservation and Impacts

The model is a set of detailed polygon selection routines. These routines are written in ArcGIS programming code (Python) to follow each scenario developed in the SSA Report. Each *Factor* (Figure B.4) has spatial criteria defined through projected on-the-ground effects. Based on these conservation or impact scenarios, potential usable area may be “added” by removing impacts through restoration or conversion, or potential usable area may be “subtracted” by increasing impacts and by selecting and changing the numeric values within the data table.



FUTURE SCENARIOS LEPC SSA

Scenario Reference	Levels of Future Changes in Usable Area		Model Designations
	Restoration	Impacts	
1	HIGH	LOW	C
2	CONTINUATION	LOW	A
3	CONTINUATION	MID	E
4	CONTINUATION	HIGH	B
5	LOW	HIGH	D

Figure B.4. Schematic of future scenarios. For each of the conservation and development factors, acreage numbers and treatment guidelines for polygon selection are developed. This information can be found in the main body of the LEPC SSA Report. Scenario References (1–5) are for the SSA Report; model designations are the references (A–E) used for the scenarios in the modeling process.

Spatial Data Inputs

Similar to the Current Condition described above, the Future Scenarios model works with four different data layers to achieve its results. The process begins with each Current Condition result dataset, described above. This layer was filtered with the Geographic Constraints features that defines where specific changes can (or cannot) occur on the landscape. This filtered Current Condition layer was then modeled using addition/subtraction selection/change routines to spatially define explicit polygons that change, based on the specific future scenario. Each of these new outputs has a percent potential usable area within one mile raster surface built from it. The new outputs were then intersected back with a vectorized version of the percent usable area layer. Those output polygons that fall within the 60% potential usable or above threshold were extracted as the Un-impacted Potential Usable Area Blocks (Figures B.5a–B.5f illustrate the process).

1. Geographic Constraints:

The geographic constraint layers are large landscape features which drive, or focus, where changes or effects on the landscape might occur with higher (or lower) frequency. All layers were clipped to our analysis area. These features came from a variety of source spatial material. Each is described below. Part 2 of this Appendix and Appendix C discuss in more detail the biological and spatial parameters that went into the development of these layers for geographic constraints;

a. **WAFWA's Southern Great Plains Crucial Habitat Assessment Tool (CHAT) Focal Areas and Connectivity Zones.** We used these zones to help target and concentrate potential conservation actions or habitat expansion on the landscape. Data were downloaded from SGP CHAT website: https://www.sgpchat.org/.

b. **Oil & Gas high concentration areas.** We used these areas to define where potential expansion of oil and gas development activities may occur for the purposes of this model. This feature is a 2-mile buffer of all known and selected active wells (from the IHS data). Areas outside this zone will not show any new oil and gas development within the model.

c. **Wind Farm Development:** To capture the potential of wind farm development, we created a "fishnet" grid of approx. 35,000-acre rectangles to be a large-area selection filter for applying potential wind farm development projects to the landscape. Within the model, these 35,000-acre cells can be randomly selected to model a footprint of a potential wind farm. These selected rectangles are usually comprised of a variety of land cover types, which may or may not include potentially usable area polygons. Wind development areas will not overlap designated protected areas. Detailed discussion is included in Appendix C, Section C.3.4.

d. Tillage likelihood. We identified areas at a higher potential for tillage risk (using the PLJV Tillage Risk) raster data. The raster was converted to vector data (no smoothing). Polygons were categorized with unique values (Layer Properties – Symbology) ranging from 0–1 (representing 0–100% likelihood of tillage). Criteria for constraint (polygons):

Polygons ranked >= 0.4 score (40%–100%);
Polygon acreage greater than or equal to 80 acres; and
Only polygons that overlap (our) potentially usable land cover will be used.

e. Precipitation zones. We added a precipitation threshold to address expected differences in woody plant encroachment along a precipitation gradient from East to West. This separated the western areas of the Sand Sagebrush and Mixed-Grass Ecoregions to reduce the rate of tree encroachment expansion (see Appendix C, Section C.3.2) in the drier areas of these ecoregions. These western areas are defined by average annual precipitation of 19 inches or less (PRISM 1981–2010 Annual Average Precipitation by State; https://datagateway.nrcs.usda.gov/). In these areas the tree encroachment rate is reduced from the eastern areas, which are identified by 20 inches of precipitation or greater (see details in next section).

f. Tree expansion potential. We used the un-buffered tree data layer for the Current Condition (see Appendix C, Section C.3.2) to help define the Tree Encroachment Geographic Constraint. For the Shinnery Oak Ecoregion, only the mesquite data from the NRCS Percent Canopy data layer will be used. A 5-mile buffer will define where tree encroachment may occur. The remaining three ecoregions will use all of the tree data layers to create the Geographic Constraint. Also using the precipitation zones, the western areas of the Sand Sagebrush and Mixed-Grass Ecoregions (19 inches and below) will get a 2.5-mile buffer, while the eastern areas (20 inches precipitation or greater) and all of the Short-Grass/CRP Ecoregion will use a 5-mile buffer. These areas are the only place where woody plants can expand in the model projections.

g. Conservation Ownership. These will be conservation areas that are precluded from a specific impact in the future scenario modeling. Data containing protected areas and conservation easements from the USGS Protected Areas Database 2.0 (PAD-US 2.0; USGS GAP 2018) were modified to include additional conservation properties in the analysis area and attribution identifying where a specific impact was precluded or not was added to the dataset. These conservation areas are removed or erased from each applicable development Geographic Constraint Layers, which protects them from being affected by impacts in the model. An example would be a conservation area that may not allow oil and gas development but may allow trees to grow. For this situation, the conservation area would be removed from the Geographic Constraint for oil and gas (meaning no development could be placed there), but not removed from the Tree Encroachment Geographic Constraint.

2. Percent Usable Land Cover within One Mile Raster Surface Layer

This raster layer was created from the output of un-impacted land cover types of each iteration for all scenario runs (the same as we did for the Current Condition Neighborhood Analysis). We used a Neighborhood Analysis (ArcGIS/Toolbox/Spatial Analyst/Neighborhood/Focal Statistics) algorithm to rank the percentage of un-impacted potential usable area features that are within 1 mile of each other. The resulting raster will have cell values which will be calculated from 0–100%. The process for creating this layer is described above.

Modeling Spatial Changes for Conservation and Development Scenarios Process

The attribute coding will vary slightly from the Current Condition coding to accommodate existing programming scripts from previous modeling efforts (Table B.4).

1. Polygons were selected from the Current Condition layer (Figure B.5a) based on their numeric value attributes as potentially usable space in the data table using a Python script.
2. The selection of the polygon can be focused or directed by one of the geographic constraint layers (Figure B.5b).
3. Each geographic constraint has an "in" or "out" numeric value coded into the script. This is specified in the scenario definition criteria. Other spatial criteria applied to the selection coding were:
   - Minimum/Maximum polygon size (to avoid hundreds of tiny selections, or one large selection, and generally reflect real world treatments).
   - Total acreage to change (varies per ecoregion and per scenario).
4. Each scenario was run twenty times (i.e., iterations; see Model Limitations below). A "random polygon selector" sub-routine inserted into the code created a different landscape configuration for each iteration (figure B.5c). Each run was non-cumulative, though some polygons could be added/subtracted within the same scenario multiple times depending upon the sequence of the addition/subtraction. The number of selections each polygon goes through is tracked in the data table. This created twenty final outputs for each of the five scenarios within the four ecoregions, for four hundred (400) final (year 25) outputs.
5. Each Year-25 landscape had the new un-impacted potential usable area polygons (1111 Total Rank attributes) extracted to create a Neighborhood Analysis raster surface (Figure B.5d) to identify the percent of usable land cover within one mile of other usable polygons (see detailed procedures above). The raster surface was then compared back with the original vector polygonal data. Potential usable land cover polygons that fell within the 60% and higher range (Figure B.5e) were considered Potential usable Blocks (Figure B.5f).

Examples of Spatial Layers and Outputs for the Future Scenario Modeling

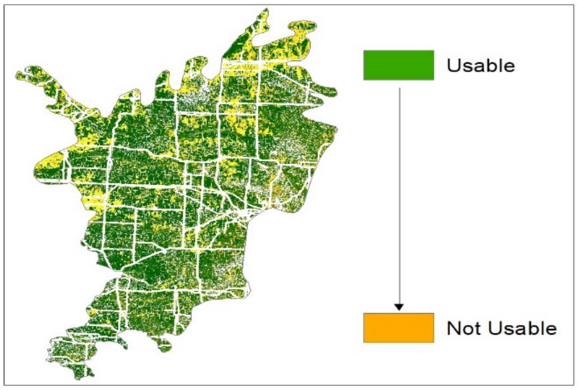


Figure B.5a: Current Condition Layer. Describes all Usable Area features (exclusion layer is removed), intersected/combined with impact layers, ranking all polygons based on land cover type and occurrence of impact features.

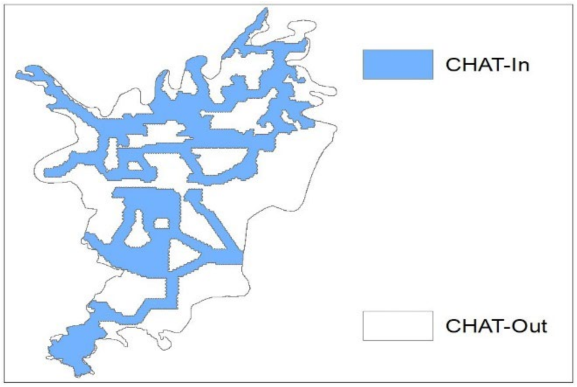


Figure B.5b: Geographic Constraints Layer. It is accessed with the Python selection scripts. The example here is the CHAT Focal Areas and Connectivity Zones (combined).

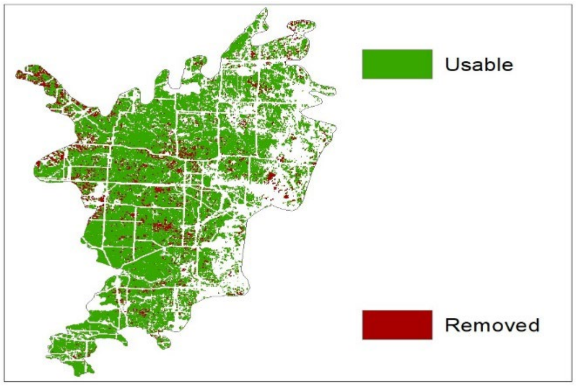


Figure B.5c: This is a representation selection output based on scenario criteria; un-impacted Usable polygons are "added" (removal of impact features) or "removed" (addition of impact features). This example shows Usable features (red) removed in a high development scenario.

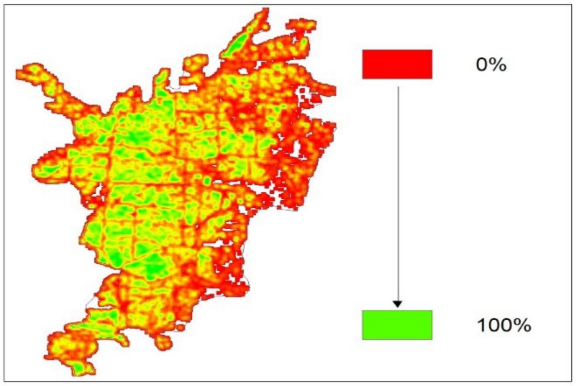


Figure B.5d: Neighborhood Analysis (Usable area within one mile); this raster layer is constructed from each scenario output. Each output only identifies the un-impacted Usable features after the scenario changes were implemented.

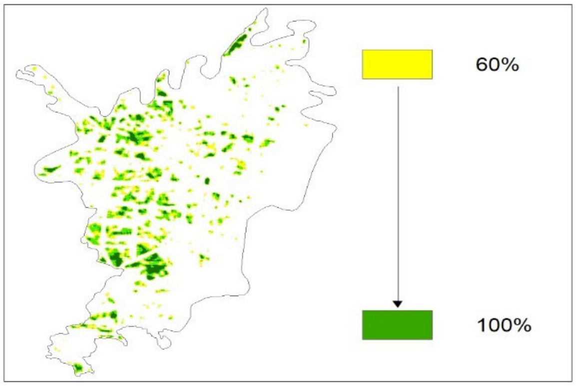


Figure B.5e: This is the 60%+ Usable land cover within one mile layer. This layer is vectorized to then be intersected with the output layers (example, Figure B.5c) from each scenario run.

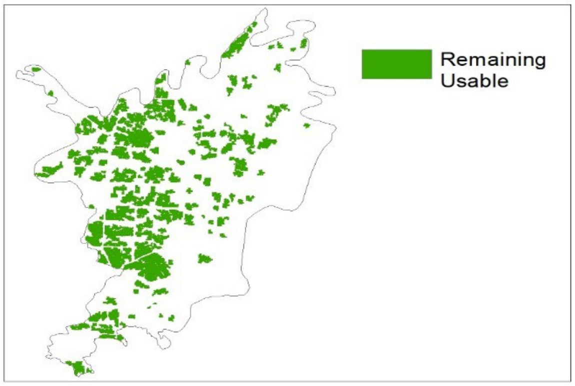


Figure B.5f: this is an example of the final output for each scenario. Only un-impacted Usable features, which intersect the 60% + threshold, are left. This is where each scenario acreage calculation is made.

Figure B.5. Visual example of data layers and general processes for future scenario modeling, within Mixed-Grass Ecoregion.

5. Contemporary LEPC research has shown that higher thresholds (percent habitat within one mile greater than 60%) may be needed for LEPC viability. To account for this, acreage calculations were also done at a 60%, 70%, 80%, and 90% usable area within one mile (results of this analysis are provided in the Future Condition Results section below). This provided an assessment of the consequences if lower levels of fragmentation are needed to support LEPC populations. For further discussion of the basis for this approach, these results are presented and detailed in the SSA Report (Section 4.5.1).

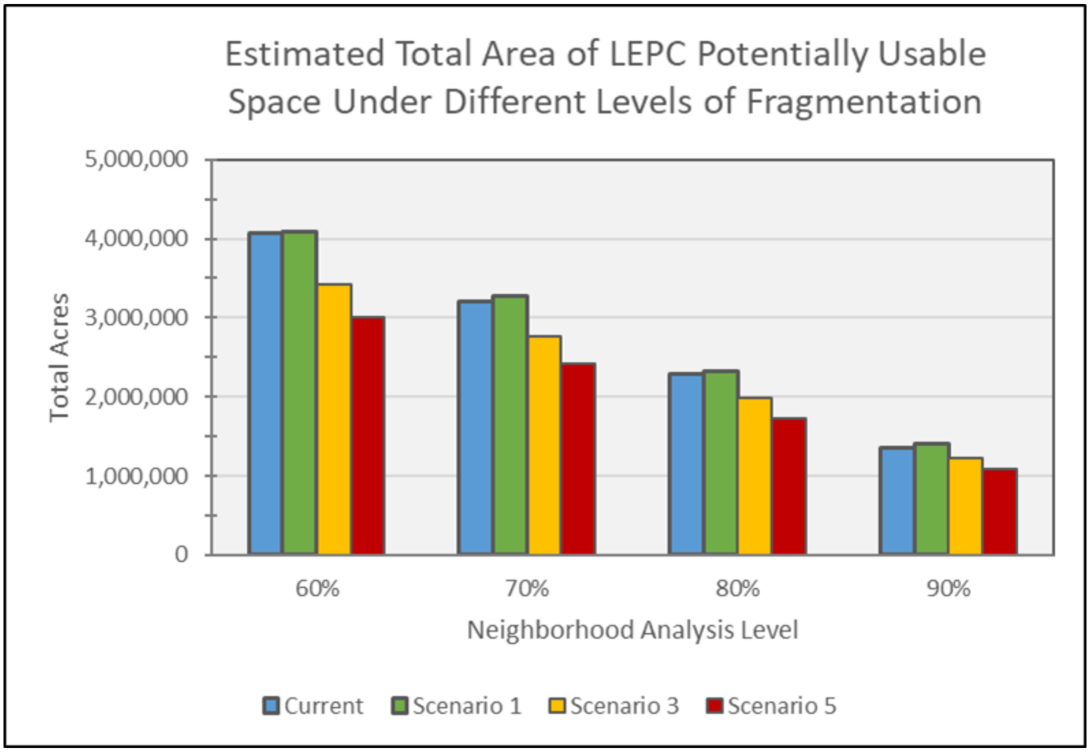


Figure B.6. Output of total potential usable area for the LEPC SSA spatial model at four levels of the neighborhood analysis at current condition and three future scenarios.

Model Limitations

Spatial Descriptions

This data/model was not designed for, and should never be used for, identifying predicted areas of change or predicting how and where features and effects may change on the ground. This model was designed to project multiple feasible scenarios of how changes to the landscape, defined by the (hypothetical) future scenarios, may affect the spatial relationship of usable LEPC area, by increasing decreasing block sizes and configurations.

Processing and Data Management Constraints

The scope and scale of this spatial analysis were adapted to the time available to meet the needs of the LEPC SSA Report and associated 12-month finding. As designed, the future scenario model generated 400 output data layers, of which there were a multitude of interim layers. This involved extensive time, effort, and hardware to keep the data organized. Any future analyses or revisions will also require extensive time to complete.

General Limitations for this Spatial Model

1. Limited data availability, including that needed to characterize current condition, and/or support informed projections of future rates, amounts, or extents.
2. Biological assumptions that were made throughout the process impact the results.
3. Assumptions made around the rates of change and geographic constraints of that change directly impact the results.
4. Limitations based on the complexity, which could be incorporated in a spatial context.
5. Only three factors for Usable Area impacts were considered for this model.

Future Condition Results

All acreage calculations and conclusions from the future scenario analysis are summarized in the main LEPC SSA Report. All acreage calculations were taken from the final future scenario output Feature Class.

E. Location and Storage of GIS Data and Products

For information on the location, storage and access to these data and results please send an inquiry email to arles@fws.gov.

F. Reference: Spatial Analysis Tables

Table B.1. Data Layers used in the LEPC SSA spatial analysis.

Data Layer	Application(s)	Source	Acquisition/Location
LandFire 2016 (EVT)	Primary Usability Layer/Forest Cover Impacts & Geographic Constraint	U.S. Department of Agriculture, Forest Service and U.S. Department of Interior	https://www.landfire.gov/
LandFire 2016 (Slope)	Exclusion Layer; Canyon Breaks	U.S. Department of Agriculture, Forest Service and U.S. Department of Interior	https://www.landfire.gov/
NLCD 2016 Land Cover Data	Urban Exclusions/Forest Cover Impacts & Geographic Constraint	Multi-Resolution Land Characteristics Consortium of 10 Agencies	https://www.mrlc.gov/
TIGER Line Data	Exclusions; Roads/Railroads & Urban Footprint	U.S. Census Bureau	https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html
Oil & Gas (O&G) well locations	O&G Impact Layer & Geographic Constraint	IHS-Homeland Security	https://ihsmarkit.com/energy
Texas O&G Wells	Future Projections	Texas Railroad Commission	https://www.rrc.state.tx.us/about-us/resource-center/research/data-sets-available-for-download/#digital-map-data-table
New Mexico O&G Wells	Future Projections	New Mexico EMNRD	http://www.emnrd.state.nm.us/OCD/ocdgis.html
Colorado O&G Wells	Future Projections	Colorado Oil & Gas Conservation Commission	https://cogcc.state.co.us/data.html
Oklahoma O&G Wells	Future Projections	OK Conservation Commission	https://www.occeweb.com/OG/ogforms.html
Kansas O&G Wells	Future Projections	Kansas Geological Survey	http://www.kgs.ku.edu/PRS/petroDB.html
Transmission Lines	Exclusion Layer	Platts (S&P Global)	Provided by Region 6 (licensing agreement)
Urban Footprints	Exclusion Layer	ESRI, Inc.	In-house Resource
Building Footprints	Exclusion Layer	Microsoft, Inc. through USGS	https://www.sciencebase.gov/catalog/item/5d27a8dfe4b0941bde650fc7

Data Layer	Application(s)	Source	Acquisition/Location
Ecoregion Boundaries/EOR (Updated)	Project Boundaries/Work Area	Interstate Working Group	Shared
EOR+10 Boundary	Reference/Data Collection Extent	Created from updated EOR	N/A
Percent Canopy Cover	Forest Cover Impact Layer	SGP CHAT	https://www.sgpchat.org/
CHAT FA's and CZ's	Conservation Geographic Constraint	SGP CHAT	https://www.sgpchat.org/
Buffered Current Known Lek Data	Reference/Quality Control (QC)	SGP CHAT	https://www.sgpchat.org/
Cropland Data Layer	Reference/QC	NRCS	https://www.nass.usda.gov/Research_and_Science/Cropland/SARS1a.php
Wetland/Riparian data	Exclusion Layer	USFWS-NWI	https://www.fws.gov/wetlands/data/Mapper.html
Tillage Likelihood	Crop Conversion Geographic Constraint	PLJV	Shared
Wind Turbines and tall structures	Impact Layer & Geographic Constraint	FAA (Digital Obstacle File)	https://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/dof/
Wind Turbines	Impact Layer & Geographic Constraint	USGS Wind Turbine Database	https://eerscmap.usgs.gov/uswtdb/
Crop/Non-Crop	Reference	WAFWA	Shared
Leks outside of EOR	Reference	WAFWA	Shared
RWP % Suitable	Reference/QC	WAFWA/SGP CHAT	Shared
PADUS 2.0	Conservation Geographic Constraint	USGS	https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap/science/protected-areas
PRISM Climate Data	Precipitation Geographic Constraint	NRCS PRISM	https://www.wcc.nrcs.usda.gov/climate/

Table B.2. LANDFIRE EVT classes and their relative usability ranking for LEPC SSA spatial analysis.

LANDFIRE EVT Name	LANDFIRE Value	USFWS LEPC Classification
Western Great Plains Sandhill Steppe	7094	Potential Usable Area
Apacherian-Chihuahuan Semi-Desert Shrub-Steppe	7121	Potential Usable Area
Chihuahuan Gypsophilous Grassland and Steppe	7122	Potential Usable Area
Inter-Mountain Basins Semi-Desert Shrub-Steppe	7127	Potential Usable Area
Central Mixedgrass Prairie Grassland	7132	Potential Usable Area
Chihuahuan Sandy Plains Semi-Desert Grassland	7133	Potential Usable Area
Western Great Plains Foothill and Piedmont Grassland	7147	Potential Usable Area

LANDFIRE EVT Name	LANDFIRE Value	USFWS LEPC Classification
Western Great Plains Sand Prairie	7148	Potential Usable Area
Western Great Plains Shortgrass Prairie	7149	Potential Usable Area
Western Great Plains Tallgrass Prairie	7150	Potential Usable Area
Recently Logged-Herb and Grass Cover	7191	Potential Usable Area
Recently Logged-Shrub Cover	7192	Potential Usable Area
Recently Burned-Herb and Grass Cover	7195	Potential Usable Area
Recently Burned-Shrub Cover	7196	Potential Usable Area
Recently Disturbed Other-Herb and Grass Cover	7198	Potential Usable Area
Central Mixedgrass Prairie Shrubland	7207	Potential Usable Area
Apacherian-Chihuahuan Semi-Desert Grassland	7256	Potential Usable Area
Southeastern Great Plains Tallgrass Prairie	7423	Potential Usable Area
Chihuahuan Loamy Plains Desert Grassland	7503	Potential Usable Area
Chihuahuan-Sonoran Desert Bottomland and Swale Grassland	7504	Potential Usable Area
Western Cool Temperate Pasture and Hayland	7967	Potential Usable Area
Inter-Mountain Basins Active and Stabilized Dune	9004	Potential Usable Area
North American Warm Desert Active and Stabilized Dune	9145	Potential Usable Area
Northern & Central Plains Ruderal & Planted Shrubland	9316	Potential Usable Area
Great Plains Comanchian Ruderal Shrubland	9325	Potential Usable Area
Northern & Central Plains Ruderal & Planted Grassland	9816	Potential Usable Area
Great Plains Comanchian Ruderal Grassland	9825	Potential Usable Area
Western Great Plains Mesquite Shrubland	7111	Potential Woody Veg. Restoration
Madrean Juniper Savanna	7116	Potential Woody Veg. Restoration
Recently Burned-Tree Cover	7197	Potential Woody Veg. Restoration
Recently Disturbed Other-Shrub Cover	7199	Potential Woody Veg. Restoration
Western Cool Temperate Developed Ruderal Evergreen Forest	7921	Potential Woody Veg. Restoration
Eastern Cool Temperate Developed Ruderal Shrubland	7933	Potential Woody Veg. Restoration
Western Great Plains Floodplain Herbaceous	9527	Potential Woody Veg. Restoration
Western Cool Temperate Row Crop - Close Grown Crop	7963	Potential Land Use Conversion
Western Cool Temperate Row Crop	7964	Potential Land Use Conversion
Western Cool Temperate Close Grown Crop	7965	Potential Land Use Conversion
Western Cool Temperate Fallow/Idle Cropland	7966	Potential Land Use Conversion
Western Cool Temperate Wheat	7968	Potential Land Use Conversion

LANDFIRE EVT Name	LANDFIRE Value	USFWS LEPC Classification
Eastern Cool Temperate Row Crop - Close Grown Crop	7973	Potential Land Use Conversion
Eastern Cool Temperate Row Crop	7974	Potential Land Use Conversion
Eastern Cool Temperate Close Grown Crop	7975	Potential Land Use Conversion
Eastern Cool Temperate Fallow/Idle Cropland	7976	Potential Land Use Conversion
Eastern Cool Temperate Pasture and Hayland	7977	Potential Land Use Conversion
Eastern Cool Temperate Wheat	7978	Potential Land Use Conversion
Western Warm Temperate Row Crop - Close Grown Crop	7983	Potential Land Use Conversion
Western Warm Temperate Row Crop	7984	Potential Land Use Conversion
Western Warm Temperate Close Grown Crop	7985	Potential Land Use Conversion
Western Warm Temperate Fallow/Idle Cropland	7986	Potential Land Use Conversion
Western Warm Temperate Wheat	7988	Potential Land Use Conversion
North American Warm Desert Ruderal & Planted Grassland	9810	Potential Land Use Conversion
Western Great Plains Dry Bur Oak Forest and Woodland	7013	Non-Usable
Madrean Encinal	7023	Non-Usable
Madrean Pinyon-Juniper Woodland	7025	Non-Usable
Rocky Mountain Foothill Limber Pine-Juniper Woodland	7049	Non-Usable
Southern Rocky Mountain Ponderosa Pine Woodland	7054	Non-Usable
Southern Rocky Mountain Pinyon-Juniper Woodland	7059	Non-Usable
Chihuahuan Creosotebush Desert Scrub	7074	Non-Usable
Chihuahuan Mixed Salt Desert Scrub	7075	Non-Usable
Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub	7076	Non-Usable
Chihuahuan Succulent Desert Scrub	7077	Non-Usable
Inter-Mountain Basins Mixed Salt Desert Scrub	7081	Non-Usable
Rocky Mountain Lower Montane-Foothill Shrubland	7086	Non-Usable
Chihuahuan Mixed Desert and Thornscrub	7100	Non-Usable
Madrean Oriental Chaparral	7101	Non-Usable
Rocky Mountain Gambel Oak-Mixed Montane Shrubland	7107	Non-Usable
Southern Rocky Mountain Ponderosa Pine Savanna	7117	Non-Usable
Southern Rocky Mountain Juniper Woodland and Savanna	7119	Non-Usable
Inter-Mountain Basins Greasewood Flat	7153	Non-Usable
Recently Logged-Tree Cover	7193	Non-Usable
Recently Disturbed Other-Tree Cover	7200	Non-Usable
Open Water	7292	Non-Usable

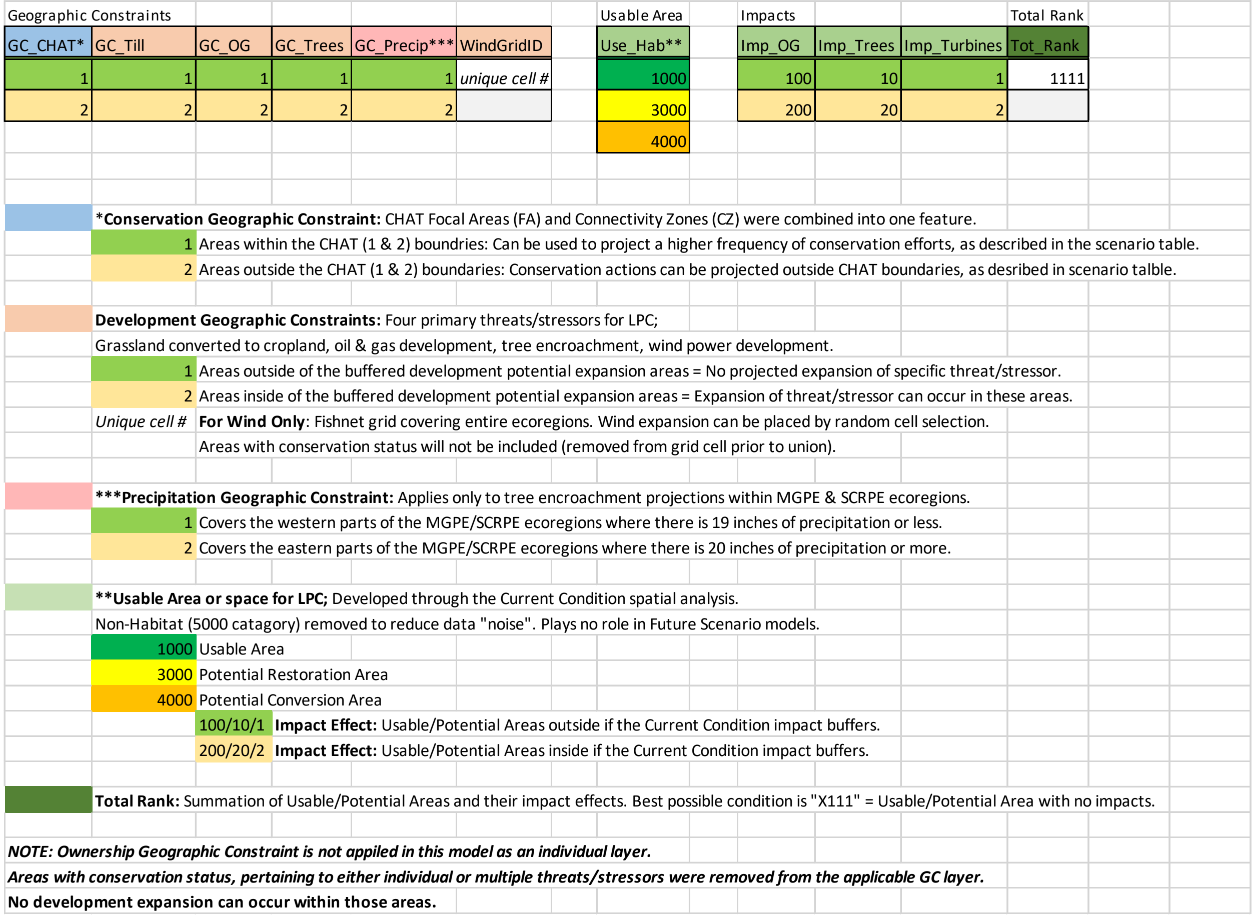
LANDFIRE EVT Name	LANDFIRE Value	USFWS LEPC Classification
Quarries-Strip Mines-Gravel Pits-Well and Wind Pads	7295	Non-Usable
Developed-Low Intensity	7296	Non-Usable
Developed-Medium Intensity	7297	Non-Usable
Developed-High Intensity	7298	Non-Usable
Developed-Roads	7299	Non-Usable
Crosstimbers Oak Forest and Woodland	7308	Non-Usable
Edwards Plateau Limestone Savanna and Woodland	7383	Non-Usable
Great Plains Wooded Draw and Ravine Woodland	7385	Non-Usable
Western Cool Temperate Urban Deciduous Forest	7900	Non-Usable
Western Cool Temperate Urban Evergreen Forest	7901	Non-Usable
Western Cool Temperate Urban Mixed Forest	7902	Non-Usable
Western Cool Temperate Urban Herbaceous	7903	Non-Usable
Western Cool Temperate Urban Shrubland	7904	Non-Usable
Eastern Cool Temperate Urban Deciduous Forest	7905	Non-Usable
Eastern Cool Temperate Urban Evergreen Forest	7906	Non-Usable
Eastern Cool Temperate Urban Mixed Forest	7907	Non-Usable
Eastern Cool Temperate Urban Herbaceous	7908	Non-Usable
Eastern Cool Temperate Urban Shrubland	7909	Non-Usable
Western Warm Temperate Urban Deciduous Forest	7910	Non-Usable
Western Warm Temperate Urban Evergreen Forest	7911	Non-Usable
Western Warm Temperate Urban Mixed Forest	7912	Non-Usable
Western Warm Temperate Urban Herbaceous	7913	Non-Usable
Western Warm Temperate Urban Shrubland	7914	Non-Usable
Western Cool Temperate Developed Ruderal Deciduous Forest	7920	Non-Usable
Western Cool Temperate Developed Ruderal Mixed Forest	7922	Non-Usable
Western Cool Temperate Developed Ruderal Shrubland	7923	Non-Usable
Western Cool Temperate Developed Ruderal Grassland	7924	Non-Usable
Western Warm Temperate Developed Ruderal Deciduous Forest	7925	Non-Usable
Western Warm Temperate Developed Ruderal Evergreen Forest	7926	Non-Usable
Western Warm Temperate Developed Ruderal Shrubland	7928	Non-Usable
Western Warm Temperate Developed Ruderal Grassland	7929	Non-Usable
Eastern Cool Temperate Developed Ruderal Deciduous Forest	7930	Non-Usable
Eastern Cool Temperate Developed Ruderal Mixed Forest	7932	Non-Usable
Eastern Cool Temperate Developed Ruderal Grassland	7934	Non-Usable
Western Cool Temperate Developed Ruderal Deciduous Forested Wetland	7940	Non-Usable
Western Cool Temperate Developed Ruderal Mixed Forested Wetland	7942	Non-Usable
Western Cool Temperate Developed Ruderal Shrub Wetland	7943	Non-Usable
Western Cool Temperate Developed Ruderal Herbaceous Wetland	7944	Non-Usable
Eastern Cool Temperate Developed Ruderal Deciduous Forested Wetland	7950	Non-Usable
Eastern Cool Temperate Developed Ruderal Shrub Wetland	7953	Non-Usable

LANDFIRE EVT Name	LANDFIRE Value	USFWS LEPC Classification
Eastern Cool Temperate Developed Ruderal Herbaceous Wetland	7954	Non-Usable
Western Cool Temperate Orchard	7960	Non-Usable
Western Warm Temperate Orchard	7980	Non-Usable
Inter-Mountain Basins Shale Badland	9009	Non-Usable
North American Arid West Emergent Marsh	9011	Non-Usable
Western Great Plains Cliff and Outcrop	9024	Non-Usable
Western Great Plains Closed Depression Wetland	9025	Non-Usable
Western Great Plains Floodplain Forest and Woodland	9026	Non-Usable
Western Great Plains Open Freshwater Depression Wetland	9027	Non-Usable
Western Great Plains Riparian Woodland	9028	Non-Usable
Western Great Plains Saline Depression Wetland	9029	Non-Usable
North American Warm Desert Riparian Woodland	9034	Non-Usable
North American Warm Desert Lower Montane Riparian Woodland	9035	Non-Usable
Llano Estacado Caprock Escarpment and Breaks Shrubland and Steppe	9121	Non-Usable
North American Warm Desert Badland	9146	Non-Usable
North American Warm Desert Bedrock Cliff and Outcrop	9147	Non-Usable
North American Warm Desert Cienega	9148	Non-Usable
North American Warm Desert Pavement	9150	Non-Usable
North American Warm Desert Playa	9151	Non-Usable
North American Warm Desert Riparian Mesquite Bosque Woodland	9152	Non-Usable
North American Warm Desert Wash Woodland	9154	Non-Usable
Southwestern Great Plains Canyon	9265	Non-Usable
Madrean Mesic Canyon Forest and Woodland	9289	Non-Usable
North American Warm Desert Ruderal & Planted Scrub	9310	Non-Usable
Northern & Central Native Ruderal Forest	9315	Non-Usable
Southeastern Native Ruderal Forest	9321	Non-Usable
Interior West Ruderal Riparian Forest	9327	Non-Usable
Western Great Plains Floodplain Shrubland	9526	Non-Usable
Western Great Plains Riparian Shrubland	9528	Non-Usable
Western Great Plains Riparian Herbaceous	9529	Non-Usable
North American Warm Desert Riparian Herbaceous	9533	Non-Usable
North American Warm Desert Riparian Shrubland	9534	Non-Usable
North American Warm Desert Lower Montane Riparian Shrubland	9535	Non-Usable
North American Warm Desert Riparian Mesquite Bosque Shrubland	9652	Non-Usable
North American Warm Desert Wash Shrubland	9654	Non-Usable
Interior West Ruderal Riparian Scrub	9827	Non-Usable

Table B.3. Impact radii/buffer distances used in LEPC SSA spatial analysis. Detailed descriptions and definitions of features are available on-line from the source agency.

Feature	Layer	Buffer (Meters)	Buffer - 2 (Meters)	Comments	Source(s)
Airport or Airfield	Exclusion	1000			US Census/TIGER
Runway/Taxiway	Exclusion	1000			US Census/TIGER
Power Line (Operational only)	Exclusion	700		Greater than 69kv	Platts
Power Line (Operational only)	Exclusion	700		Less than 69kv	Platts
Railroad Feature (Main, Spur, or Yard)	Exclusion	67			US Census/TIGER
Primary Road	Exclusion	850			US Census/TIGER
Secondary Road	Exclusion	850			US Census/TIGER
Local Neighborhood Road, Rural Road, City Street	Exclusion	67			US Census/TIGER
Ramp	Exclusion	850			US Census/TIGER
Service Drive (limited access highway)	Exclusion	850			US Census/TIGER
Parking Lot Road	Exclusion	67			US Census/TIGER
BLDG	Exclusion	200			FAA
BLDG-TWR	Exclusion	1000			FAA
CTRL TWR	Exclusion	200			FAA
ELEC SYS	Exclusion	200			FAA
ELEVATOR	Exclusion	200	1000 (grter than 40ft.)		FAA
NAVAID	Exclusion	200 (grter than 40ft.)			FAA
PLANT	Exclusion	200			FAA
POLE	Exclusion	200 (grter than 40ft.)			FAA
REFINERY	Exclusion	1000			FAA
SIGN	Exclusion	200			FAA
STACK	Exclusion	1000			FAA
TANK	Exclusion	200 (grter than 40ft.)			FAA
T-L TWR	Exclusion	200 (grter than 40ft.)			FAA
TOWER	Exclusion	200 (grter than 40ft.)	667 (grter than 150ft.)		FAA
WINDMILL	Impact	1800			FAA/USGS
Urban Footprint	Exclusion	667			ESRI, Inc.
Building Footprint	Exclusion	No Buffer		900 sq. m or larger only	Microsoft, Inc. USGS
Oil & Gas well (Surface)	Impact	300			IHS
Trees (SGPE, MGPE, SBBPE)	Impact	329			USGS/NRCS
Trees (SSOPE)	Impact	224			USGS/NRCS

Table B.4. Spatial data model for future scenarios.



Geographic Constraints						Usable Area	Impacts			Total Rank
GC_CHAT*	GC_Till	GC_OG	GC_Trees	GC_Precip***	WindGridID	Use_Hab**	Imp_OG	Imp_Trees	Imp_Turbines	Tot_Rank
1	1	1	1	1	*unique cell #*	1000	100	10	1	1111
2	2	2	2	2		3000	200	20	2	
						4000				

*Conservation Geographic Constraint:** CHAT Focal Areas (FA) and Connectivity Zones (CZ) were combined into one feature.

1 Areas within the CHAT (1 & 2) boundries: Can be used to project a higher frequency of conservation efforts, as described in the scenario table.

2 Areas outside the CHAT (1 & 2) boundaries: Conservation actions can be projected outside CHAT boundaries, as desribed in scenario talble.

Development Geographic Constraints: Four primary threats/stressors for LPC;
Grassland converted to cropland, oil & gas development, tree encroachment, wind power development.

1 Areas outside of the buffered development potential expansion areas = No projected expansion of specific threat/stressor.

2 Areas inside of the buffered development potential expansion areas = Expansion of threat/stressor can occur in these areas.

Unique cell # **For Wind Only**: Fishnet grid covering entire ecoregions. Wind expansion can be placed by random cell selection.
Areas with conservation status will not be included (removed from grid cell prior to union).

*****Precipitation Geographic Constraint:** Applies only to tree encroachment projections within MGPE & SCRPE ecoregions.

1 Covers the western parts of the MGPE/SCRPE ecoregions where there is 19 inches of precipitation or less.

2 Covers the eastern parts of the MGPE/SCRPE ecoregions where there is 20 inches of precipitation or more.

****Usable Area or space for LPC;** Developed through the Current Condition spatial analysis.
Non-Habitat (5000 catagory) removed to reduce data "noise". Plays no role in Future Scenario models.

1000 Usable Area

3000 Potential Restoration Area

4000 Potential Conversion Area

100/10/1 **Impact Effect:** Usable/Potential Areas outside if the Current Condition impact buffers.

200/20/2 **Impact Effect:** Usable/Potential Areas inside if the Current Condition impact buffers.

Total Rank: Summation of Usable/Potential Areas and their impact effects. Best possible condition is "X111" = Usable/Potential Area with no impacts.

NOTE: Ownership Geographic Constraint is not appiled in this model as an individual layer.

Areas with conservation status, pertaining to either individual or multiple threats/stressors were removed from the applicable GC layer.

No development expansion can occur within those areas.

Part 2. Development of Geographic Constraint and Impact Data Layers

A. *Geographic Constraint GIS Datasets*

These layers are large landscape features, developed for the Future Scenarios, which can drive or focus where changes or effects on the landscape might occur with higher (or lower) frequency.

1. Oil and Gas Geographic Constraint

- Original input data
  - IHS US Well Data; downloaded through the Enerdeq Map Browser (HIS Markit Energy Products website). USFWS access through paid contract; USFWS, Region 6 Regional Office, Lakewood, Colorado. IHS Markit website, https://ihsmarkit.com/index.html

- Processing
  - The geographic constraint for oil and gas wells was derived from processing IHS OG Wells Surface data, and some assumptions as stated below. The initial downloaded well data contained 276,862 records, covering the EOR+ 10 areas. Using attribute information from FINAL_STAT and FINAL_CODE fields, as cross walked with IHS Data Dictionary information for WELL STATUS and WELL CLASS, and reviews of subsets of the dataset as overlaid on recent aerial photography, the original dataset was reduced to account for well locations that were likely still in operation and/or had infrastructure still on the site. This reduction resulted in the final dataset used to create the oil and gas geographic constraint having 111,945 records. The list of FINAL_STAT codes and expanded names for wells used in the development of the oil and gas geographic constraint are provided below (Table B.5).

  The construction of the Oil & Gas Geographic Constraint are as follows:

  - All final dataset points within the EOR+10 areas were buffered 3218 meters (2 miles).
  - The buffer polygons were dissolved to remove overlap.
  - The buffer layers were clipped to each of the four ecoregion boundaries.
  - A “Gridcode” attribute field was added to each new dissolved polygon, Value=1.
  - The polygons rasterized, 30-m cell size, snapped to Current Condition raster for each ecoregion. This is done so the new raster layer aligns with other 30-m raster layer, avoiding slivers/gaps.
  - New raster layer is combined with a 30-m background grid to give in/out area. Cell Statistics used to combine, SUM overlay statistic. Cell values reclassified to 1 = Outside potential OG development, 2 = Inside potential OG development.
  - Rasters converted back to (vector) polygons for final union. Acreage and **GC_OG** selection fields added. This is done because the Future Scenario selection scripts only run on vector data.

The resulting vector polygon output was used to geographically constrain the development of oil and gas (i.e., development allowed within, but not outside, the polygon) in the future scenarios portion of the LEPC SSA GIS modeling.

- Uses
  - This layer is used as the method to narrow to only a portion of the analysis area allowed to be considered for oil and gas developments in the future scenario modeling. The resulting layer is illustrated in Figure B.7.

- Assumptions
  - Once processed as stated above, the IHS oil and gas well data are a conservative approximation of the occurrence of active well locations. The original input data relies upon multiple other sources (e.g., state permitting agency) for reporting and is known to have errors associated with imprecise or incorrect locations reported and well locations not reported in the database.
  - Past oil and gas development is indicative of ongoing activities and future development likelihood. The use of occurrence of wells and a defined extent around them is reasonable method for estimating the location where much of the future oil and gas development activities will occur in the modeled area. We acknowledge that some development will likely occur outside the geographic constraint, but we believe the majority will occur within the polygon.

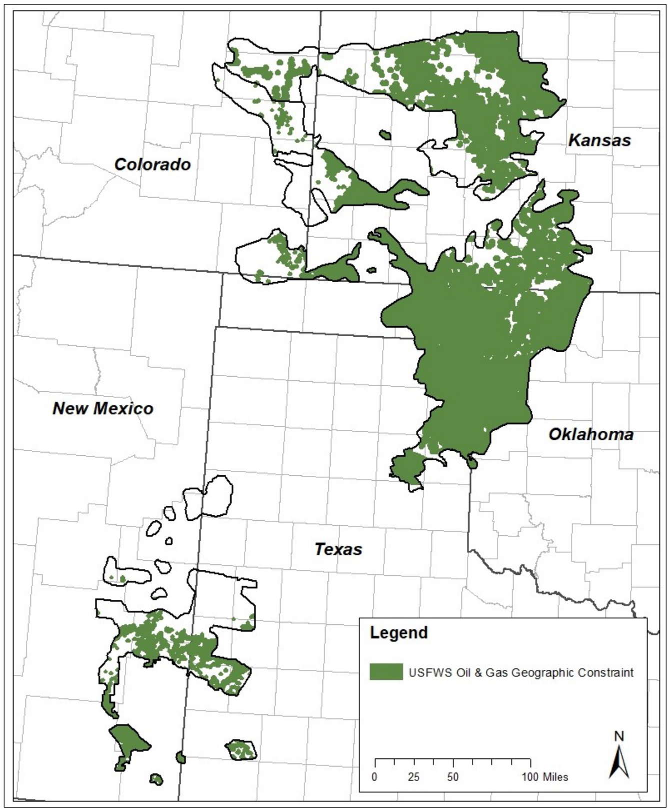


Figure B.7. U.S. Fish and Wildlife Service Oil and Gas Geographic Constraint Modeling Layer. Areas in green are where oil and gas development can occur in model runs.

Table B.5. List of IHS well data as identified by FINAL_STAT attribution used in construction of Oil and Gas Geographic Constraint layer used in LEPC SSA GIS modeling.

	FINAL_STAT	FINAL_STAT_DEFINITIONS
1	1G&1IW	1 GAS & 1 INJECTION WELL WORKOVER
2	1G&1WI	1 GAS & 1 WATER INJECTION WELL
3	1G1WIW	1 GAS & 1 WATER INJECTION WELL WORKOVER
4	1O&1G	1 OIL & 1 GAS WELL
5	1O&1GW	1 OIL & 1 GAS WELL WORKOVER
6	1O&1I	1 OIL & 1 INJECTION WELL
7	1O&1IW	1 OIL & 1 INJECTION WELL WORKOVER
8	1O&1S	1 OIL & 1 SERVICE WELL
9	1O&1SW	1 OIL & 1 SERVICE WELL WORKOVER
10	1O&1WI	1 OIL & 1 WATER INJECTION WELL
11	1O&2G	1 OIL & 2 GAS WELL
12	1O&2GW	1 OIL & 2 GAS WELL WORKOVER
13	1O&3G	1 OIL & 3 GAS WELL
14	1O&4G	1 OIL & 4 GAS WELL
15	1O1I1S	1 OIL & 1 INJECTION & 1 SERVICE WELL
16	1O1WIW	1 OIL & 1 WATER INJECTION WELL WORKOVER
17	1WI1SW	1 WATER INJECTION & 1 SERVICE WELL WORKOVER
18	2G&1WI	2 GAS & 1 WATER INJECTION WELL
19	2GAS	2 GAS MULTIPLE PRODUCER
20	2GASWO	OLD WELL WORKED OVER-COMPLETED AS 2 MULTIPLE GAS
21	2O&1G	2 OIL & 1 GAS WELL
22	2O&1GW	2 OIL & 1 GAS WELL WORKOVER
23	2O&1I	2 OIL & 1 INJECTION WELL
24	2O&1WI	2 OIL & 1 WATER INJECTION WELL
25	2O&2G	2 OIL & 2 GAS WELL
26	2OIL	2 OIL MULTIPLE PRODUCER
27	2OILWO	OLD WELL WORKED OVER-COMPLETED AS 2 MULTIPLE OIL
28	3GAS	3 GAS MULTIPLE PRODUCER
29	3GASWO	OLD WELL WORKED OVER-COMPLETED AS 3 MULTIPLE GAS
30	3O&1G	3 OIL & 1 GAS WELL
31	3O&1GW	3 OIL & 1 GAS WELL WORKOVER
32	3O&3G	3 OIL & 3 GAS WELL
33	3OIL	3 OIL MULTIPLE PRODUCER
34	3OILWO	OLD WELL WORKED OVER-COMPLETED AS 3 MULTIPLE OIL
35	4GAS	4 GAS MULTIPLE PRODUCER
36	4OIL	4 OIL MULTIPLE PRODUCER
37	4OILWO	OLD WELL WORKED OVER-COMPLETED AS 4 MULTIPLE OIL
38	5GAS	5 GAS MULTIPLE PRODUCER

	FINAL_STAT	FINAL_STAT_DEFINITIONS
39	7GAS	7 GAS MULTIPLE PRODUCER
40	GAS	GAS PRODUCER
41	GAS-CB	GAS-COALBED METHANE PRODUCER
42	GAS-WO	GAS PRODUCER-OLD WELL WORKED OVER
43	IOD-G	IODINE WELL-GAS SHOWS
44	IODINE	IODINE PRODUCER
45	IODW	IODINE WELL-OLD WELL WORKED OVER
46	IODWG	IODINE WELL-OLD WELL WORKED OVER-GAS SHOWS
47	O&G-WO	OIL & GAS PRODUCER-OLD WELL WORKED OVER
48	OIL	OIL PRODUCER
49	OIL-WO	OIL PRODUCER-OLD WELL WORKED OVER
50	OSTG	OIL STORAGE

Table B.6. List of IHS well data as identified by FINAL_STAT attribution ***not*** used in construction of Oil and Gas Geographic Constraint layer used in LEPC SSA GIS modeling.

	FINAL_STAT	FINAL_STAT_DEFINITIONS
1	1G&1S	1 GAS & 1 SERVICE WELL
2	1G&1SW	1 GAS & 1 SERVICE WELL WORKOVER
3	ABD-GSTG	ABANDONED GAS STORAGE WELL
4	ABD-GW	ABANDONED GAS PRODUCER
5	ABD-IW	ABANDONED INJECTION WELL
6	ABDOGW	ABANDONED COMBINATION OIL & GAS PRODUCER
7	ABD-OW	ABANDONED OIL PRODUCER
8	ABD-SW	ABANDONED SERVICE WELL
9	ABD-SWD	ABANDONED SALT WATER DISPOSAL
10	ABD-WTRSUP	ABANDONED WATER SUPPLY WELL
11	AB-LOC	ABANDON LOCATION
12	AT-TD	AT TOTAL DEPTH
13	BRINE	BRINE WELL
14	CANCEL	CANCELLED PERMIT-WORKOVER
15	CATHODIC	CATHODIC PROTECTION
16	CO2IJW	CARBON DIOXIDE INJECTION WELL WORKOVER
17	CO2INJ	CARBON DIOXIDE INJECTION WELL
18	CO2W	CARBON DIOXIDE PRODUCER-OLD WELL WORKED OVER
19	D&A	DRY & ABANDONED
20	D&A-G	DRY & ABANDONED-GAS SHOWS
21	D&A-O	DRY & ABANDONED-OIL SHOWS
22	D&A-OG	DRY & ABANDONED-OIL & GAS SHOWS
23	D&AW	DRY & ABANDONED-OLD WELL WORKED OVER

	FINAL_STAT	FINAL_STAT_DEFINITIONS
24	D&AWG	DRY & ABANDONED-OLD WELL WORKED OVER-GAS SHOWS
25	D&AWO	DRY & ABANDONED-OLD WELL WORKED OVER-OIL SHOWS
26	D&AWOG	DRY & ABANDONED-OLD WELL WORKED OVER-OIL & GAS SHOWS
27	G-INJ	GAS INJECTION WELL
28	G-INJW	GAS INJECTION WELL-OLD WELL WORKED OVER
29	GI-O	GAS INJECTION WELL-OIL SHOWS
30	GSTG	GAS STORAGE WELL
31	GSTG-O	GAS STORAGE WELL - OIL SHOWS
32	GSTGW	GAS STORAGE WELL-OLD WELL WORKED OVER
33	I-G	UNDESIGNATED INJECTION WELL-GAS SHOWS
34	INJ	UNDESIGNATED INJECTION WELL
35	INJW	UNDESIGNATED INJECTION WELL-OLD WELL WORKED OVER
36	INJW-O	UNDESIGNATED INJECTION WELL-OLD WELL WORKED OVER-OIL SHOWS
37	INSITU	INSITU COMBUSTION WELL
38	O-INJ	OIL INJECTION WELL
39	I-O	UNDESIGNATED INJECTION WELL-OIL SHOWS
40	I-OG	UNDESIGNATED INJECTION WELL-OIL & GAS SHOWS
41	J&A	JUNKED & ABANDONED
42	J&A-G	JUNKED & ABANDONED-GAS SHOWS
43	J&A-O	JUNKED & ABANDONED-OIL SHOWS
44	J&A-OG	JUNKED & ABANDONED-OIL & GAS SHOWS
45	J&AW	JUNKED & ABANDONED-OLD WELL WORKED OVER
46	J&AWG	JUNKED & ABANDONED-OLD WELL WORKED OVER-GAS SHOWS
47	J&AWO	JUNKED & ABANDONED-OLD WELL WORKED OVER-OIL SHOWS
48	MONITOR	MONITOR WELL - NO SHOWS
49	MONTW	MONITOR WELL-OLD WELL WORKED OVER
50	OBSERV	OBSERVATION WELL-NO SHOWS
51	OBS-G	OBSERVATION WELL-GAS SHOWS
52	OBS-O	OBSERVATION WELL-OIL SHOWS
53	OBS-OG	OBSERVATION WELL-OIL & GAS SHOWS
54	OBSW	OBSERVATION WELL-OLD WELL WORKED OVER
55	PERMIT	WELL PERMIT
56	PILOT	PILOT HOLE
57	PILOTW	PILOT HOLE - OLD WELL WORKOVER
58	PSEUDO	PSEUDO-ORIGINAL WELL - UNKNOWN CLASS
59	SALT	SALT PRODUCER
60	SALW	SALT PRODUCER-OLD WELL WORKED OVER
61	SALWOG	SALT PRODUCER-OLD WELL WORKED OVER-OIL & GAS SHOWS
62	SERVCE	SERVICE WELL-DISPOSAL, WATER SUPPLY, ETC
63	SERVG	SERVICE WELL-GAS SHOWS
64	SERVO	SERVICE WELL-OIL SHOWS

	FINAL_STAT	FINAL_STAT_DEFINITIONS
65	SERVOG	SERVICE WELL-OIL & GAS SHOWS
66	SERW	SERVICE WELL-OLD WELL WORKED OVER
67	SERWG	SERVICE WELL-OLD WELL WORKED OVER-GAS SHOWS
68	SERWO	SERVICE WELL-OLD WELL WORKED OVER-OIL SHOWS
69	SERWOG	SERVICE WELL-OLD WELL WORKED OVER-OIL & GAS SHOWS
70	SF-PLUG	STATE FUNDED PLUG
71	SPUD-ABD	SPUD AND ABANDONED
72	START	WELL START
73	STEAM	STEAM INJECTION WELL
74	SUS	SUSPENDED WELL
75	SUS-G	SUSPENDED WELL-GAS SHOWS
76	SUS-O	SUSPENDED WELL-OIL SHOWS
77	SUS-W	SUSPENDED WELL-OLD WELL WORKED OVER
78	SWD	SALT WATER DISPOSAL
79	SWDCOM	SALT WATER DISPOSAL COMMERCIAL
80	SWDCOM-WO	SALT WATER DISPOSAL COMMERCIAL WELL WORKED OVER
81	SWDOP	SALT WATER DISPOSAL O&G OPERATOR
82	SWDOP-WO	SALT WATER DISPOSAL O&G OPERATOR WELL WORKED OVER
83	SWD-WO	SALT WATER DISPOSAL WELL WORKED OVER
84	TA	TEMPORARILY ABANDONED
85	TA-G	TEMPORARILY ABANDONED-GAS SHOWS
86	TA-O	TEMPORARILY ABANDONED-OIL SHOWS
87	TA-OG	TEMPORARILY ABANDONED-OIL & GAS SHOWS
88	TAW	TEMPORARILY ABANDONED-OLD WELL WORKED OVER
89	TAWG	TEMPORARILY ABANDONED-OLD WELL WORKED OVER-GAS SHOWS
90	TAWO	TEMPORARILY ABANDONED-OLD WELL WORKED OVER-OIL SHOWS
91	TAWOG	TEMPORARILY ABANDONED-OLD WELL WORKED OVER-OIL & GAS SHOWS
92	TREATD	TREATED PENDING COMPLETION
93	UNKWN	UNKNOWN STATUS
94	WI-EOR	WATER INJECTION - ENHANCED OIL RECOVERY
95	WI-G	WATER INJECTION WELL-GAS SHOWS
96	W-INJ	WATER INJECTION WELL
97	W-INJW	WATER INJECTION WELL-OLD WELL WORKED OVER
98	WI-O	WATER INJECTION WELL-OIL SHOWS
99	WI-OG	WATER INJECTION WELL-OIL & GAS SHOWS
100	WIWO	WATER INJECTION WELL-OLD WELL WORKED OVER-OIL SHOWS
101	WTRSUP	WATER SUPPLY WELL
102	WTRSUP-WO	WATER SUPPLY WELL WORKED OVER

2. Wind Energy Development Geographic Constraint

- Original input data:
  - Not applicable because this was a dataset created by USFWS.

- USFWS-created dataset. A rectangular "fishnet" grid, with a 35,000-acre cell size, was generated using ArcGIS 10.6.1 using parameters listed below.

- Processing
  - The creation of the fishnet grid defined the extent as the LEPC SSA analysis area. It used a row height of approximately 8,070 m and column widths of 17,550 m for a total area of 34,997 acres (closest size to 35,000 achievable with 30m by 30 m pixel size). This resulted in 927 grid cells across the EOR extent.
  - The grid created from resampled 30 m raster (cell size=17,550m x 8070m, or 585 pixels x 269 pixels = 34,997 acres).
  - The new raster was converted to center points (Conversion Tool - Rater to Points).
  - Points used to build fishnet grid (Data Management Tool - Sampling). Resampled raster parameters used to construct grid.
  - The new grid was clipped to each ecoregion. Grid cells match all 30m raster data (Snap Raster). Area = 34,997 acres.
  - A unique ID assigned to each cell (transfer/copy OID field to new ID field=**WindGridID**)

- Description

  The grid dimensions were used to approximate the recent trend in typical wind energy developments in the southern Great Plains when individual turbines are buffered by 1,800 m. We used data from the United States Wind Turbine Database (ver. 3.0.1, May 2020; https://eerscmap.usgs.gov/uswtdb/) and the 1800-m impact radius to standardize the calculation of density of turbines in relation to the potential indirect impacts if developed in LEPC habitat. These wind energy developments generally consist of long strings of turbines with rows that are longer East to West than they are North to South. The total area of the individual fishnet grid were based on an analysis of a subset of wind turbine projects (i.e., > 19 turbines in a project, and had complete attribution) from the United States Wind Turbine Database that occurred in or near the analysis area. Data from the last five years showed a significant increase in relative density of wind energy developments over earlier developments. Methods used for this SSA analysis were similar to those used by the Service in previous analysis characterizing wind energy development (USFWS 2016a). They were originally used to evaluate impact radii distances of wind energy developments (USFWS 2016b) for assessing effects of wind energy and in assessing landscapes for conservation potential (USFWS 2014a).

- Uses
  - This layer is used as the method to semi-randomly select the location of model wind energy developments in the future scenario modeling.

- Assumptions
  - The use of the USFWS fishnet grid to define location of future wind projects is reasonable for our modeling analysis. The selected grid parameters are representative of the recent trend (last 5 years) of area encompassed by wind energy developments in or adjacent to the range when individual wind turbines are buffed by 1,800 m.

    - USFWS considered further geographically constraining wind energy development potential by using only areas identified as having wind energy potential of greater than 6 meters per second identified the NREL/AWS Truewind 80 m (262.5 ft) wind energy resource potential models. However, due to increasing trend in higher turbine hub heights and the greater wind resource classes at greater heights, we chose to allow for wind developments to occur randomly within the created USFWS wind energy development fishnet grid due to widespread access to greater than 6 meters per second wind resource classes through the majority of the modeled area.

3. Precipitation Geographic Constraint

- Original input data:
    - Parameter-elevation Regressions on Independent Slopes Model (PRISM) climate data, Average Annual Precipitation (1981–2010) by State as provided by Natural Resource Conservation Service (NRCS) through Geospatial Data Gateway (https://datagateway.nrcs.usda.gov/)

- Processing
    - Vector shapefiles for each State were downloaded from Geospatial Data Gateway. Data depict interpolated one-inch precipitation zones using PRISM methods that were derived from gridded point estimates. The data indicates a trend of predominantly wetter (East) to drier (West) in the analysis area.
    - Individual state data were grouped (merged) into one dataset, then intersected and clipped to the analysis area, resulting in a range of 12–29 inches in the analysis area. A visual assessment of the location and extent of woody plant occurrences was evaluated using all available data depicting trees (NLCD, LandFire and NRCS Percent Canopy Cover). The assessment indicated a majority of tree encroachment depicted occurred in the eastern portion of the PRISM data at 20 inches or more of average annual precipitation.
    - For the purpose of the LEPC SSA Future Scenario modeling of woody plant encroachment focused on eastern red cedar we decided to implement two zones (Figure B.8.): 20 inches of average annual precipitation (eastern portions of the Short-Grass/CRP Ecoregion and Mixed-Grass Ecoregion) and 19 inches of average annual precipitation (western portions of the Short-Grass/CRP Ecoregion and Mixed-Grass Ecoregion and all of the Sand Sagebrush Ecoregion ecoregion). It should be noted all of the Shinnery Oak Ecoregion falls within the 19 inches or less zone, but the Geographic Constraint will not be used in this ecoregion due to the assumption that majority of woody plant encroachment comes from mesquite, not eastern red cedar.
    - These vector files are then converted to raster (resampled to 300 m cell size) and reclassified; Value: 1 = 19 inches or below, 2 = 20 inches or above. Values will reside in the **GC_Precip** field.

- Uses
    - This layer will only affect the treatment Woody Plant Encroachment in ecoregions (Mixed-Grass, Sand Sagebrush, and Short-Grass) that assume eastern red cedar encroachment in the Future Scenarios.
    - The treatment of trees in the western portions (19 inches or less) of the Mixed-Grass Ecoregion, Short-Grass/CRP Ecoregion, and all of the Sand Sagebrush Ecoregion will receive a lower change rates and smaller buffer size for the Woody Encroachment Geographic Constraint (4,023 m or 2.5 miles).

  - The treatment of trees in the eastern portions of the Mixed-Grass Ecoregion, Short-Grass/CRP Ecoregion, and the Shinnery Oak Ecoregion will maintain the higher change rates and larger 8,047 m (5 mile) buffer for the Geographic Constraint.

- Assumptions
  - The assessment of precipitation gradient and existing trees is a reasonable basis for differentiating the woody plant encroachment rates in the respective geographies.
  - When focused on eastern red cedar, Western areas of 19 inches or less should have lower rates of woody plant encroachment, while eastern areas of 20 inches or more should have higher rates of woody plant encroachment.

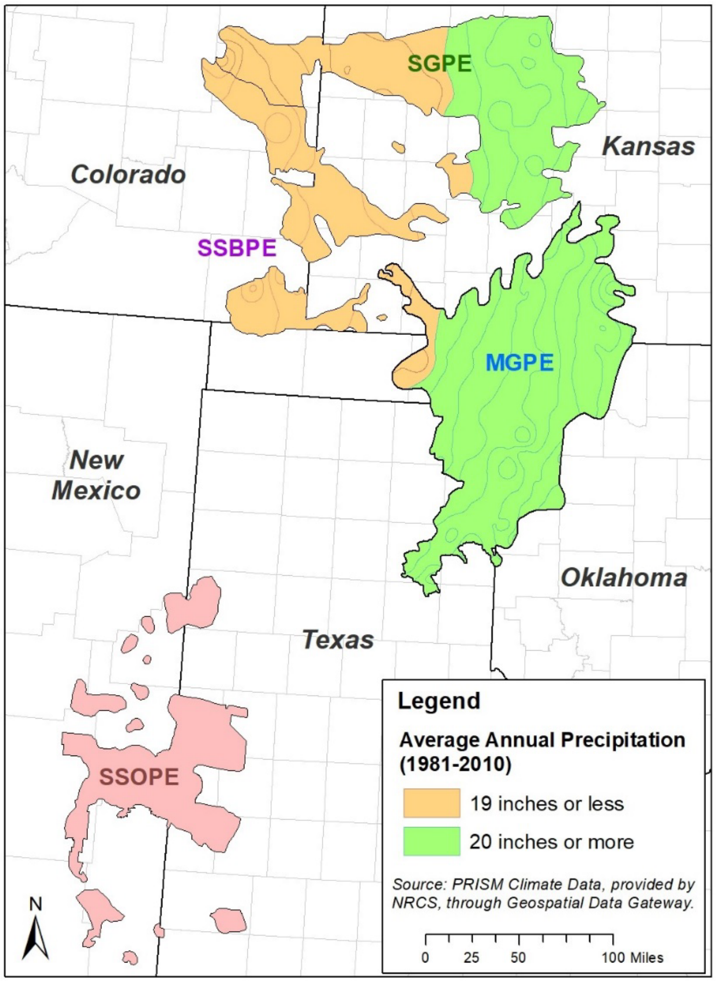


Figure B.8. Map of Precipitation Geographic Constraint. NOTE; This Geographic Constraint does not apply to the Sand Shinnery Oak Ecoregion.

4. Woody Plant Encroachment Geographic Constraint

- Original input data
  - LANDFIRE EVT tree land cover classes (not including any wetland/riparian classes or ruderal/developed) were extracted from the original (pre-reclassified and resampled) dataset.
  - NLCD (National Land Cover Dataset) Forested classes were extracted from the original (pre-reclassified and resampled) dataset.

  - From the SGP CHAT website, the NRCS Percent Canopy Cover of Conifer and Mesquite was used.

- USFWS derived dataset created from above public sources.

- Processing
  - Mixed-Grass Ecoregion, Short-Grass/CRP Ecoregion, Sand Sagebrush Ecoregion: Extract original EVT tree values (excluding wetland/riparian, ruderal/developed classes). AND Extract tree values from NLCD.
  - Shinnery Oak Ecoregion: Extract values 5% and greater from USDA NRCS Percent Canopy Cover Layer.
  - Reclassify EVT, NLCD, and USDA NRCS layers to remove unique values to one value (simplifies remaining processing). Gridcode = "1".
  - All extracts; Convert raster features to vector.
  - Add Current Condition layer. Extract all/only Usable Area polygons. Intersect with newly created vector layers.
  - Select intersecting features from newly created vector layers. Create new layers (for each ecoregion) from selection.
  - Buffer layers at 8,047 meters (5 miles) for Mixed-Grass Ecoregion, Short-Grass/CRP Ecoregion (over 20 inch precip. zones) & Shinnery Oak Ecoregion. Merge/dissolve to remove overlapping buffers.
  - Buffer layers at 4,023 meters (2.5 miles) for SSBP & Mixed-Grass Ecoregion/Short-Grass/CRP Ecoregion (under 19 inches precip. zones). Merge/dissolve to remove overlapping buffers.
  - Clip new buffers to ecoregion boundaries.
  - Convert back to raster 30m (snap to applicable Current Condition raster). This will align layer with other usable and Geographic Constraint layers.
  - Use Cell Statistics to "merge" converted layers with blank 30m grid layer. This will create "In/Out" differentiations.
  - Convert raster to vector (no simplify, no multi-part polys). New field name = **GC_Trees**.
  - Dissolve all polygons by gridcode (value). Eliminates like polys that are adjacent.
  - The datasets identified above were buffered by 2.5 miles (4,023 m) and 5 miles (8,047 m), to create a polygon, allowing for a reasonable amount of area in proximity to current encroachment to allow expansion of woody plants as projected in our future scenarios, instead of allowing it to occur anywhere within the modeled landscape. Additionally, using topography and soils datasets, areas identified as ‘canyons’ or ‘breaks’ with steep slopes were used to erase tree cover data, because these areas were added to the exclusions due to them not being habitat.

- Uses
  - This layer is used as the method to semi-randomly select the location of model tree encroachment in the future scenario modeling.

- Assumptions
  - For the sections of the Mixed-Grass Ecoregion and Short-Grass/CRP Ecoregion (20 or greater inches of average annual precipitation zones) a 5-mile (8,047 m) buffer of existing trees was used assuming that encroachment and dispersal of seed source of woody plants is more likely to occur closer to existing sources, and the likelihood and total area of new encroachment decreases further from existing sources. This buffer distance was reduced to

2.5 miles (4,023 m) in the drier (19 inches or less of average annual precipitation zones) sections of the Mixed-Grass Ecoregion, Short-Grass/CRP Ecoregion, and all of the Sand Sagebrush Ecoregion (Figure B.9).

- For the Shinnery Oak Ecoregion where only mesquite encroachment was considered, the 5-mile (8,047 m) buffer was retained.

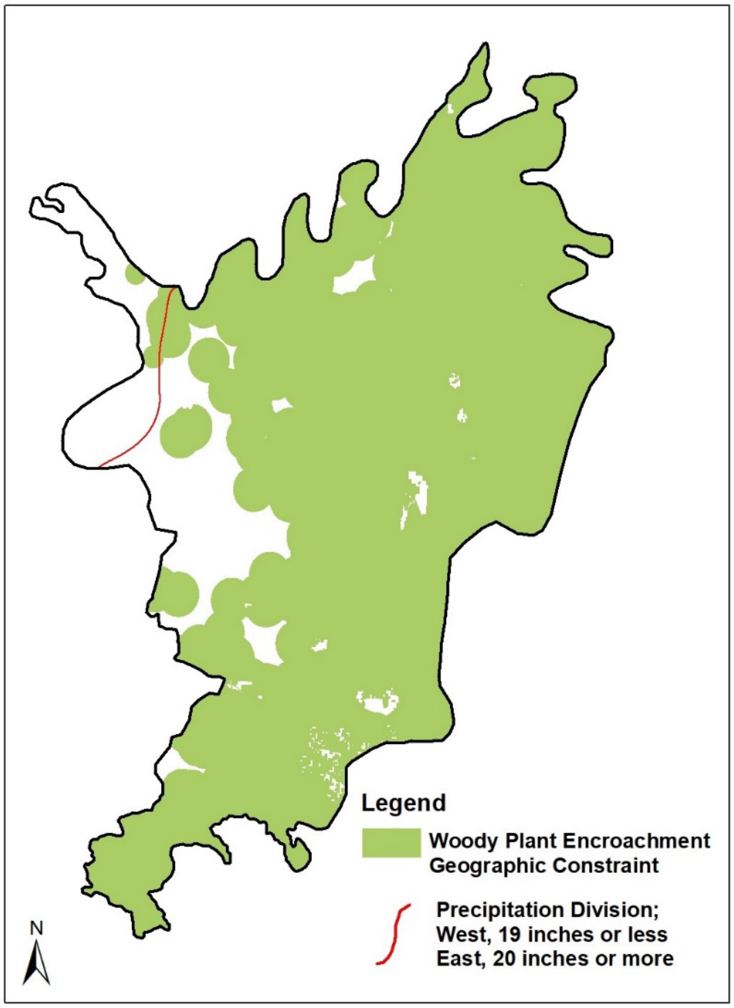


Figure B.9. Example, Mixed-Grass Ecoregion Woody Plant Encroachment Geographic Constraint.

5. Tillage Risk Geographic Constraint

- Original input data:
  - Playa Lakes Joint Venture created Tillage Risk Likelihood.

- USFWS derived dataset created from above sources.

- Processing
  - The PLJV Tillage Risk model is a raster dataset that ranks each pixel on its potential to be tilled. To help focus our Future Scenario model by looking at 40% or greater (likelihood of conversion to cropland), and applying that to polygons 80 acres or larger out of potential conversion possibility (Figure B.9).
  - PLJV raster data in floating point format. It must be converted to assigned integer format to perform analysis.
  - Use Raster Calculator (Spatial Analyst-> Math Algebra), formula: "Raster_Name"*100 (this converts org values, 0–1, to new values, 0–100. Naming convention; "raster_name"_rc).
  - Convert to singed integer raster; (Spatial Analyst->Math->Int. Naming convention; "raster_name"_int).
  - Reclassify new raster; Values 0–39 = 1 (Outside high tillage likelihood; no conversion), 40–100 = 2 (Inside high tillage likelihood; conversion possible). New field name = **GC_Till**.
  - Clip (Extract by Mask) to ecoregion boundaries.
  - Resample to 30m x 30m.
  - Convert raster to vector (no simplify, no multi-part polys).
  - Select all polys less than 80 acres (values = 1&2), Use Eliminate to "merge" with largest neighbor.
  - Dissolve all polygons by gridcode (value). Eliminates like polys that are adjacent (to remove remaining data "noise").

- Uses
  - This layer, illustrated in an example in Figure B.10, is used as the method to limit which sites were selected for conversion of grassland to cropland in the future scenario modeling. The above layer was only used where it intersected with the Service’s usable land cover dataset.

- Assumptions:
  - The PLJV Tillage Risk Likelihood, based on methods from Smith *et al.* 2016, represent a reasonable approximation of risk of land cover / land use change throughout the range of the species.

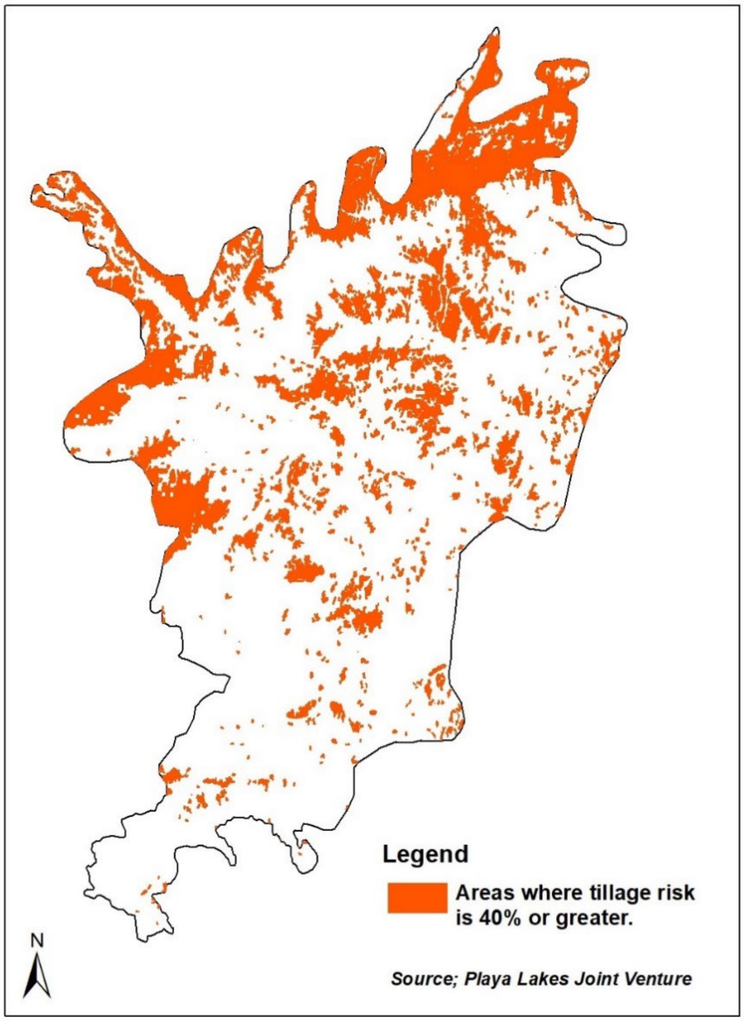


Figure B.10. Example, Mixed-Grass Prairie Ecoregion Tillage Risk Geographic Constraint.

6. Conservation Ownership Geographic Constraint

- Original input data:
  - Protected Areas Database of the United States 2.0 (PAD-US; https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap/science/protected-areas

- USFWS derived dataset modified from above sources.

- Processing
  - The Conservation status was determined, using the USGS PADUS v 2.0 data layer and reviewing and ranking individual conservation areas within the ecoregions.
  - Each conservation area was designated with an “Allowed” or “Not_Allowed” attribute defining conservation status.
  - Areas with conservation status (Not Allowed), pertaining to either individual or multiple impacts were removed from the applicable GC layer(s) described earlier in this document. No development expansion can occur within those areas (Figure B.11).
  - Each impact represented with a geographic constraint layer had applicable conservation areas removed. This will not allow projected development to occur in these areas.

    - Known WAFWA permanent conservation properties, not in the PADUS dataset were added and given a “Not_Allowed” status.

- Uses
    - These data are used as part of the method to limit the location of where impact actions could occur in our future scenario modeling. Example illustrated in Figure B.10

- Assumptions:
    - Entries from the WAFWA modified PAD-US are assumed to have some level of ability to exclude development impacts to LEPC from occurring on them (e.g., mineral rights are owned by the surface owner). These sites may or may not be LEPC habitat. These sites may or may not have active management to maintain or improve LEPC habitat. The underlying usable land cover data will assist in determining potentially usable area. Taking a conservative approach, if a given impact was unknown or uncertain if it was allowed, we assumed it was not allowed.

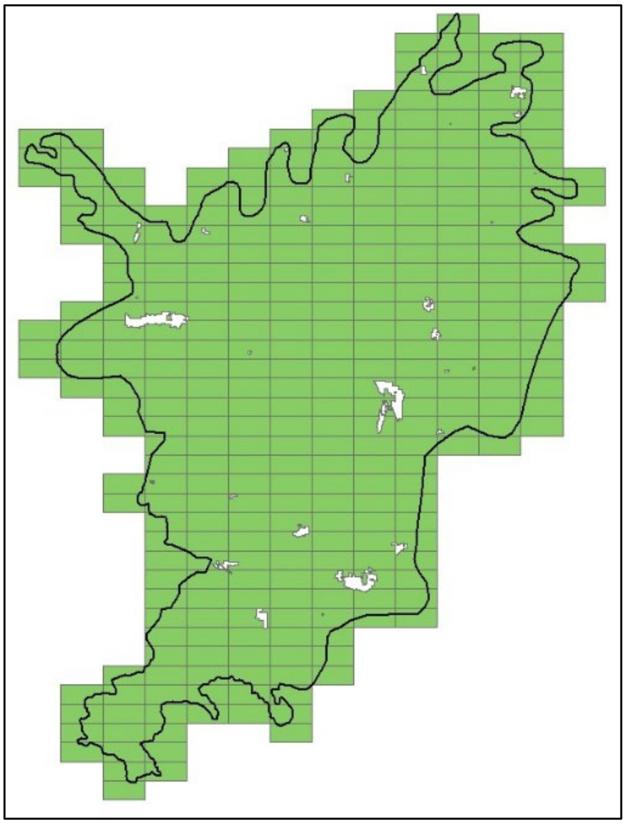


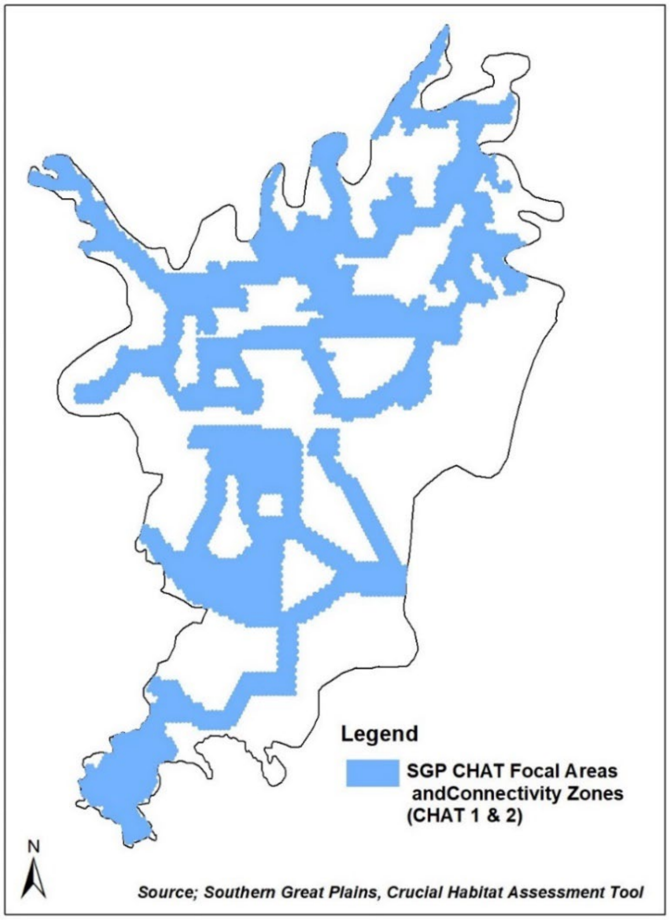
Figure B.11. Example, Mixed-Grass Prairie Ecoregion Wind Grid with “Not Allowed” conservation areas removed.

7. SGP CHAT Conservation Geographic Constraint

- Original input data:
  - Southern Great Plains Crucial Habitat Assessment Tool; https://www.sgpchat.org/

- Processing
  - CHAT Focal Areas & Connectivity Zones (CHAT 1&2) data downloaded from SGP CHAT website (Figure B.12.).
  - Focal Areas and Connectivity Zones combined to create one layer.
  - New CHAT layer is resampled to 30m resolution and matched (Snap Raster) to existing raster data.
  - New layer is clipped to each new ecoregion boundary.
  - Cell values are reclassified to 1 = Inside CHAT areas, 2 = Outside CHAT areas.
  - Raster layers converted to vector polygons for final union. **GC_CHAT** selection fields added.

- Uses
  - This layer, illustrated by example in Figure B.11, is used to focus Future Scenario conservation actions.



Source; Southern Great Plains, Crucial Habitat Assessment Tool

Figure B.12. Example, Mixed-Grass Prairie Ecoregion SGP CHAT Conservation Geographic Constraint.

B. Impacts GIS Datasets

Impacts are actions identified as having a potential effect on the LEPC or its habitat and for which GIS data existed to represent the current conditions and projections of future scenarios.

1. Oil and Gas Impacts

- Original input data
  - IHS US Well Data; downloaded through the Enerdeq Map Browser (HIS Markit Energy Products website). USFWS access through paid contract; USFWS, Region 6 Regional Office, Lakewood, Colorado. IHS Markit website, https://ihsmarkit.com/index.html
- Processing
  - An impact radius of 300 meters (984.3 ft.) was applied to selected surface well records.
- Uses
  - This layer is used to represent existing oil and gas development in the current condition and as a source of sites for oil and gas remediation in the future scenarios modeling.
- Assumptions:
  - IHS surface wells data are reasonably, but by no means completely, representative of the occurrence of oil and gas development infrastructure throughout the LEPC EOR.

2. Wind Energy Development Impact

- Original input data
  All wind turbines identified in FAA Digital Obstacle File and USGS Wind Turbine database within the EOR. Buffer distance was 1,800 meters (5,905.5 ft.). See Table B.1 for web locations of datasets.
- USFWS derived dataset created from above public sources, and available from, https://www.fws.gov/southwest/es/Energy_Wind_FAA.html
- Processing
  - Description of the processing of the original FAA-OEAAA data can be found at the link above. An impact radius of 1,800 meters (5,905.5 ft.) was applied to all turbines.
- Uses
  - This layer is used as the method to depict wind energy developments in the current condition.
- Assumptions
  - The wind turbine data used was a representative depiction of wind energy development throughout the range of the LEPC.

3. Woody Plant Encroachment Impact

- Original input data:
  - LANDFIRE EVT 2016 tree land cover classes (not including any wetland/riparian classes) were extracted from the original (pre-reclassified and resampled) dataset.
  - NLCD (National Land Cover Dataset) 2016 Forest classes.
  - NRCS Percent Canopy Conifer and Mesquite Canopy

- USFWS derived dataset created from above public sources.
  - Landfire, https://www.landfire.gov/ and
  - NRCS, Percent Conifer/Mesquite Canopy (Data shared with USFWS)
  - NLCD, https://www.mrlc.gov/

- Processing

- For our spatial analysis for the LEPC SSA, we are processing landcover data as well as other available spatial data regarding impacts to the LEPC to characterize the current condition of the landscape as it relates to its ability to meet the biological needs of the species. One of the primary drivers of space use and thus habitat availability for the LEPC is the encroachment of woody vegetation, specifically the encroachment of eastern red cedar in the Northern portion of the range and honey mesquite in the Southern portion of the range.

- We will be utilizing both Landfire 2016 Existing Vegetation Type (EVT_LF attribute field) raster data that is identified as trees in the attribute table and the Percent Conifer/Mesquite Canopy Cover data, >/=1% canopy in the Short-Grass Ecoregion, Sand Sagebrush Ecoregion and the Mixed-Grass Ecoregion, and >/=5% canopy for the Shinnery Oak Ecoregion.

- Areas where extensive steep slopes occur (i.e., topographic breaks or canyons) will be identified using a couple of sources of information, including slopes identified as > 25 degrees from Landfire 2016 Slope and Landfire 2016 EVT pixels from EVT_PHYS attribute field that are identified as riparian. These identified features will be used as an exclusion dataset and trees that occur within the exclusion datasets will not be used in the modeling process.

- The original geospatial data were converted from raster to vector format, merged, and have exclusion areas erased from them. We will apply an impact radius to the remaining vectorized data (native format was raster of two different resolutions, 30 m (98.4 ft.) and 23.4 m (76.8 ft) respectively by the following proposed process.

- We used the research and publication out of KSU (Lautenbach *et al*. 2017) to address avoidance of trees except mesquite. An initial decision was made to use a threshold of 50 percent utilization which was 375 m (1,230.3 ft) (Haukos pers. comm. 2017).

- The approach for mesquite was explored using data from NMSU (Boggie *et al*. 2017). The data and methods for this approach were not as easy to transform into a distance based recommendation for applying an impact radius to mesquite. Here are some of the findings from Boggie *et al*. 2017:
  - The findings from Boggie et al. 2017 suggest that in both the breeding and non-breeding seasons prevalence of mesquite canopy within utilization distributions (i.e. home ranges) were relatively low and decreased precipitously from outer to inner areas of utilization distributions, suggesting avoidance of areas with mesquite present (see Boggie et al. 2017, Fig. 4A−4B).
  - The class of mesquite canopy that accounted for the largest percent within utilization distributions of all birds was the lowest class (<1% mesquite canopy), which contained many values where percent mesquite canopy was zero, and the highest class of mesquite canopy (>50% mesquite canopy) was not found in the utilization distributions of any birds in either season (see Boggie et al. 2017, Fig. 4A−4B). Moreover, the 1−5% canopy class comprised <15% of all utilization distributions regardless of season, suggesting overall low tolerance of mesquite. Moreover, the pattern of general mesquite avoidance seasonally is supported by low prevalence of mesquite within any location in the utilization distribution (<0.05% for any rescaled value of the utilization distributions) and the steep decline in percent of mesquite in areas of low to high intensity of use (Boggie et al. 2017, Fig. 4C−4D).

    - Mesquite appears to limit habitat regardless of canopy cover extent. Furthermore, when mesquite is present in areas of use by lesser prairie-chickens, it is represented by the lowest canopy cover classes (1–15%). Medium to high canopy cover classes (16–50%) were rarely present in areas used by lesser prairie-chickens.
    - Likewise, average distance to nearest mesquite bush from the centroid of the 1% isopleth of home ranges in the breeding season 1,183.7± 227.4 ft (360.8 ± 69.3 m) and nonbreeding season 1,380.9± 233.9 ft (420.9 ± 71.3 m) was similar (t48 = 0.60, P = 0.55).
    - The estimated resource utilization function for the both seasons from this study revealed a clear avoidance of mesquite (see Boggie et al. 2017, Fig. 2A).

- The findings from Boggie *et al.* 2017 indicate that LEPC are avoiding mesquite. For our SSA spatial analysis for mesquite, we are proposing to use the following methodology to represent the effects of mesquite on space use for the lesser prairie-chicken:
    - Use the % conifer/mesquite spatial layer from the SGP CHAT Tool to identify areas with mesquite presence.
    - Use the results from Boggie et al. 2017 to establish a threshold canopy cover to which will be applied to the % conifer/mesquite spatial layer with areas greater than the threshold considered non-habitat (with the potential to be restored) in our characterization of the landscape.
- Canopy Cover Threshold – 5%
    - This is based upon that finding that the 1−5% canopy class comprised <15% of all utilization distributions regardless of season, suggesting low tolerance of mesquite.
    - Once we use the % conifer/mesquite layer from the SGP CHAT Tool and categorize areas with greater than 5% mesquite canopy cover as areas that are unsuitable for LEPC, the next step is to determine what at what distance the indirect effects (effects that extend beyond the footprint) of mesquite have on space use. To do this, we would apply an impact radius to the areas which have been spatially identified to contain greater than 5% canopy cover.
    - Impact Radius to Account for Avoidance – 951.4 ft (290 m)
    - While Boggie *et al*. (2017) found the average distance to nearest mesquite bush from the centroid of the 1% isopleth of home ranges in the breeding season was 1,183.7± 227.4 ft (360.8 ± 69.3 m) and was 1,380.9± 233.9 ft (420.9 ± 71.3 m) for the nonbreeding season, these are not direct measures of an avoidance distance by the lesser prairie-chicken with regard to mesquite. Instead, these are a measure of the distance from geometric center of the 1% Isopleth area to nearest mesquite bush. The 1% isopleth area represents the highest concentration of use within the home range. So, using these as a direct measure could result in an overestimate of the indirect negative effects of mesquite, as space use does occur between the 1% isopleth area and the nearest mesquite bush, but at a lower rate. Since this is the only information available to make this decision, we will use the smaller distance found (which was 1,183.7± 227.4 ft (360.8 ± 69.3 m) for the breeding season) and subtract the standard error from this ensure we using the lower end in an attempt to be account for potential overestimate. This results in approximately 951.4 ft (290 m) being used as impact radius.

    - Because we do not have individual trees as point data, but rather a pixel based raster of estimated canopy cover, applying a distance-based metric that is to be applied to individual trees requires accounting for the potential spatial difference between individual trees and a raster pixel. For the NRCS Percent Conifer/Mesquite Canopy, discussion of part of the specific methodology is described in Falkowski report (undated, entire). The available publications indicate the data for conifer and mesquite cover were derived from two different remote sensing methods that identified individual trees and/or crowns, converted to binary canopy/no canopy at a minimum 1-meter resolution, then calculated canopy cover on an ~1-acre resolution 210 ft x 210 ft pixel (64 m x 64 m). The version of the NRCS data available to us from WAFWA's SGP CHAT is labeled as 30-m resolution product (Pct_Canopy_30meter.img) but is actually done at resolution of approximately 76.8 ft x 76.8 ft (23.4 m x 23.4 m) pixels. We could not find information from the available publications that talked about the treatment of the canopy density estimates within the raster, including the final data output resolution, or the symbology methodology used to classify and display the information. So, for our purpose, we assumed that the 76.8 ft (23.4 m) resolution data we have is based on some form of aggregation of 1-meter pixels as analyzed with the ~1 acre square moving window analysis. Half the distance of the diagonal of the ~1 acre square (maximum distance sampled to determine the 1-meter cell value) is 148.4 ft (45.225 m). We will subtract 150.9 ft (46 m) from our proposed tree impact radius distances, including (1) 1,230.3 ft – 150.9 ft = 1,079.4 ft (375 m - 46 m = 329 m) for all trees treated in our model in the Mixed-Grass Prairie, Short-Grass Prairie, and Sand Sagebrush Prairie ecoregions, and (2) 951.4 ft – 150.9 ft = 800.5 ft (290 m - 46 m = 244 m) for all trees treated in our model in the Shinnery Oak Prairie ecoregion.

- For consistency of the application of the impact radius, we will apply this reduction to both the NRCS and the LandFire EVT tree data. This approach is redundantly conservative with respect to the expression of effects of trees in LEPC range. Data underestimates occurrence of trees and impact analysis identifies effects through percentage reductions of space use out well beyond the proposed impact radius of 1,079.4 ft (329 m) and 800.5 ft (244 m).

- Uses
    - ▪ This layer is used as the method to identify the location of tree encroachment in the current condition and to identify the locations where conservation action of cutting trees could be applied in the future scenario modeling.

- Assumptions
    - ▪ We are unable to differentiate between tree species, including conifer and mesquite, in the datasets we have access to. We know it is a generalization, but we are only using the mesquite methodology in the Shinnery Oak Prairie Ecoregion, and only using the other methodology/impact radius for the trees found in the other 3 ecoregions

- Considerations
    - ▪ Our purpose is to identify anything that is trees. Effects of trees on LEPC and grassland conservation are generally well understood. However, available geospatial data to represent this threat to the species is poor quality, or of limited coverage relative to the LEPC range. All available tree datasets underestimate occurrence of trees in grassland and shrubland systems, especially low density occurrence of small trees (<3 ft (0.9 m) tall and less than 6 ft (1.8 m) canopy).

      Case in point, as excerpted from Falkowski *et al.* 2016:

> "Generally, Spatial Wavelet Analysis (SWA [or any other object-based remote sensing approach]) cannot detect objects smaller than approximately two times the image spatial resolution (i.e., pixel size). In this case, because we leverage 1-m spatial resolution NAIP data, trees below 2 m in crown diameter (equivalent to 4 pixels in the NAIP imagery) were likely not successfully detected, which could certainly impact end users specifically targeting restoration strategies in early-phase invasion sites."

4. Tillage Risk Impact

- This impact was identified and applied in our modeling solely through conversion of LANDFIRE EVT 2016 data that was identified as LEPC usable land cover and that occurred within the Tillage Risk Likelihood Geographic Constraint. There was no specific data used to represent this, but rather was a conversion of LANDFIRE EVT cover types. See discussion in this document of the processing of the Tillage Risk Likelihood Geographic Constraint for additional information.

- LANDFIRE EVT 2016 was reclassified by USFWS as detailed in Appendix B Table B.2.

C. Reference Information for Geospatial Impact Distances

Research has documented effects from functional loss and fragmentation of habitat caused by indirect effects of impacts in and adjacent to habitat of LEPC as described in Chapter 3 of the main body of the SSA report. Gaps in knowledge and understanding still exist with regard to the effects of many of these development actions. Assessment of effects and implementation of conservation actions for LEPC require accounting for these negative indirect effects. Conservation efforts and development actions continue throughout the range of the species. To support a more standardized approach to assessments and planning, the Service evaluated the available information (e.g., peer reviewed publications, conservation plans) and compiled a list of impact radii for use in assessing potential effects and conservation planning (USFWS 2014d). In support of designing effects assessment methods for a proposed HCP, the Service completed a more in-depth review of wind energy (USFWS 2016b). During the development of this SSA the Service reviewed and summarized all existing literature on the direct and indirect effects of these features on the LEPC (Chapter 3 in the main body of the report). The results of these reviews and identified impact radii were used as part of the Service's geospatial analysis and modeling to account for the indirect effects of features on the landscape (Table B.7).

Table B.7 U.S. Fish and Wildlife Service impact radii for assessment of effects to Lesser Prairie-Chickens.

Impact Distances			
	Impact Radii		
Feature	Meters	Feet	Reference
Gas Line Compressor Station	805	2,641	Pitman *et al.* 2005, p.
Coal Fired Power Plant	1,609	5,279	Pitman *et al.* 2005. p.
Oil or gas well*	300	984	Hagen *et al.* 2011, p.
Small compressor station	200	656	Van Pelt *et al.* 2013, p.95
Transmission line	700	2,297	Hagen et al. 2011, p.
Distribution line	10	33	Van Pelt et al. 2013, p.95
Wind turbine	1,800	5,906	Hagen 2010, p.
Large vertical structure (>150')	667	2,188	Van Pelt et al. 2013, p.95
Vertical structure (30' - 149')	200	656	Treated similar to residential building
Improved paved road	850	2,789	Hagen 2010, p.
Improved gravel road	67	219	Van Pelt et al. 2013, p.95
Unimproved road	30	98	Robel *et al.* 2004, p.
Railroad track	67	219	Treated similar to improved gravel road
Commercial building	1,000	3,281	WAFWA 2012, unnumbered
Residential building	200	656	WAFWA 2012, unnumbered
Pipelines**	850	2,789	Treated similar to improved road

* Muffle or otherwise control exhaust noise from pump jacks and compressors so that operational noise will not exceed 49 dB measured at 30 feet from the source (based on Blickley et al. 2012b, p. 4-5)

** Temporal considerations. Impact radius may only be applicable during the construction phase. This same concept may be applicable to other projects that have short term impacts.

For impact features in the spatial datasets that do not exist in Table B.7 the Service based the impact radii on the most similar feature with respect to impacts to the LEPC.

In addition to the impact radii developed for anthropogenic features which are identified in Table B.7, recent research has documented the effects of woody vegetation encroachment on the LEPC (Lautenbach *et al.* 2017; Boggie *et al.* 2017). The Service incorporated the findings of this research to further quantify the effects of woody vegetation encroachment on the LEPC within our geospatial analysis.

After discussions with the LEPC SSA Working Group involved in version 1.0 of the LEPC SSA, it was decided to use the research and publication out of KSU (Lautenbach *et al*. 2016) to address avoidance of woody vegetation encroachment in areas where the most common type of encroachment is Eastern Red Cedar (the Short-Grass/CRP, Mixed-Grass, and Sand Sagebrush eco-regions). An initial decision was made to use an impact radii of 375 m (this represented a threshold of 50 percent utilization) (Haukos 2017, pers. comm.).

The approach for mesquite was explored using data from NMSU (Boggie *et al*. 2017). The data and methods for this approach were not as easy to transform into a distance based recommendation for applying an impact radius to mesquite. Here are some of the findings from Boggie *et al*. 2017:

- In both the breeding and non-breeding seasons prevalence of mesquite canopy within utilization distributions (i.e. home ranges) were relatively low and decreased precipitously from outer to inner areas of utilization distributions, suggesting avoidance of areas with mesquite present (see Boggie *et al.* 2017, Fig. 4A−4B).
- The class of mesquite canopy that accounted for the largest percent within utilization distributions of all birds was the lowest class (<1% mesquite canopy), which contained many values where percent mesquite canopy was zero, and the highest class of mesquite canopy (>50% mesquite canopy) was not found in the utilization distributions of any birds in either season (see Boggie *et al.* 2017, Fig. 4A−4B). Moreover, the 1−5% canopy class comprised <15% of all utilization distributions regardless of season, suggesting overall low tolerance of mesquite. Moreover, the pattern of general mesquite avoidance seasonally is supported by low prevalence of mesquite within any location in the utilization distribution (<0.05% for any rescaled value of the utilization distributions) and the steep decline in percent of mesquite in areas of low to high intensity of use (Boggie *et al.* 2017, Fig. 4C−4D).
- Mesquite appears to limit habitat regardless of canopy cover extent. Furthermore, when mesquite is present in areas of use by lesser prairie-chickens, it is represented by the lowest canopy cover classes (1–15%). Medium to high canopy cover classes (16–50%) were rarely present in areas used by lesser prairie-chickens.
- Average distance to nearest mesquite from the centroid of the 1% isopleth of home ranges in the breeding season 1,183.7± 227.4 ft (360.8 ± 69.3 m) and nonbreeding season 1,380.9± 233.9 ft (420.9 ± 71.3 m) was similar (t^{48} = 0.60, P = 0.55).
- The estimated resource utilization function for both seasons from this study revealed a clear avoidance of mesquite (see Boggie *et al.* 2017, Fig. 2A).

The findings from Boggie *et al.* (2017, entire) indicate that lesser prairie-chickens are avoiding mesquite. For our SSA geospatial analysis for mesquite the Service initially planned to use the following methodology to represent the effects of mesquite on space use for the lesser prairie-chicken:

- Use the % conifer/mesquite spatial layer from the SGP CHAT Tool to identify areas with mesquite presence.

- Use the results from Boggie *et al.* (2017, entire) to establish a threshold canopy cover to which will be applied to the % conifer/mesquite spatial layer with areas greater than the threshold considered non-habitat (with the potential to be restored) in our characterization of the landscape in the Shinnery Oak Eco-region.
  - Canopy Cover Threshold – 5%
    - This is based upon that finding that the 1−5% canopy class comprised <15% of all utilization distributions regardless of season, suggesting low tolerance of mesquite.
  - Once we use the % conifer/mesquite layer from the SGP CHAT Tool and categorize areas with greater than 5% mesquite canopy cover as areas that are unsuitable for LEPC, the next step is to determine what at what distance the indirect effects (effects that extend beyond the footprint) of mesquite have on space use. To do this we would apply an impact radius to the areas which have been spatially identified to contain greater than 5% canopy cover.
    - Impact Radius to Account for Avoidance – 951.4 ft (290 m)
    - While Boggie *et al*. 2017, found the average distance to nearest mesquite bush from the centroid of the 1% isopleth of home ranges in the breeding season was 1,183.7± 227.4 ft (360.8 ± 69.3 m) and was 1,380.9± 233.9 ft (420.9 ± 71.3 m) for the nonbreeding season, these are not direct measures of an avoidance distance by the lesser prairie-chicken with regard to mesquite. Instead these are a measure of the distance from geometric center of the 1% Isopleth area to nearest mesquite bush. With the 1% isopleth area representing the highest concentration of use within the home range. So, using these as a direct measure could result in an overestimate of the indirect negative effects of mesquite as space use does occur between the 1% isopleth area and the nearest mesquite bush but at a lower rate. Since this is the only information available to make this decision, we will use the smaller distance found (which was 1,183.7± 227.4 ft (360.8 ± 69.3 m) for the breeding season) and subtract the standard error from this ensure we using the lower end in an attempt to be account for potential overestimate. This results in approximately 951.4 ft (290 m) being used as impact radius.

Both of the above methods for accounting for the effects of eastern red cedar and mesquite were revised based on input from external experts, and the Service's subsequent review of the methods used to generate the geospatial data being used to represent trees in the LEPC SSA GIS modeling work. We applied the following methodology to our modeling to account for indirect effects of woody vegetation:

- Because we do not have individual trees as point data, but rather a pixel based raster of estimated canopy cover, applying a distance based metric that is to be applied to individual trees requires accounting for the potential spatial difference between individual trees and a raster pixel. Falkowski (undated, entire) provides discussion of specific methodolgy for the NRCS Percent Conifer/Mesquite Canopy dataset. The available publications indicate the data for conifer and mesquite cover was derived from two different remote sensing methods that identified individual trees and/or crowns, converted to binary canopy: no canopy at a minimum 1-meter resolution, then estimates of canopy cover was calculated on an ~1-acre resolution 210 ft x 210 ft pixel (64 m x 64 m). The version of the NRCS data available to the

Service from WAFWA's SGP CHAT is labeled as 30 m resolution product (Pct_Canopy_30meter.img), but is actually done at resolution of approximately 76.8 ft x 76.8 ft (23.4 m x 23.4 m) pixels. We could not find information from the available publications that talked about the treatment of the canopy density estimates within the raster, including the final data output resolution, or the symbology methodology used to classify and display the information. So, for our purpose we will assume that the 76.8 ft (23.4 m) resolution data we have is based on some form of aggregation of 1-meter pixels as analyzed with the ~1 acre square moving window analysis. Half the distance of the diagonal of the ~1 acre square (maximum distance sampled to determine the 1-meter cell value) is 148.4 ft (45.225 m). To continue with our redundantly conservative approach in our treatment of this information we rounded up to 46 m.

- Based upon this understanding, we subtracted 150.9 ft (46 m) from our proposed tree impact radius distances, including (1) 1,230.3 ft – 150.9 ft = 1,079.4 ft (375 m - 46 m = 329 m) for all trees treated in our model in the Mixed-Grass Prairie, Short-Grass Prairie, and Sand Sagebrush Prairie eco-regions, and (2) 951.4 ft – 150.9 ft = 800.5 ft (290 m - 46 m = 244 m) for all trees treated in our model in the Shinnery Oak Prairie eco-region.

- For consistency of the application of the impact radius, the Service applied this reduction to both the NRCS and the LandFire EVT tree data. This approach is redundantly conservative with respect to the expression of effects of trees in LEPC range. Data underestimates occurrence of trees and impact analysis identifies effects through percentage reductions of space use out well beyond the applied impact radii of 1079.4 ft (329 m) and 800.5 ft (244 m).

Part 3. Supplemental Analysis: Comparison of Publicly Available Lek Data with Potential Usable Area Land Cover Model

Background & Purpose

To evaluate the selection and distribution of LEPC Potential Usable Area (Un-impacted Usable Are) and Potential Usable Area Blocks (60% Usable Within One Mile) in the current condition developed by the USFWS, a comparison was done with the publicly available lek data. This dataset is free and downloadable from the Southern Great Plains, Crucial Habitat Assessment Tool (SPG-CHAT; https://www.sgpchat.org/. Filename; *LPC_ActiveHistoricLeksBuffered_2019_shapefile*).
The lek data are comprised of buffered points (1.25-mile buffer) within and outside of the EOR boundaries. Buffered features outside of the LEPC analysis area were not considered in this comparison. The accuracy and quality of this dataset was not available.

To complete the comparison, a simple intersect was done between the two datasets. Therefore, any buffered Lek feature that touch any part of a Potential Usable Area or feature was counted as being within our usable layer. Without more detailed data and information concerning the lek location data, this was the most efficient way to compare the two datasets.

Results

The following tables will show the results of the intersection of the two datasets. Only the buffered leks dated; 2015–2019 (in the shapefile data table) were used for this comparison.

Table B.8. Current condition results of LEPC SSA spatial analysis (for reference).

Ecoregion	Ecoregion Total Area	All Usable Area	Un-Impacted Usable Area	60%+ Usable Within One Mile
MGPE	6,298,014	2,961,318	1,985,766	1,023,894
SCRPE	8,527,718	6,335,451	2,264,217	994,483
SSBPE	3,153,420	1,815,434	1,358,405	1,028,523
SSOPE	3,850,209	2,626,305	1,423,417	1,023,572
Total	21,829,361	13,738,508	7,031,805	4,070,472

Table B.9. Number of buffered leks intersecting output of LEPC SSA spatial analysis.

Ecoregion	Total Within Ecoregion	All Usable Area	Un-Impacted Usable Area	60%+ Usable Within One Mile
MGPE	**392**	392	392	316
SCRPE	**147**	147	147	120
SSBPE	**58**	58	58	56
SSOPE	**634**	634	634	614
Total	**1231**	1231	1231	1106

Table B.10. Percent of buffered leks intersecting output of LEPC SSA spatial analysis.

Ecoregion	All Usable Area	Un-Impacted Usable Area	60%+ Usable Within One Mile
MGPE	100%	100%	81%
SCRPE	100%	100%	82%
SSBPE	100%	100%	97%
SSOPE	100%	100%	97%
Average	100%	100%	90%

Conclusion

The total number of buffered leks downloaded from SGP CHAT, with dates from 2015–2019, was 1,252. Of that data, 21 features fell outside of the LEPC SSA analysis area (leaving 1,231) and were not used for comparison in this supplemental analysis.

For all four ecoregions, all (100%) of the buffered leks intersected the USFWS Usable Area layer. This includes All Usable Area (Exclusions removed, but no impacts removed), and Un-Impacted Usable Area (Exclusions and Impacts removed). For the comparison with the 60% or greater usable area within one mile (Neighborhood Analysis), overall, 90% of the buffered leks intersected those output areas.

Part 4. Supplemental Analysis: Frequency Analysis of Usable Area Blocks

Background & Purpose

Conservation recommendations from LEPC experts frequently reference the need for large areas of habitat to ensure persistence of populations of this notoriously boom-bust-repeat species in part because of the life history strategies of the species and the dynamically extreme environment where the habitat occurs. Recommendations on sufficient area of habitat vary and are often context-specific but include recommendations ranging from 486–20,234 ha (1,201–50,000 acres) (Haukos and Zavaleta 2016, p. 99).

Analyzing LEPC usable area using a geospatial model allows for greater understanding of the occurrence and potential implications of habitat loss and fragmentation, as compared to a tabular summary of estimated habitat acres. The arrangement and relative proximity of habitat acres is important. Remaining suitable land cover often occurs in a wide range of configurations and can range from relatively contiguous and intact to landscapes spread out over extended areas and fractured by impacts and other non-habitat.

The configuration and composition of the habitat matrix is important (Sullins 2017, p. 205). A significant limitation of current geospatial analyses of LEPC habitat is the inability to assess, with high degrees of confidence, metrics of habitat quality such as vegetation species composition or vegetation structure. Furthermore, the limitation associated with interpreting this analysis, especially in the Short-Grass/CRP Ecoregion, absent CRP should be considered. Occurrence of LEPC is only recently established in this ecoregion, and CRP is excessively relied upon by LEPC in this ecoregion due to the lack of sufficient vegetation structure in the short-statured native plant community.

As described in previous documentation (Appendix B. Part 1), a variety of land cover and other thematic spatial data were modeled to estimate Potential Usable Area that could support LEPC activities. Within these areas of Potential Usable Area polygons, we conducted a further geospatial analysis to examine the size and proximity of these Usable Area polygons to each other. For the primary geospatial modeling analysis purposes, rural and local roads and their buffers (70 meters per side for 140 m total) were excluded from consideration as usable. Even though these features may fragment potentially larger blocks in the geospatial model, they are small enough to allow movement and utilization between the individual polygons and are not expected to be barriers to movements that support aspects of the species life history. The remaining road and transmission line buffer sizes are 850 and 700 meters, respectively. Roads and transmission lines are the most common linear fragmenting features in our geospatial analysis. For modeling purposes, these features were considered large enough to negatively impact utilization between individual polygons.

To spatially evaluate the connectivity across rural and local roads, a buffering and selection routine was developed to group, or block, polygons within a specific distance together. The following geoprocessing was run on all 60% Current Condition outputs for each ecoregion and Median Future Scenario Usable Area Outputs for scenarios 1, 3, and 5.

Process

The source or starting data layers are the un-impacted usable area polygons selected from the intersection with the 60% and greater neighborhood analysis. To identify Potential Usable Area polygons that were separated only by rural and local roads, the following logic was applied;

Step 1. Dissolve all un-impacted usable area polygons by the Total Rank field (1111). This removes any internal breaks or divisions between like polygons that may exist.

Step 2. Create a Buffer Layer (Analysis Tools->Proximity->Buffer, buffer distance=70m, Dissolve Type=All) from the above layer.

Step 3. Add new field to Buffer Layer, “Buff_ID”, populate w/ unique number (Use field calculator to copy OBJECTID field into the new field).

Step 4. Run Spatial Join (Analysis Tools->Overlay->Spatial Join);
Target Feature=Dissolved un-impacted polygon layer
Join Feature=Buffer Layer
Join Operation=JOIN_ONE_TO_ONE
Check; Keep all Target Features
Math Option=INTERSECT
This joins the attributes of the two layers together. Each individual polygon from the first un-impacted polygon layer will have the unique number from the buffer polygon, which will “group” any un-impacted polygons that fall within the larger buffer polygon together.

Step 5. Dissolve the new grouped polygon layer using “Buff_ID” field. Check; Create multipart features. Add “Acres” field, calculate acreages for each multipart polygon. This will create multipart polygon features grouped by the “Buff_ID” field, so each new polygon group will have its own acreage calculation.

Step 6. The new outputs are then exported to Microsoft Excel and grouped into the following “Bins” for display in frequency bar graphs:

Bins (Acres)
< 12,000
12,000–25,000
25,000–50,000
>50,000

Figures B.13 – B.15 are illustrative examples of these geoprocessing methods and interim outputs.

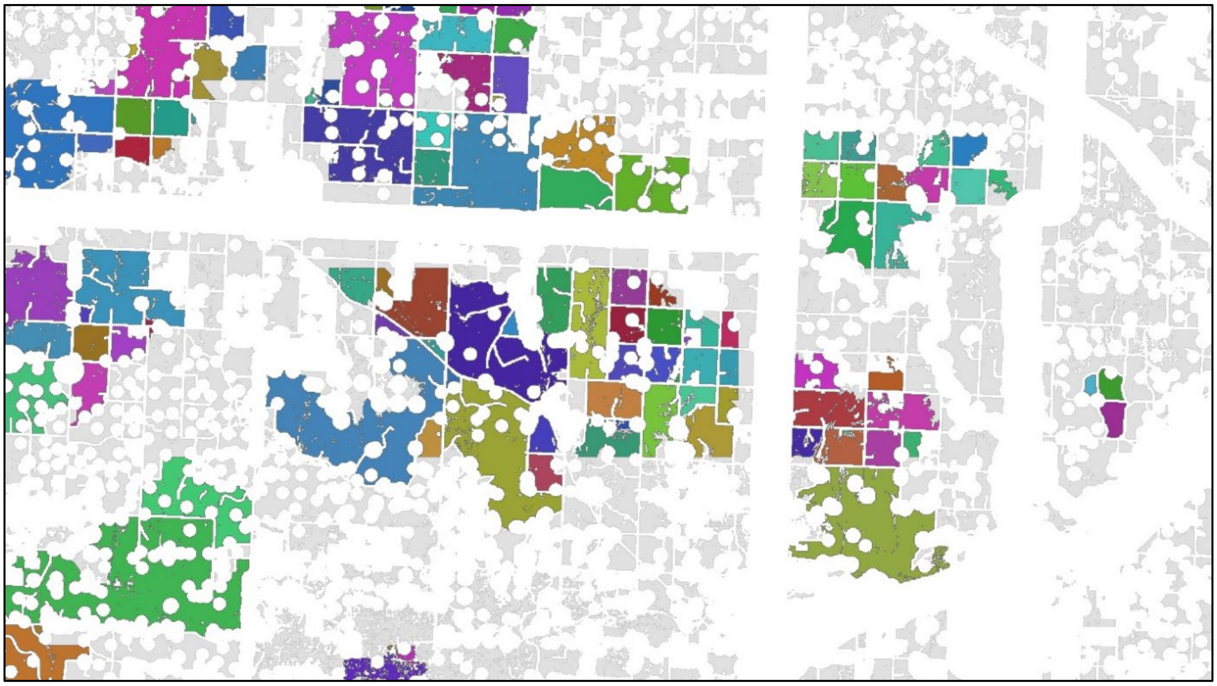


Figure B.13. Step 1. The different colors represent each individual un-impacted potential usable area polygon patch that intersected the 60% or greater neighborhood analysis threshold. The smallest separation between polygons is 140 meters.

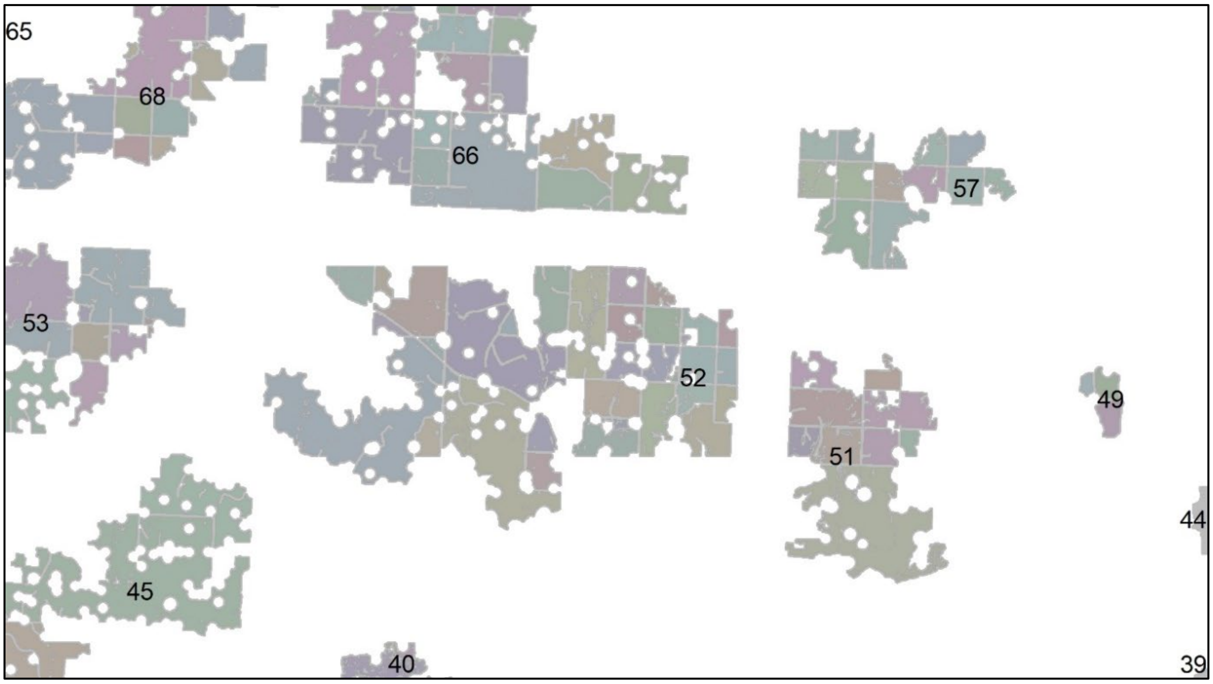


Figure B.14. Steps 2 and 3. A 70-meter buffer polygon layer (gray transparent) is created from every polygon (buffer layer is a separate Feature Class). All separations less than 140 meters are now removed in the Buffer Layer. Each buffer polygon has a unique number (from the Buff_ID field).

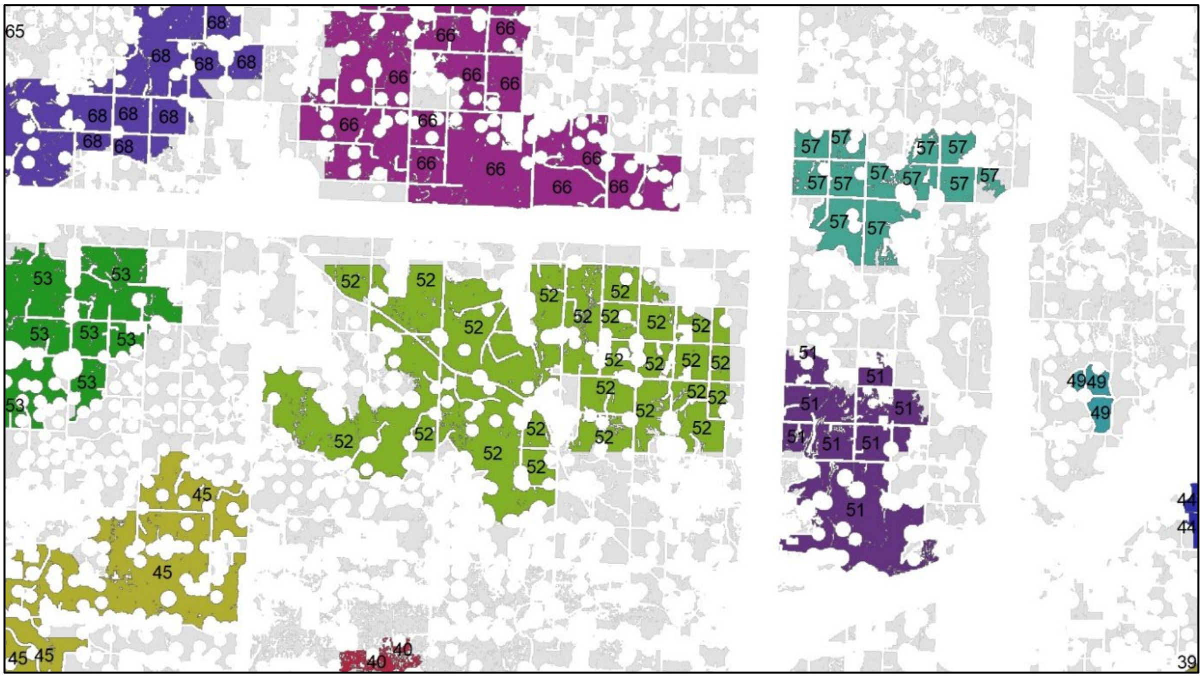


Figure B.15. Steps 4 and 5. The un-impacted potential usable area polygons are then dissolved by the Buff_ID field. All polygons within its group are now considered a block (shown as different colors in the map); one multi-part polygon (based on its intersection with the buffer layer polygons) with one acreage total equaling all its individual polygons in its group.

Results

We completed this analysis on the results of the current condition and the outputs of the future condition projections model. Those results are discussed in the main body of the SSA Report.

Part 5. Supplemental Analysis: Evaluation of CRP

Background and Purpose

The Service did not have access to spatially explicit data regarding enrollment in the Conservation Reserve Program (CRP) for our spatial analysis. The Service has worked for years to gain access to spatially explicit data from Farm Service Agency (FSA) regarding enrollment within CRP to include within spatial analysis exercises such as the one described above. Unfortunately, due to concerns over landowner privacy, the Service and FSA have not been able to develop an agreement that would allow access to the spatial data at the appropriate scale for inclusion in such analyses while ensuring landowner privacy.

If the Service had been able to obtain spatially explicit CRP data, we would have simply used it to ensure that areas enrolled in CRP are categorized as potential usable area within our current condition of the spatial analysis. We would assume CRP enrolled lands are all potentially usable space for LEPC. This would be a way to correct any land cover classification errors that occurred within the spatial data sets we used. For example, if any areas within the land cover data were classified as cropland but were actually enrolled in CRP, we would classify those area as potential usable space. Since the Service could not gain access to the spatially explicit CRP data, we worked with FSA on this issue.

Process

The Service provided FSA with spatial files for each ecoregion which delineated areas based on our raw land cover classifications as either potential usable area, potential woody restoration areas, potential cropland conversion areas, or non-usable areas. The Farm Service Agency was able to use their CRP data to provide us with summaries by ecoregion of how many acres of CRP enrollment occurred within each of those categories. Based upon those summaries, we were able to analyze the implications of not have spatially explicit CRP data for our analysis.

Results

The summary results of this comparison are presented in Table B.11. The results of the analysis presented above from FSA show that the lack of spatially explicit CRP data did not have a significant impact on our spatial analysis for the LEPC SSA. Specifically, this comparison indicated that, of the 1,451,603 ac of CRP enrollment within the LPC SSA analysis area, 1,231,280 ac were classified as potential usable area, 37,355 acres were impacted by woody vegetation encroachment, 127,065 acres were classified as cropland, and 55,903 acres were classified as non-usable area. This comparison indicated that range-wide there were potentially 182,968 acres of CRP enrollment that were in areas that we classified as cropland or non-usable areas (4000 or 5000 classification). If we were to assume that all of those 182,968 acres represent area that should have been classified as potential usable space in our analysis, it would have increased the land cover classified as currently potential usable space from 13,738,509 acres to 13,921,477 acres, or an increase of 1.33%. From this comparison, we can conclude that the lack of having spatially explicit CRP enrollment data has very minor implications to our spatial analysis and did not have significant impacts on the results of our current condition analysis of potential usable area for the LEPC.

Table B.11. Results, in acres, of CRP enrollment per USFWS land cover classification for the LEPC SSA by ecoregion and range-wide. USFWS land cover classifications: 1000 = potential usable area; 3000 = potential woody vegetation restoration; 4000 = potential conversion cropland; and 5000 = non-usable area. The red rows indicate areas of CRP that were not classified as potential usable areas in current condition spatial analysis.

USFWS Land cover Classification	**Ecoregions**				**Range-wide**
	Sand Sagebrush	**Shinnery Oak**	**Mixed-Grass**	**Short-Grass**	
1000	284,377	302,715	331,186	313,002	1,231,280
3000	1	36,829	351	174	37,355
4000	31,204	41,731	25,176	28,954	127,065
5000	7,786	18,113	18,498	11,506	55,903
Total	323,368	399,388	375,211	353,636	1,451,603

Part 6. Supplemental Analysis: Evaluation of Wind Development Impact Radii

Background and Purpose

During the development of the methodology of this spatial analysis detailed throughout this appendix, we reviewed the best available scientific information to account for threats to the LEPC. Part of this process included evaluating the literature to account for indirect habitat loss caused by different anthropogenic features. As detailed throughout Chapter 3 of the main body of the LEPC SSA report, anthropogenic features not only impact the species by direct removal of habitat, but most anthropogenic disturbances also alter the way in which the LEPC use the space adjacent to those features, creating indirect habitat loss. As part of our spatial analysis for the LEPC SSA, we assigned impact radii to features to account for this indirect habitat loss (see Part 2 of this Appendix).

The State biologists that participated in the development of this SSA recommended that we consider adopting the impact radii outlined with the LEPC Range-Wide Conservation Plan (Van Pelt *et al*. 2013, p. 94). While we did consider those impact radii, we also evaluated the best available science to inform our choices for those parameters in the model. There was particular concern over the impact radius used for wind turbines because the difference between what is included as part of the Range-Wide Plan (667 m) is considerable smaller than what we used (1,800 m).

Process

To evaluate the implications of wind development impact radii, we conducted a sensitivity analysis to estimate the difference in the output of our spatial model using the smaller, 667 m impact radii. While we didn’t fully rerun the model, we used the model outputs to roughly estimate the implications of the results had we used the smaller impact radius. The smaller impact radius results in footprints of wind projects of 15,200 ac (instead of 35,000 ac). Using this value and the same proportion of potential usable area impacted by wind in spatial projections, we were able to estimate the difference in total impacts. Table B.12 summarizes the number of projected impact acres using the 1,800-m impact radius and an estimation of the number of acres that would have been impacted if we would have utilized an impact radius of 667 meters by ecoregion by scenario.

Results

In summary, if we had used an impact radius of 667 m for projecting the future impacts of wind energy development, it would have decreased the acres projected to be impacted by wind within our analysis of future conditions and reduced the overall projection of future useable area available. The specific amounts of additional impacts range from 2,000 ac to 73,000 ac depending on the scenario, iteration, and ecoregion (Table B.12). Range-wide, the additional impacts range from 92,000 to 222,000 acres of additional impacts using the 1,800-m impact radius. The implications for the overall results, where we have approximately 4 million ac of potential usable space, is relatively small. A comparison of the percent change in potential usable space of current projected future conditions under both impact radii is presented in Table B.13). Overall, the difference in the results spatial analysis ranged from an increase of 0.2 to 7.4 across different iterations, scenarios, and ecoregions. Range-wide, the differences were 2.0 to 5.4% and the overall average was about 4% change.

Table B.12. Comparison of impacts of wind development using 1,800 m and 667 m for impact radii. Scenarios are the five future scenarios described in Part 1 of this Appendix and Chapter 4 of the main body of the LEPC SSA report. The projected impacts for 1,800-m radius analysis and represent the results from the median iteration output for each scenario and ecoregion. The "% of Max Wind" is the proportion of the potential wind impacts (max wind) that actual impacted potential usable LEPC areas. The Differences in Wind Impacts are the additional impacts from the 1,800-m radius subtracting the 667-m radius impacts.

	Future Projections		Assuming 1,800-m Impact Radii (35,000 ac per Wind Project)			Assuming 667-m Impact Radii (15,200 ac per Wind Project)		
Ecoregion	Scenario	# of wind projects	Max Wind Impacts (ac)	Projected Wind Impacts (ac)	% of Max Wind	Max Wind Impacts (ac)	Adjusted Wind Impacts (ac)	Difference in Wind Impacts (ac)
Short-Grass/CRP	1	7	245,000	68,313	27.9%	106,400	29,667	38,645
	2	7	245,000	75,160	30.7%	106,400	32,641	42,519
	3	11	385,000	92,743	24.1%	167,200	40,277	52,466
	4	16	560,000	129,992	23.2%	243,200	56,454	73,538
	5	16	560,000	134,184	24.0%	243,200	58,274	75,910
Mixed-Grass	1	10	350,000	50,236	14.4%	152,000	21,817	28,419
	2	10	350,000	71,761	20.5%	152,000	31,165	40,596
	3	18	630,000	85,100	13.5%	273,600	36,958	48,142
	4	25	875,000	151,302	17.3%	380,000	65,708	85,594
	5	25	875,000	106,011	12.1%	380,000	46,039	59,972
Sand Sagebrush	1	1	35,000	3,855	11.0%	15,200	1,674	2,181
	2	1	35,000	15,192	43.4%	15,200	6,598	8,594
	3	2	70,000	14,151	20.2%	30,400	6,146	8,005
	4	3	105,000	36,119	34.4%	45,600	15,686	20,433
	5	3	105,000	21,295	20.3%	45,600	9,248	12,047
Shinnery Oak	1	4	140,000	41,711	29.8%	60,800	18,115	23,597
	2	4	140,000	33,941	24.2%	60,800	14,740	19,201
	3	7	245,000	70,185	28.6%	106,400	30,481	39,705
	4	10	350,000	68,726	19.6%	152,000	29,847	38,879
	5	10	350,000	66,510	19.0%	152,000	28,884	37,626
Rangewide Totals	1	22	770,000	164,114	21.3%	334,400	71,272	92,842
	2	22	770,000	196,054	25.5%	334,400	85,143	110,910
	3	38	1,330,000	262,179	19.7%	577,600	113,861	148,319
	4	54	1,890,000	386,139	20.4%	820,800	167,695	218,445
	5	54	1,890,000	327,999	17.4%	820,800	142,445	185,554

Table B.13. Projected changes in future LEPC potential usable space in 25 years under five future scenarios given two different levels of impact radii from wind development projects.

Ecoregion	Scenario	Projected Change with 1,800-m Radii	Projected Change with 667-m Radii	Difference
Short-Grass/CRP	1	**-4.8%**	**-1.0%**	3.8%
	2	**-6.6%**	**-2.5%**	4.2%
	3	**-14.3%**	**-9.2%**	5.1%
	4	**-21.1%**	**-13.9%**	7.2%
	5	**-24.2%**	**-16.8%**	7.4%
Mixed-Grass	1	**-2.0%**	**0.8%**	2.9%
	2	**-13.0%**	**-9.0%**	4.1%
	3	**-25.3%**	**-20.5%**	4.8%
	4	**-34.7%**	**-26.1%**	8.6%
	5	**-36.6%**	**-30.6%**	6.0%
Sand Sagebrush	1	**-3.5%**	**-3.3%**	0.2%
	2	**-4.7%**	**-3.9%**	0.8%
	3	**-9.3%**	**-8.6%**	0.8%
	4	**-13.7%**	**-11.8%**	2.0%
	5	**-14.0%**	**-12.8%**	1.2%
Shinnery Oak	1	**12.3%**	**14.6%**	2.3%
	2	**-3.5%**	**-1.6%**	1.9%
	3	**-15.1%**	**-11.2%**	3.9%
	4	**-24.6%**	**-20.8%**	3.8%
	5	**-30.4%**	**-26.8%**	3.7%
Rangewide Totals	1	**0.5%**	**2.5%**	2.0%
	2	**-6.9%**	**-4.1%**	2.8%
	3	**-15.9%**	**-12.8%**	3.1%
	4	**-23.4%**	**-18.0%**	5.4%
	5	**-26.2%**	**-21.6%**	4.6%

Appendix C. Quantification of Future Conservation and Impacts for the LEPC

C.1 Introduction

As part of the Lesser Prairie-Chicken (LEPC) Species Status Assessment (SSA), the U.S. Fish and Wildlife Service (Service) explicitly projected the potential effects of both conservation efforts and impacts on the amount of grassland available for the LEPC over the next 25 years for each ecoregion. Within these projections, we included only those plausible future conservation efforts or impacts that are likely to affect the LEPC at the population level and for which we have information available to provide a basis for projection. The geographic extent of these projections was our SSA analysis area as depicted in Figure 2.2 in the main body of the LEPC SSA Report. These projections were then incorporated into the spatial analysis discussed in Appendix B. Below is documentation of the steps which were taken to project conservation efforts and impacts over the next 25 years for each ecoregion. Rationales for the inclusion of these efforts in our future projections can be found in Chapters 3 and 4 of the SSA Report.

These future projections are only intended to be estimates for use in modeling future potentially usable area for the purposes of informing our LEPC SSA. There are many confounding and complex factors that will determine the actual future LEPC habitat available in the southern Great Plains beyond what we can include in a simple model. However, this work provides a rational basis for using the best available information to forecast a range of the future potential useable area available for the LEPC.

All calculations and results of these projections are only reported in acres (1 ac = 0.4 ha).

C.2 Future Conservation Efforts

A summary of currently ongoing conservation efforts for the LEPC can be found in Section 3.4 of the main SSA Report. To project conservation efforts over the next 25 years, we contacted the primary conservation entities who are involved in implementing LEPC conservation programs to assist in characterizing future conservation actions.

Because it is impossible to accurately predict the future, we projected a range of plausible future conservation efforts by projecting three levels of effort; low, continuation, and high efforts.

- **Low efforts** were defined as the average rate at which we would expect for a given effort for a specific program if support and/or funding were to end or substantially decrease (the level of plausible decrease is specific for each program).

- **Continuation efforts** were defined as assuming conservation efforts were to continue at the average rate at which have recently been occurring for the given effort for a specific program, assuming support and funding continue at the current levels.

- **High efforts** were defined as the average rate at which we would expect for a given effort for a specific program if support and/or funding were to increase (the level of plausible increase is specific for each program).

In general, conservation efforts for the LEPC fall into one of two categories: **restoration efforts** and **enhancement efforts**. For these projections, we defined **restoration efforts** as an activity or action which converts non-usable area to usable area for the LEPC. For our purposes, restoration efforts include removal of woody vegetation, removal of energy infrastructure, and conversion of cropland to grassland. We defined **enhancement efforts** as those conservation activities or actions that enhance area that is already habitat for the LEPC; these efforts serve to maintain or increase habitat quality for the LEPC. Enhancement efforts include prescribed grazing, grazing deferment, disking, grass inter-seeding, planting cover crops, shrub plantings, prescribed fires, and other activities conducted to enhance or maintain the quality of existing LEPC habitat. Because some of this information was to be used in a spatial land cover analysis which did not directly assess LEPC occupancy of given sites, we did not address the species presence or absence in terms of defining these conservation efforts for this analysis. Thus, we assumed for this analysis that all efforts are either in areas which are currently occupied or which will become occupied by LEPC in the future and thus will have a positive impact on the biological status of the LEPC. Restoration efforts are included in our spatial model in the SSA while conservation efforts are reported separately in the SSA.

We requested conservation entities provide information to quantify future efforts for programs that they implement. For each ecoregion, we asked for a rate of conservation which they would expect for each given action that they are implementing for the three different levels of effort. Additionally, we requested further information to assist in characterizing those actions, such as geographic application[1], expected effectiveness, and the expected life span of a given action.

Once all raw inputs were compiled, they were then converted from a rate (e.g., annual or 10-year rates) to a 25-year projection. We did not calculate the annual estimates of future conservation, but instead we only projected the results of the actions at year 25. The total benefit for each action was then calculated at year 25 by combining efforts for each entity within each ecoregion, with further refinement being provided by the life span of the action as well as the geographic application of the action. The specific methods for the calculation for each action are described below.

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[1] Because all programs implementing conservation efforts for the LEPC are either using the Southern Great Plains Crucial Habitat Assessment Tool (CHAT) to target conservation efforts or are aware of this resource we asked that entities provide information on how they expect conservation efforts to be spatially applied on the landscape by CHAT category. For further information on CHAT, please see https://www.sgpchat.org/.

C.2.1 Restoration Efforts

C.2.1.1 Removal of Woody Vegetation

Two species of woody vegetation are primarily removed for LEPC conservation: eastern red cedar (*Juniperus virginiana*; ERC) and honey mesquite (*Prosopis glandulosa*; mesquite). Eastern red cedar primarily occurs in the northern portion of the LEPC range, specifically within the Short-Grass/CRP Ecoregion, Sand Sagebrush Ecoregion, and the Mixed-Grass Ecoregion. Mesquite primarily occurs in the southern portion of the LEPC range, specifically the Shinnery Oak Ecoregion and in some portions of the Mixed-Grass Ecoregion. While we know that some mesquite occurs in the Mixed-Grass Ecoregion, the majority of woody vegetation encroachment in that ecoregion is ERC and, due to the limitations associated with the spatial data, we did not delineate between tree species. Therefore, for the purposes of our spatial analysis and projections, we assumed that all woody vegetation encroachment in the Mixed-Grass Ecoregion is ERC. Eastern red cedar and mesquite differ both biologically and physically, resulting in differences in the potential effects to the LEPC and to the methods for removal. Because of these differences, we treated them differently in our projections of plausible conservation efforts. Below are the assumptions that were made for each species for these conservation actions.

C.2.1.1.1 Eastern Red Cedar Removal

Assumptions for ERC removal

- All conservation efforts for removal of woody vegetation in the Short-Grass/CRP, Mixed-Grass, and Sand Sagebrush ecoregions were treated as removal of ERC.

- When ERC is removed from a given area, this does not result in that area being void of ERC in perpetuity, and, because of this fact, we had to estimate an expected life span of a given ERC removal effort. Factors contributing to woody plant expansion are diverse and conditions resulting in establishment can be complex (Archer *et al*. 2017, pp. 41–43). However, previous experience in the range of the LEPC and research has indicated that if ERC is removed from a given area, and no follow up management actions (e.g., prescribed fire) are conducted, in approximately 5–15 years ERC begins to reappear in those areas (Briggs *et al*. 2002, pp. 584–585; Engle and Kulbeth 1992, p. 304). If programs do not commit to follow up management for treatment of ERC, we expect the area will likely be reinvaded by ERC of sufficient size and densities to result in negative effects to LEPC. This assumption is based on: the wide extent of occurrence of seed sources in and around treatment areas; limited spatial extent of treatments; wildland or prescribed fire frequencies being too low to prevent reestablishment and encroachment; continued management that lead to the original encroachment; and encroachment rates plus growth rates of ERC and other woody species. Therefore, we assumed that each acre of ERC removal would have a 10-year life span[2] unless the entity could commit to follow up management beyond 10 years on those acres.

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[2] For conservation entities that cannot commit to follow management when converting rates to total effort at the end of year 25, this assumption results in acreage calculation being cumulative for the first 10 years and then the acreage is constant after that time, as acreage is added in year 11 and the acreage from year 1 is subtracted and so on.

- We assumed that the initial treatments for ERC removal have a 100% effectiveness for the project life span.

- The currently available spatial datasets have a limited ability to detect short stature and low density stands of trees. The implication of this limitation is that our spatial analysis (described in Appendix B) likely underestimates current levels of ERC encroachment. Based on our experience and past discussions with the entities delivering ERC removal, it is apparent that the majority of ERC removal efforts are targeted at areas with low density stands of trees because those are the areas where efforts are most economical. This means that most of the ERC removal efforts are targeted toward areas that do not register as trees within our spatial model (Appendix B). Because we plan to use these projections within our spatial model, we needed to adjust our projections to account for this. We adjusted the projections within each ecoregion based upon the spatial distribution and density of ERC on the landscape. Within the Sand Sagebrush Ecoregion, we did not adjust the numbers due to the minimal acres of trees and minimal removal efforts within that ecoregion. Within the Short-Grass/CRP Ecoregion, we assumed that 25% of the ERC removal efforts would occur in areas of high density trees that are captured in the land cover data sets because most of the ERC within this ecoregion is short stature and low density stands. Within the Mixed-Grass Ecoregion, we assumed that 50% of the ERC removal efforts would occur in areas of high density trees that are captured in the land cover data sets, as the occurrence of trees that are larger in stature and occur at higher densities is more prevalent within this ecoregion when compared to that other two ecoregions[3].

- Research documents a strong avoidance by LEPC of a relatively large area around trees (Lautenbach *et al.* 2017, pp. 2–3). We used this information to establish impact radii around geospatial datasets identifying trees[4], and we logically assumed that removal of trees not only restores the immediate area where the tree exists but also opens up additional area that could be used by LEPC. Ideally, in our model we would have applied treatment to trees and then recalculated the impact radii of the remaining trees to account for the full treatment benefit. However, applying this multi-step approach to the modelled removal of trees was not feasible due to limitations in our spatial model structure as well as limitations associated with the spatial data. To manage these constraints, we used an approach based on parameters of the tree spatial data and the associated impact radii used for trees in the model. We divided the total area encompassed within the tree data (including impact radii) by the original acres of tree data without the impact buffers. This resulted in a calculation of the "relative density" of trees (i.e., acres of impact radii per acre of actual trees). These relative density calculations clearly showed that tree occurrence on the landscape varies across the ecoregions, as the estimates ranged from 3.8–297.9 impact radii acres/acre of trees. Therefore, we treated each ecoregion differently to calculate change in the model. Assuming a similar pattern would occur in the future, the relative tree density calculation was used to estimate a projected area

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[3] It should be noted this was done for the purpose of our spatial analysis. Efforts to remove ERC in areas with low density/short stature stands of ERC are highly beneficial for the LEPC and encouraged by the Service as a priority for conservation targeting.

[4] For further details regarding the impact radii please see Appendix B and Service (2014, entire).

of impact based on increases in (unbuffered) trees over 25 years. This value was reduced by 50 percent to constrain the maximum woody plant expansion allowed in the model, which is a simplification of the complexities of woody plant encroachment (Archer *et al*. 2017, pp. 41–43), such as latitudinal and longitudinal differences and local weather and climate conditions that affect rates of encroachment.
As a result of this process, to adjust our final ERC removal efforts to account for the additional benefits realized from removal of ERC to LEPC space use, we used a relative tree density of: 131.8 in the eastern and 297.9 in the western portions of the Short-Grass/CRP Ecoregion; 10.7 in the eastern and 16.2 in the western portions of the Mixed-Grass Ecoregion; and 38.8 in the Sand Sagebrush Ecoregions. We have taken a reasonable approach to estimate the overall LEPC benefits of tree removal efforts given data and modeling constraints.

- As discussed above and detailed further in Appendix B, ERC densities are different in the eastern vs. western portions of the Short-Grass/CRP and Mixed-Grass Ecoregions. The eastern portions contain higher densities and more overall trees and the western portions contain fewer trees at much lower densities. For modeling purposes, therefore, we assumed that all projected ERC removal for these two ecoregions occur in the eastern portions, and we use the relative densities associated with the eastern portion to account for the indirect benefits of ERC removal within those two ecoregions.

<u>Calculations for ERC removal</u>

The above assumptions result in the following process to calculate the total beneficial effect of removal of ERC at year 25 for each conservation entity for each LEPC ecoregion.

1. Compile information received on rates, time for which the rate represents, project life spans, and geographic application for ERC removal for each entity for each ecoregion (Table C.1).

Table C.1. Information received for estimated rate of acres of ERC removed by conservation entity and LEPC ecoregion.

	Level of Future Effort (Acres)					
Entity/Program	**Low**	**Continuation**	**High**	**Time (Years)**	**Life Span**	**Geographic Distribution**
Short-Grass/CRP Ecoregion						
KDWP	0	80	300	1	10	50% in CHAT 1&2; 50% outside of CHAT 1&2
USFWS PFW (KS)	0	520	640	1	10	50% in CHAT 1&2; 50% outside of CHAT 1&2
Mixed-Grass Ecoregion						
WAFWA	0	0	4,730	25	25	100% in CHAT 1&2
NRCS	1,965	2,620	3,275	1	10	50% in CHAT 1&2; 50% outside of CHAT 1&2
KDWP	0	20	200	1	10	50% in CHAT 1&2; 50% outside of CHAT 1&2
ODWC	100	250	400	1	10	50% in CHAT 1&2; 50% outside of CHAT 1&2
TPWD	0	0	100	1	10	5% in CHAT 1&2; 95% outside of CHAT 1&2
USFWS PFW (KS)	0	2,000	8,000	1	10	90% in CHAT 1&2; 10% outside CHAT 1&2
USFWS PFW (OK)	1,626	2,306	2,676	1	10	65% in CHAT 1&2; 35% outside CHAT 1&2
Sand Sagebrush Ecoregion						
KDWP	0	0	60	1	10	50% in CHAT 1&2; 50% outside of CHAT 1&2

2. For each entity, convert the rate provided to the overall effort at year 25 and incorporate the project life span for each entity to provide the total effort per entity at year 25 (Table C.2).

    - For entity committing to follow up management:

      Annual Rate x 25 Years = Total Effort

    - For entity which could not commit to follow up management:

      Annual Rate x 10 Years = Total Effort

Table C.2. Estimated ERC removal efforts in acres at year 25 for the LEPC ecoregions.

Entity/Program	Level of Future Effort (Acres)			Geographic Distribution
	Low	Continuation	High	
Short-Grass/CRP Ecoregion				
KDWP	0	800	3,000	50% in CHAT 1&2; 50% outside of CHAT 1&2
USFWS PFW (KS)	0	5,200	6,400	50% in CHAT 1&2; 50% outside of CHAT 1&2
Mixed-Grass Ecoregion				
WAFWA	0	0	4,730	100% in CHAT 1&2
NRCS	19,650	26,200	32,750	50% in CHAT 1&2; 50% outside of CHAT 1&2
KDWP	0	200	2,000	50% in CHAT 1&2; 50% outside of CHAT 1&2
ODWC	1,000	2,500	4,000	50% in CHAT 1&2; 50% outside of CHAT 1&2
TPWD	0	0	1,000	5% in CHAT 1&2; 95% outside of CHAT 1&2
USFWS PFW (KS)	0	20,000	80,000	90% in CHAT 1&2; 10% outside CHAT 1&2
USFWS PFW (OK)	16,260	23,060	26,760	65% in CHAT 1&2; 35% outside CHAT 1&2
Sand Sagebrush Ecoregion				
KDWP	0	0	600	50% in CHAT 1&2; 50% outside of CHAT 1&2

3. Account for the spatial application of ERC removal efforts. For simplification within our spatial analysis, all efforts were spatially delineated as either occurring within CHAT 1 and 2 or outside of CHAT 1 and 2 (Table C.3).

4. Total all efforts at low, continuation, and high levels for all entities delineated by acres of efforts falling within CHAT 1 and 2 and acres occurring outside CHAT 1 and 2 (Table C.3).

Table C.3. ERC removal efforts in acres at year 25 delineated by CHAT categories for each LEPC ecoregion.

	Level of Future Effort (Acres)					
	Low		**Continuation**		**High**	
Entity/Program	**Within CHAT 1&2**	**Outside CHAT 1&2**	**Within CHAT 1&2**	**Outside CHAT 1&2**	**Within CHAT 1&2**	**Outside CHAT 1&2**
Short-Grass/CRP Ecoregion						
KDWP	0	0	400	400	1,500	1,500
USFWS PFW (KS)	0	0	2,600	2,600	3,200	3,200
TOTAL	**0**	**0**	**3,000**	**3,000**	**4,700**	**4,700**
Mixed-Grass Ecoregion						
WAFWA	0	0	0	0	4,730	0
NRCS	9,825	9,825	13,100	13,100	16,375	16,375
KDWP	0	0	100	100	1,000	1,000
ODWC	500	500	1,250	1,250	2,000	2,000
TPWD	0	0	0	0	50	950
USFWS PFW (KS)	0	0	18,000	2,000	72,000	8,000
USFWS PFW (OK)	10,569	5,691	14,989	8,071	17,394	9,366
TOTAL	**20,894**	**16,016**	**47,439**	**24,521**	**113,549**	**37,691**
Sand Sagebrush Ecoregion						
KDWP	0	0	0	0	300	300
TOTAL	**0**	**0**	**0**	**0**	**300**	**300**

5. Account for efforts occurring in low density stands of trees which are likely not captured within current remote sensing datasets; see discussion above in the assumptions section for further information (Table C.4).

6. Account for the indirect effects of removal of trees by multiplying the adjusted raw ERC removal acres by the ecoregion specific relative density; see discussion above in the assumptions section for further information (Table C.4).

Table C.4. Total ERC removal efforts in acres for each LEPC ecoregion at year 25 with additional area accounting for indirect benefits.

Ecoregion	Level of Future Effort (Acres)					
	Low		Continuation		High	
	Within CHAT 1&2	Outside CHAT 1&2	Within CHAT 1&2	Outside CHAT 1&2	Within CHAT 1&2	Outside CHAT 1&2
Short-Grass/CRP Ecoregion						
TOTAL	**0**	**0**	**49,410**	**49,410**	**77,409**	**77,409**
Mixed-Grass Ecoregion						
TOTAL	**56,100**	**43,003**	**127,374**	**65,839**	**304,879**	**101,200**
Sand Sagebrush Ecoregion						
TOTAL	**0**	**0**	**0**	**0**	**564**	**564**

C.2.1.1.2 Honey Mesquite Removal

Assumptions for mesquite removal

- As discussed above, restoration efforts for removal of mesquite woody vegetation were limited to the Shinnery Oak Ecoregion, although a small amount of mesquite removal does occur in the Mixed-Grass Ecoregion.

- When mesquite is removed from a given area, this does not result in that area being void of mesquite in perpetuity. Therefore, we had to estimate an expected life span of a given mesquite removal effort. Previous experience has indicated that if mesquite is removed from a given area and no follow up actions are conducted, reinvasion will occur. For example, a study in north Texas found that an area which had all mesquite removed via root-plow methods increased from 0% canopy cover of mesquite immediately following the removal to almost 15% canopy cover in less than 15 years, with an estimated increase of 1.1% per year (Ansley *et al*. 2001, p. 173). If programs do not follow up management for treatment of mesquite, we expect the area will likely be reinvaded by mesquite of sufficient size and densities to result in negative effects to LEPC. This assumption is based on: the wide extent of occurrence of seed sources in and around treatment areas; wildland or prescribed fire frequencies being too low to prevent encroachment; continued management that leads to the original encroachment; and encroachment rates plus growth rates of mesquite and other woody species. Therefore, we assumed that each acre of mesquite removal would have a 10-year life span unless the conservation entity could commit to follow up management beyond 10 years on those acres.

- Recent research documents the effect of mesquite canopy cover on LEPC habitat use (Boggie *et al*. 2017, entire)[5]. Based on this information, we assume that areas with greater than 5%

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[5] See Appendix B, Part 3, for further information regarding the impacts of mesquite density on the LEPC.

canopy cover of mesquite should not be classified as LEPC usable area. In our spatial model, only those areas with greater than 5% canopy cover were identified as non-usable area; therefore, when projecting conservation efforts, we must estimate the portion of the efforts that will be targeted toward areas with greater than 5% canopy cover[6]. Based on our experience and previous discussions with entities performing removal of mesquite, we assumed that 75% of the total mesquite removal efforts would be targeted towards areas with canopy cover greater than 5%[7].

- Mesquite is a deciduous plant and recent research documents that LEPC avoid mesquite regardless of whether the plant has leaves or not (Boggie *et al.* 2017, entire). Based upon that research, it is apparent that chemically treating the mesquite without removing the dead standing structure will not result in the restoration of those areas as the standing mesquite will still be influencing space use by the LEPC. Thus, when projecting mesquite removal, we asked conservation entities to not project the acres of chemical treatment but instead to project acres of on-the-ground mesquite removal. NRCS estimates only included acres for chemically treated mesquite, so we assumed that dead standing tree skeletons will be removed on 25% of the acres that were chemically treated by NRCS.
- Research documents a strong avoidance of mesquite by LEPC (Boggie *et al*. 2017, entire). Specifically, the findings suggest that, in both the breeding and non-breeding seasons, prevalence of mesquite canopy within LEPC home ranges were relatively low and decreased precipitously from outer to inner areas of the home range, suggesting avoidance of areas with mesquite present[8]. Based upon this logic, we assumed that removal of mesquite not only restores the immediate area where the mesquite exists but also now opens up additional habitat which could be used by the LEPC. Ideally, our model would apply treatment to mesquite and then recalculate the impact radius of the remaining areas with mesquite to account for the full treatment benefit. However, applying this multi-step approach to model removal of trees was not feasible due to our spatial model structure and limitations associated with the spatial data. To account for these constraints, we used an approach based on parameters of the tree spatial data (includes mesquite and other trees), and the associated impact radii used for trees in the model. We divided the total area encompassed within the tree data (including the impact radii) by the original acres of tree data, which resulted in the "relative density" of trees (i.e., acres of impact radii per acre of actual trees) within their extent of their impact radii. These relative density calculations clearly showed that tree occurrence on the landscape varies across the ecoregions, as the estimates ranged from 3.8–297.9 impact radii acres/acre of trees. Therefore, we treated the ecoregions differently to calculate change in the model. Assuming a similar pattern would occur in the future, the relative tree density calculation was used to estimate a projected area of impact based on increases in (unbuffered) trees over 25 years. This value was reduced by 50 percent to

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[6] It should be noted this was done for the purpose of our spatial analysis. Efforts to remove mesquite in areas with less than 5% canopy cover are highly beneficial for the LEPC and encouraged by the Service as a priority for conservation targeting.

[7] With the exception of NMDGF because this was already factored into their calculations.

[8] See Appendix B, Part 3, for additional information regarding avoidance of mesquite by LEPC.

constrain the maximum woody plant expansion allowed in the model, which is a simplification of the complexities of woody plant encroachment (Archer *et al*. 2017, pp. 41–43), such as latitudinal and longitudinal differences, and local weather and climate conditions that affect rates of encroachment. The final result of this process is that we used the relative density of 1.88 in the Shinnery Oak Ecoregion to adjust our final mesquite removal efforts to account for the additional benefits realized from removal of mesquite to LEPC space use. Our approach is simplified to support this modeling effort because, in real world application, the resulting ratio of area of mesquite to area of impact radius treated would be highly variable due to the relationship of the shape and extent of mesquite treatments and their corresponding impact radii (i.e., area to perimeter ratios). We have taken a reasonable approach to estimate the overall LEPC benefits of mesquite removal efforts based upon limitations of the data and model.

Calculations for mesquite removal

The above assumptions result in the following process to calculate the total effect of removal of mesquite at year 25 for each entity.

1. Compile information received on rates and geographic distribution regarding the removal of mesquite for each entity (Table C.5).

Table C.5. Estimated rate for acres of mesquite removed by conservation entity and LEPC ecoregion.

Entity/Program	**Level of Future Effort (Acres)**			**Time (Years)**	**Life Span (Years)**	**Geographic Distribution**
	Low	**Continuation**	**High**			
Shinnery Oak Ecoregion						
WAFWA	0	0	3,252	25	25	100% in CHAT 1&2
NRCS	4,655	6,207	7,758	1	10	50% in CHAT 1&2; 50% Outside CHAT 1&2
TPWD	0	75	300	1	10	15% in CHAT 1&2; 85% Outside CHAT 1&2
CEHMM	3,000	6,000	12,000	1	10	100% in CHAT 1&2
BLM	500	2,000	5,000	1	10	50% in CHAT 1&2; 50% Outside CHAT 1&2
NMDGF	35	35	35	25	25	100% in CHAT 1&2

2. For each entity, convert the rate provided to the overall effort at low, continuation, and high levels, in acres at year 25 and adjust NRCS numbers to account for removal of dead standing tree skeletons[9] (Table C.6).

Table C.6. Mesquite removal efforts projected for 25 years.

	Level of Future Effort (Acres)			
Entity/Program	**Low**	**Continuation**	**High**	**Geographic Distribution**
Shinnery Oak Ecoregion				
WAFWA	0	0	3,252	100% in CHAT 1&2
NRCS	11,637	15,518	19,395	50% in CHAT 1&2; 50% Outside CHAT 1&2
TPWD	0	750	3,000	15% in CHAT 1&2; 85% Outside CHAT 1&2
CEHMM	30,000	60,000	120,000	100% in CHAT 1&2
BLM	5,000	20,000	50,000	50% in CHAT 1&2; 50% Outside CHAT 1&2
NMDGF	35	35	35	100% in CHAT 1&2

3. Account for the estimated proportion of the effort which is targeted towards areas with greater than 5% canopy cover and other information (Table C.7).

   Total Effort x 75%

Table C.7. Mesquite removal efforts in acres projected for 25 years adjusted for efforts which are targeted at areas with greater than 5% canopy cover.

	Level of Future Effort (Acres)			
Entity/Program	**Low**	**Continuation**	**High**	**Geographic Distribution**
Shinnery Oak Ecoregion				
WAFWA	0	0	2,439	100% in CHAT 1&2
NRCS	8,728	11,638	14,546	50% in CHAT 1&2; 50% Outside CHAT 1&2
TPWD	0	563	2,250	15% in CHAT 1&2; 85% Outside CHAT 1&2
CEHMM	22,500	45,000	90,000	100% in CHAT 1&2
BLM	3,750	15,000	37,500	50% in CHAT 1&2; 50% Outside CHAT 1&2
NMDGF	35	35	35	100% in CHAT 1&2

4. Account for the spatial application of those efforts. For simplification within our spatial analysis, all efforts were spatially defined by occurring within CHAT 1 and 2 or outside of CHAT 1 and 2 (Table C.8).

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[9] See assumptions above for further discussion.

5. Total all efforts for each entity delineated by acres of efforts falling with CHAT 1 and 2 and acres occurring outside CHAT 1 and 2 (Table C.8).

6. Account for the indirect effects of removal of mesquite by multiplying the total acres of raw mesquite removal by the relative tree density[10] (Table C.8).

Table C.8. Mesquite removal projected (in acres) for 25 years at three levels of effort, adjusted for efforts which are targeted at areas with greater than 5% canopy cover and accounting for indirect benefits.

	Level of Future Effort (Acres)					
	Low		**Continuation**		**High**	
Entity/Program	**Within CHAT 1&2**	**Outside CHAT 1&2**	**Within CHAT 1&2**	**Outside CHAT 1&2**	**Within CHAT 1&2**	**Outside CHAT 1&2**
Shinnery Oak Ecoregion						
WAFWA	0	0	0	0	2,439	0
NRCS	4,364	4,364	5,819	5,819	7,273	7,274
TPWD	0	0	84	478	338	1,912
CEHMM	22,500	0	45,000	0	90,000	0
BLM	1,875	1,875	7,500	7,500	18,750	18,750
NMDGF	35	0	35	0	35	0
Total	**28,774**	**6,239**	**58,438**	**13,797**	**118,835**	**27,936**
TOTAL w/indirect	**54,095**	**11,729**	**109,864**	**25,939**	**223,409**	**52,519**

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[10] See assumptions above for discussion on relative density

C.2.1.1.3 Summary of Woody Vegetation Removal

Table C.9. Summary of projected removal of woody vegetation in acres for each of the three levels of conservation by LEPC ecoregion at year 25.

	Level of Future Effort (Acres)					
	Low		Continuation		High	
Ecoregion	**Within CHAT 1&2**	**Outside CHAT 1&2**	**Within CHAT 1&2**	**Outside CHAT 1&2**	**Within CHAT 1&2**	**Outside CHAT 1&2**
Short-Grass/CRP*	0	0	49,410	49,410	77,409	77,409
Mixed-Grass*	56,100	43,003	127,374	65,839	304,879	101,200
Sand Sagebrush	0	0	0	0	564	564
Shinnery Oak	54,095	11,729	109,864	25,939	223,409	52,519

*All acres of removal were assumed to occur in the eastern portion of the Short-Grass/CRP and Mixed-Grass Ecoregions (See section C.3.2 for further discussion on differences in woody vegetation encroachment for portions of these ecoregions and delineation of eastern vs. western portions of these ecoregions).

C.2.1.2 Removal of Energy Infrastructure:

There are various types of energy infrastructure removed across the range of the LEPC. To account for this, we worked with the conservation entities to estimate rates of restoration that they are planning to conduct via the removal of energy-related infrastructure.

Assumptions for infrastructure removal

Below are the assumptions made to calculate effects of removing energy infrastructure.

- When energy infrastructure is removed, it has an effect greater than restoring the grassland that falls directly within the footprint of the given structures. The amount of affected habitat depends upon the type of infrastructure removed; see Appendix B, Part 2, for a further discussion of the specific impact radii. The restoration that is attributed to the Western Association of Fish and Wildlife Agencies (WAFWA) already accounts for indirect effects that the development has on space use by the LEPC; thus, no additional calculations were needed to account for indirect benefits. While we know that restoration of a variety of different anthropogenic features occur, entities cannot predict what specific features they will remove in the future. To simply the projections, we asked entities to report projected number of acres restored rather than number of structures. Because it is not known what specific features will be removed or the differences in impact radii used by different agencies, in our spatial analysis we assumed (for all entities other than WAFWA) that half of the projected acres were restoration of oil and gas well pads and the other half would be restoration of access roads. To calculate total effect of restoration acres via removal of well pads, we divided the number of acres by 1.5 (as we assume the average well pad size is 1.5 acres for this calculation) which will give us the number of well pads to be restored. We then multiply the number of well pads to be restored by 38 acres, as this is the assumed acres of usable area impacted by a single well (see section C.3.1.1 Step 7 below for additional information on acres impacted per well pad). There were no additional indirect effects calculated for the restoration of access roads, as most of those roads are smaller classed roads that have minimal indirect effects to the LEPC.

- We assumed that restored areas would remain in that condition for the entirety of the 25-year projection period.

- When energy infrastructure is removed, it is likely that there are other existing anthropogenic or landscape features that will continue to reduce or even preclude space use by the LEPC. However, to give maximum potential benefit for these actions, we assumed that after the restoration work there would be no other features present which would preclude or reduce space use by the LEPC[11].

- We only project restoration efforts for the removal of energy infrastructure occurring through the identified entities. We acknowledge that some removal of infrastructure likely occurs outside of the entities identified but no data exists to provide an estimate specific to the likely future efforts on LEPC usable area within the our analysis area.

- Removal of wind energy development structures is not considered in our analysis, as we assume new wind energy developments will have a life span of at least 30 years, and any existing wind energy developments that exceed the 30-year life span will be replaced through repowering. Repowering involves replacing older equipment with newer, upgraded technology on an existing developed site.

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[11] This assumption could result in an overestimate of the benefits to the LEPC from these efforts.

Calculations for infrastructure removal

The above assumptions result in the following process to calculate the total effect of removal of energy infrastructure at year 25 for all entities:

1. Compile input rates in acres for all entities by ecoregion for three levels of effort and spatial application of those acres (Table C.10).

Table C.10. Estimated rate for acres of energy infrastructure removal by conservation entity and LEPC ecoregion.

Entity/Program	**Level of Future Effort (Acres)**			**Time (Years)**	**Geographic Distribution**
	Low	**Continuation**	**High**		
Short-Grass/CRP Ecoregion					
WAFWA	0	100	150	1	50% in CHAT 1/2; 50% Outside Chat 1/2
Mixed-Grass Ecoregion					
WAFWA	0	18	27	1	50% in CHAT 1/2; 50% Outside Chat 1/2
Sand Sagebrush Ecoregion					
WAFWA	0	11	16.5	1	50% in CHAT 1/2; 50% Outside Chat 1/2
Shinnery Oak Ecoregion					
CEHMM	5	5	20	1	100% within Chat 1/2
BLM	0	150	350	1	50% in CHAT 1/2; 50% Outside Chat 1/2
NMDGF	0	21	84	25	100% within Chat 1/2

2. Project restored acres over next 25 years and account for spatial application (Table C.11).

Table C.11. Estimated acres of energy infrastructure removal by conservation entity and LEPC ecoregion at three levels of conservation effort over the next 25 years.

	Level of Future Effort (Acres)					
	Low		**Continuation**		**High**	
Entity/Program	**Within CHAT 1&2**	**Outside of CHAT 1&2**	**Within CHAT 1&2**	**Outside of CHAT 1&2**	**Within CHAT 1&2**	**Outside of CHAT 1&2**
Short-Grass/CRP Ecoregion						
WAFWA	0	0	1250	1250	1875	1875
Mixed-Grass Ecoregion						
WAFWA	0	0	225	225	338	338
Sand Sagebrush Ecoregion						
WAFWA	0	0	275	275	413	413
Shinnery Oak Ecoregion						
CEHMM	125	0	125	0	500	0
BLM	0	0	1875	1875	4375	4375
NMDGF	0	0	21	0	84	0

3. For entities other than WAFWA, combine all efforts for all entities and convert the input acres to account for indirect effects as discussed above. To do this, we first assume that 50% of the restored acres will be due to removal of oil and gas wells and the other 50% due to removal of access roads. We then divide the total acres of well pad removal by 1.5 (average acreage of well pad) and multiply the result by 38 acres (the average amount of usable area impacted by an individual well). Finally, we total the acres restored via well pad removal and access road removal for the total effort (Table C.12).

Table C.12. Estimated acres of energy infrastructure removal for entities other than WAFWA and LEPC ecoregion over the next 25 years accounting for the indirect benefits.

	Level of Future Effort (Acres)					
	Low		**Continuation**		**High**	
Total Effort	**Within CHAT 1&2**	**Outside of CHAT 1&2**	**Within CHAT 1&2**	**Outside of CHAT 1&2**	**Within CHAT 1&2**	**Outside of CHAT 1&2**
Shinnery Oak Ecoregion						
Total	1646	0	26,610	24,688	65,294	57,604

4. Combine the efforts for all entities in acres to give a total effort for infrastructure removal for each ecoregion (Table C.13).

Table C.13. Total effort (in acres) per ecoregion of acres restored projected at low, continuation, and high levels via removal of energy infrastructure over the next 25 years.

Ecoregion	**Level of Future Effort (Acres)**					
	Low		**Continuation**		**High**	
	Within CHAT 1&2	**Outside of CHAT 1&2**	**Within CHAT 1&2**	**Outside of CHAT 1&2**	**Within CHAT 1&2**	**Outside of CHAT 1&2**
Short-Grass/CRP	0	0	1,250	1,250	1,875	1,875
Mixed-Grass	0	0	225	225	338	338
Sand Sagebrush	0	0	275	275	413	413
Shinnery Oak	1,646	0	26,610	24,688	65,294	57,604

C.2.1.3 Conversion of Cropland to Grassland

Assumptions for conversion of cropland to grassland

The assumptions for calculating the future efforts associated with conversion of cropland to grassland calculation are listed below:

1. There are no indirect effects or avoidance distance associated with this action.
2. The lifespan of this action is assumed to be the entire 25-year projection period.
3. Because we did not have access to specific data regarding the Conservation Reserve Program (CRP) administered by USDA, we assumed no net increase or decrease in acres of CRP lands over the next 25 years; thus, no new acres of cropland conversion via CRP are projected for the purposed of this analysis.
4. For simplification within our modelling process, all efforts are delineated by occurring either within CHAT 1 and 2 or Outside CHAT 1 and 2.

Calculations of conversion of cropland to grassland

The above assumptions result in the following process to calculate the total effect for conversion of cropland to grassland at year 25 for all entities:

1. Compile information received for the rate of conversion acres for each entity per ecoregion (Table C.14).

Table C.14. Information received for estimated rate of acres of cropland conversion by conservation entity and LEPC ecoregion.

Entity/Program	Level of Future Effort (Acres)			Time (Years)	Geographic Distribution
	Low	Continuation	High		
Short-Grass/CRP Ecoregion					
KDWP	0	0	220	1	50% in CHAT 1/2; 50% Outside Chat 1/2
KS PFW	0	100	200	1	50% in CHAT 1/2; 50% Outside Chat 1/2
Mixed-Grass Ecoregion					
KDWP	0	0	20	1	50% in CHAT 1/2; 50% Outside Chat 1/2
ODWC	40	80	240	1	50% in CHAT 1/2; 50% Outside Chat 1/2
OK PFW	35	339	651	1	65% in CHAT 1/2; 35% Outside Chat 1/2
ODWC	400	600	800	25	50% in CHAT 1/2; 50% Outside Chat 1/2
Sand Sagebrush Ecoregion					
KDWP	0	0	20	1	50% in CHAT 1/2; 50% Outside Chat 1/2
CPW	0	400	800	1	100% in Chat 1/2
Shinnery Oak Ecoregion					
WAFWA	0	0	366	25	100% within Chat 1/2

2. For each entity, convert annual rates provided to the overall effort at year 25 (annual rate x 25 years) to get total acres (Table C.15).

Table C.15. Conversion of cropland to grassland effort for each entity at year 25.

Entity/Program	**Level of Future Effort (Acres)**			**Geographic Distribution**
	Low	**Continuation**	**High**	
Short-Grass/CRP Ecoregion				
KDWP	0	0	5500	50% in CHAT 1/2; 50% Outside Chat 1/2
KS PFW	0	2500	5000	50% in CHAT 1/2; 50% Outside Chat 1/2
Mixed-Grass Ecoregion				
KDWP	0	0	500	50% in CHAT 1/2; 50% Outside Chat 1/2
ODWC	1000	2000	6000	50% in CHAT 1/2; 50% Outside Chat 1/2
OK PFW	875	8475	16,275	65% in CHAT 1/2; 35% Outside Chat 1/2
ODWC	10,000	15,000	20,000	50% in CHAT 1/2; 50% Outside Chat 1/2
Sand Sagebrush Ecoregion				
KDWP	0	0	500	50% in CHAT 1/2; 50% Outside Chat 1/2[12]
CPW	0	10,000	20,000	100% in Chat 1/2
Shinnery Oak Ecoregion				
WAFWA	0	0	366	100% within Chat 1/2

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[12] For streamlining the modeling exercise all 500 acres were assumed to occur in CHAT 1 and 2.

3. Delineate the acres of the conversion effort falling inside of CHAT 1 and 2 and Outside of CHAT 1 and 2 and combine efforts for all entities per LEPC ecoregion (Table C.16).

Table C.16. Total estimated conversion of cropland to grassland at year 25 delineated by CHAT to account for spatial application.

	Level of Future Effort (Acres)					
	Low		**Continuation**		**High**	
Ecoregion	**Within CHAT 1&2**	**Outside CHAT 1&2**	**Within CHAT 1&2**	**Outside CHAT 1&2**	**Within CHAT 1&2**	**Outside CHAT 1&2**
Short-Grass/CRP	0	0	1,250	1,250	5,250	5,250
Mixed-Grass	1,269	1,006	6,809	4,266	14,229	9,346
Sand Sagebrush	0	0	10,000	0	20,500	0
Shinnery Oak	0	0	0	0	366	0

C.2.2 Enhancement Efforts

We also asked conservation entities to provide us information related to other conservation efforts for the LEPC that were being implemented that were not restoration efforts but instead were aimed at maintaining or enhancing existing LEPC habitat. These efforts only represent those which are above and beyond what is already accounted for within the current condition discussion within Chapter 3 of the main body of the SSA Report. Efforts already reported within Chapter 3 of the report which we had reasonable certainty would continue into the future are not included within this table[13]. Enhancement efforts are projected using the same three levels of conservation and incorporate a wide variety of actions (Table C.17).

Table C.17. Projected acreage of LEPC habitat enhancement over the next 25 years.

Enhancement Efforts	**Total Level of Future Effort (Acres) at Year 25**		
	Low	**Continuation**	**High**
Short-Grass/CRP Ecoregion			
KDWP Enhancement Contract	0	6740	17,500
NRCS LPCI Grazing Plan	0	0	4,000
USFWS PFW Contract	14,000	14,000	20,000
Mixed-Grass Ecoregion			
WAFWA Management Plan	0	0	118,245
KDWP Enhancement Contract	0	120	3,100
ODWC Management	1,400	3,300	6,400
ODWC Additional CCAA Enrollment	0	50,000	100,000
NRCS LPCI Grazing Plan	0	0	58,000
USFWS PFW Contract	50,000	50,000	70,000
TPWD Additional CCAA Enrollment	0	0	550,00
Sand Sagebrush Ecoregion			
KDWP Enhancement Contract	0	720	4,400
CPW Enhancement Contract	0	12,200	37,900
NRCS LPCI Grazing Plan	0	0	13,000
USFWS PFW Contract	0	6,000	18,000
Shinnery Oak Ecoregion			
WAFWA Management Plan	0	0	8,129
NRCS LPCI Grazing Plan	0	0	39,000
BLM Prescribed Fire	0	25,000	100,000
NM CCA/A Prescribed Fire	50,000	100,000	150,000
USFWS PFW Contract	5,000	15,000	50,000
TPWD Additional CCAA Enrollment	0	0	60,000

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[13] This includes all conservation efforts on acres currently managed under the Texas CCAA, Oklahoma CCAA, New Mexico CCA/CCAA, BLM management, current levels of NRCS LPCI grazing plans, Management on permanently protected lands such as State owned wildlife management areas.

C.3 Future Impacts

Reasonably projecting impacts on LEPC and its habitat in the future is a complex task, and there are variable amounts, types, and quality of data available to guide this process. To aid in projecting plausible future development, we used the best available information to forecast a range of future levels of usable area impacted from four sources: woody vegetation encroachment, oil and gas development, wind energy development, and conversion of grassland to cropland. These are not the only sources of impacts likely to affect LEPC usable area in the future, but these are the primary drivers of effects and ones where sufficient information on rates, extent, and location to support characterizing in a range of future scenarios to support the analyses. Predicting future actions singularly with precision and accuracy is not possible; therefore, we projected a range of plausible future impact levels that include three levels of potential usable area loss: low, intermediate, and high levels.

We used the best available information for each source of impacts to establish annual rates of change. All projections of the total amount of estimated impacts are limited to our analysis area in the four ecoregions and then refined later in the process by geographically constraining where this development is most likely to occur as discussed below for each impact source. Additionally, due to the nature of each individual projected future impact, we can reasonably assume that each of these will have an effect lasting throughout the 25-year projection period. Specific assumptions for the calculations for each source of impact are explained below.

C.3.1 Oil and Gas Development

We projected the number of new oil and gas wells to be drilled in our analysis area by ecoregion for the LEPC over the next 25 years. We reviewed the applicable available data that provides information to assist in projecting oil and gas development in the future including, but not limited to, information from:

- U.S. Energy Information Administration
- Baker Hughes well count and drilling activity (Baker Hughes 2017)
- IHS well count information

While this information is useful to give us an idea of general past and future trends, it does not provide the information at the appropriate geographic scale, nor for the most part do they provide information regarding wells drilled. Instead, much of the information is largely focused on total production or production trends. We also reviewed information available from WAFWA through the LEPC Range-wide Plan (RWP) and the subsequent annual reports. Within the LEPC RWP (Van Pelt *et al*. 2013, p. 138), WAFWA estimates high and low scenarios for the number of new wells drilled per year for each ecoregion based upon high and low price scenarios from the U.S. Energy Information Administration[14]. Finally, we reviewed publicly available information from each of the state permitting entities. Through those entities, we were able to obtain publicly available spatially explicit time series data on drilling activity in the past. We

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[14] WAFWA projected wells based upon the LEPC Estimate Occupied Range plus a 10-mile buffer. This area is approximately twice the size of our analysis area used in this SSA.

used this information to form the basis for our projections of the number of new wells likely to be drilled in our analysis area per ecoregion over the next 25 years.

Assumptions and Calculations for Oil and Gas Development Projections

Below are the assumptions and steps taken to project oil and gas development.

1. We gathered the publicly available spatial data for each state. Table C.18 summarizes the data we accessed.

Table C.18. Data sources utilized for available spatially explicit oil and gas well drilling data.

State	**Agency**	**Data Link**	**Download Date**
Kansas	Kansas Geological Survey	http://www.kgs.ku.edu/PRS/petroDB.html	May 2020
Colorado	Colorado Oil & Gas Conservation Commission	https://cogcc.state.co.us/data.html	May 2020
Oklahoma	Oklahoma Corporation Commission	https://www.occeweb.com/OG/ogforms.html	May 2020
Texas	Texas Railroad Commission	https://www.rrc.state.tx.us/about-us/resource-center/research/data-sets-available-for-download/#digital-map-data-table	May 2020
New Mexico	New Mexico Oil Conservation Division	http://www.emnrd.state.nm.us/OCD/ocdgis.html	May 2020

2. State-wide spatial data were filtered to only include data for wells drilled within our analysis area.

3. Within these datasets, there are multiple types of wells (for example oil, gas, injection, saltwater injection, water, CO2) and each state has its own way of categorizing and tracking wells. Additionally, some of the wells drilled result in a “dry hole” or a well that does not produce. Thus, we further filtered the data to only include wells of the following type and status:

    - Kansas – We used the “well status” attribute within the data and only included wells that were identified as:
        - O&G – produced oil and gas
        - OIL – produced oil
        - GAS – produced natural gas

- Colorado – We used the "facility status" attribute within the data and only included wells that were identified as:
    - Active
    - Producing
- Oklahoma – We used the "well type" attribute and the "well status" attribute within the data to only include wells that were identified as:
    - OIL – Active
    - GAS – Active
- Texas – We used all oil and gas wells that did not have an identified "Plug_Date" within the data.
- New Mexico – We used the "well type" and the "status" attribute within the data to only include wells that were identified as:
    - Gas – Active
    - Oil – Active

4. We then summarized the data by ecoregion to characterize the number of new wells drilled per year for the past 15 years from 2004–2019 (Table C.19). This was done by using the identified "spud date" for each well within the data attributes to assign the year drilled for Kansas, Colorado, Oklahoma, and New Mexico. The data from Texas did not have a spud date but instead included a "completion date" attribute so this was used to identify the year drilled.

Table C.19. Summary of the number of producing oil and gas wells drilled by year within each of the LEPC ecoregions.

Year Drilled	**Ecoregion**			
	Short-Grass/CRP	**Mixed-Grass**	**Sand Sagebrush**	**Shinnery Oak**
2004	87	746	23	1124
2005	129	933	13	1176
2006	206	1161	9	1433
2007	233	1056	49	1443
2008	228	1386	77	1900
2009	241	666	16	1109
2010	306	924	50	1987
2011	347	1245	19	2342
2012	427	1456	13	2567
2013	387	1469	26	2011
2014	352	1283	45	2135
2015	139	393	32	1509
2016	67	242	17	1413
2017	103	312	16	1493
2018	147	315	22	1441
2019	112	192	15	953

5. For future development we assumed an intermediate level of development would be equal to the average from 2004–2019. For the high and low development projections, we varied the projection by one standard deviation. Table C.20 summarizes the annual number of new wells projected under three different development levels for each LEPC ecoregion.

Table C.20. The projected annual number of new oil and gas wells to be drilled by LEPC ecoregion under three different levels of future development.

	Projected New Annual Wells		
Ecoregion	**Low**	**Intermediate**	**High**
Short-Grass/CRP	108	219	331
Mixed-Grass	417	861	1,306
Sand Sagebrush	10	28	46
Shinnery Oak	1,168	1,627	2,086

6. Not all areas within the ecoregions occur in usable area for the LEPC and thus many of the wells drilled within each ecoregion do not impact the LEPC. To account for this, we analyzed all wells included within our current condition analysis (see Appendix B for further detail) to determine the percentage of wells which impact areas (this includes the direct and indirect impacts of each well) that we defined as potential useable area for the LEPC. The results of this analysis indicated that within the Short-Grass/CRP Ecoregion 26.2%, the Mixed-Grass Ecoregion approximately 20.9%, the Sand Sagebrush Ecoregion 34.5%, and the Shinnery Oak Ecoregion 12.3% of wells drilled impacted potential usable area for the LEPC. We then used this information to adjust our projections for the annual number of new wells drilled per ecoregion to only reflect those which would impact potential usable area for the LEPC (Table C.21).

Table C.21. The projected annual number of new oil and gas wells to be drilled by LEPC ecoregion under three different levels of future development which are expected to impact potential usable are for the LEPC.

	Projected Impacts (wells)		
Ecoregion	**Low**	**Intermediate**	**High**
Short-Grass/CRP	28	57	87
Mixed-Grass	87	180	273
Sand Sagebrush	3	10	16
Shinnery Oak	144	200	257

7. We then converted the annual projected number of new wells drilled which will impact potential usable area for the LEPC to projected acres impacted. To account for both the

direct and indirect impacts of wells on the LEPC, we used an impact radii of 300 meters[15]. We further adjusted the number of acres impacted by the projected wells to account for the amount of potential overlap with other existing impacts that occur on the landscape. New wells are often placed near other infrastructure, including roads, power lines, and other anthropogenic features that have already impacted the landscape such that much of the area that falls within the impact radius has already been affected. Thus, the total projected impact is less than the simple addition of the acreages.

To calculate the actual estimated impacts, we begin with 69.9 acres, which is the area of a circle with a 300-meter radius, which we assumed for this analysis is the impact of an individual well on the LEPC. We then estimated how much of the area for each well is likely to be already impacted. WAFWA estimated that on average new wells mitigated through their mitigation strategy overlapped existing features by 56.7% (WAFWA 2020, unpaginated, Table 34). Additionally, WAFWA had previously estimated that prior to the range-wide conservation plan implementation that wells overlapped existing features by 42% (Wolfe *et al.* 2019, p. 70). In February 2019, WAFWA also estimated that approximately 25% of wells drilled within the range of the LEPC were being mitigated for under their mitigation strategy in 2017 (WAFWA 2019, unpaginated). Based on that information, we assumed that 25% of new wells would have an overlap of 56.7% with existing infrastructure, and 75% of new wells would have an overlap of 42%. Using the weighted average, we calculated that when overlap is considered, each new well would impact 38 acres. Table C.22 reflects the total acres of potential usable area impacted over the next 25 years by oil and gas development (annual number of new wells x 38 acres x 25 years).

Table C.22. Future projection of three levels of impacted acres of potential usable area for the LEPC from oil and gas development over the next 25 years in each ecoregion.

Ecoregion	**Project Impact (acres)**		
	Low	**Intermediate**	**High**
Short-Grass/CRP	26,848	54,618	82,388
Mixed-Grass	82,716	170,989	259,262
Sand Sagebrush	3,166	9,054	14,942
Shinnery Oak	136,539	190,144	243,749
Total	249,269	424,805	600,342

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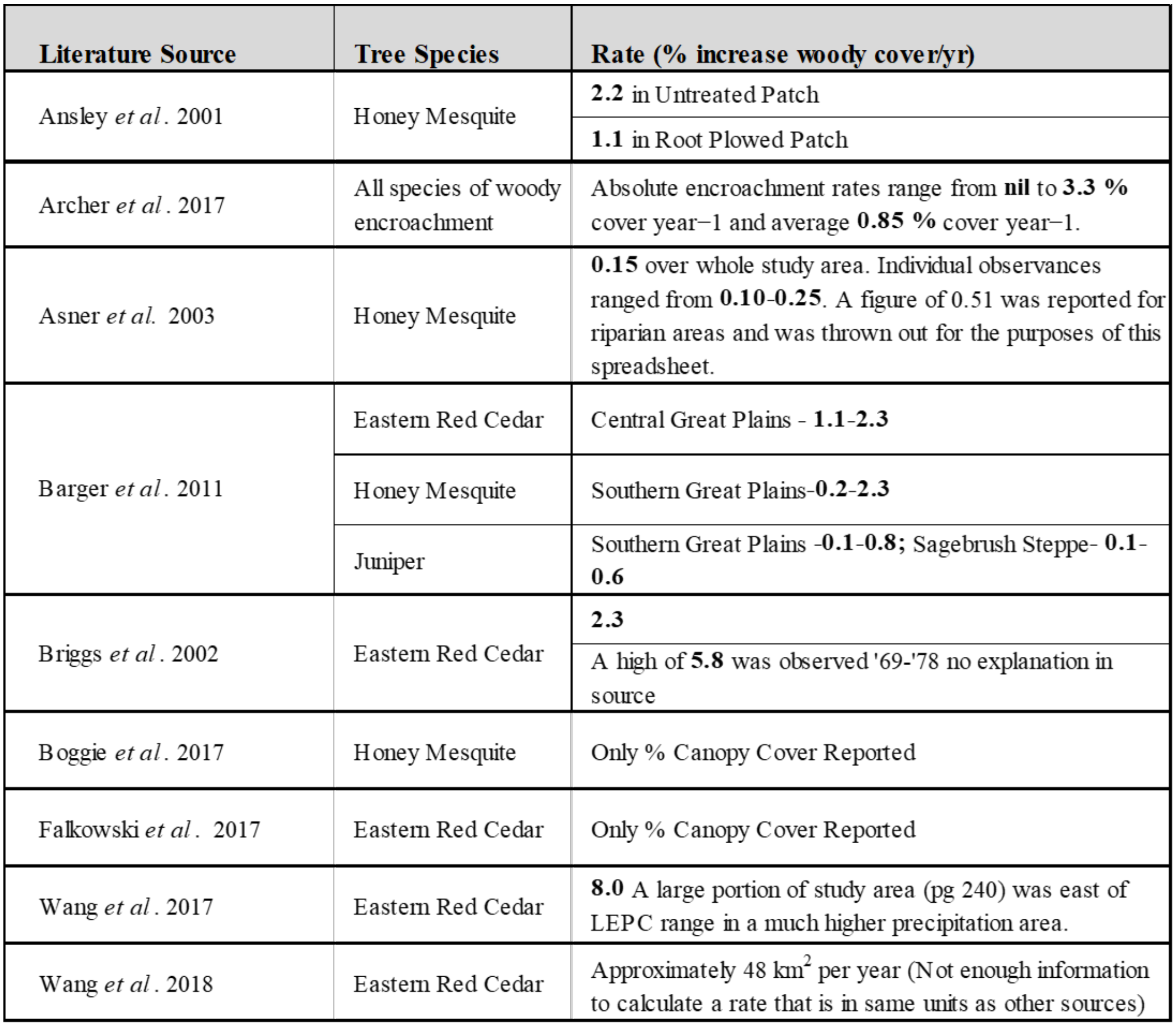
[15] See Appendix B, Part 3, for further discussions regarding impact radii.

C.3.2 Woody Vegetation Encroachment:

Honey Mesquite and Eastern Red Cedar continue to spread in the grasslands of the southern Great Plains within the LEPC range. To project future encroachment of these species, we reviewed available literature regarding encroachment rates of these two species in grassland systems. Table C.23 below shows some of the pertinent results of this literature review.

Table C.23. Literature reviewed to consider future woody vegetation encroachment rates.



Literature Source	Tree Species	Rate (% increase woody cover/yr)
Ansley *et al*. 2001	Honey Mesquite	**2.2** in Untreated Patch
		1.1 in Root Plowed Patch
Archer *et al*. 2017	All species of woody encroachment	Absolute encroachment rates range from **nil** to **3.3 %** cover year−1 and average **0.85 %** cover year−1.
Asner *et al.* 2003	Honey Mesquite	**0.15** over whole study area. Individual observances ranged from **0.10-0.25**. A figure of 0.51 was reported for riparian areas and was thrown out for the purposes of this spreadsheet.
Barger *et al*. 2011	Eastern Red Cedar	Central Great Plains - **1.1-2.3**
	Honey Mesquite	Southern Great Plains-**0.2-2.3**
	Juniper	Southern Great Plains -**0.1-0.8;** Sagebrush Steppe- **0.1-0.6**
Briggs *et al*. 2002	Eastern Red Cedar	**2.3**
		A high of **5.8** was observed '69-'78 no explanation in source
Boggie *et al*. 2017	Honey Mesquite	Only % Canopy Cover Reported
Falkowski *et al*. 2017	Eastern Red Cedar	Only % Canopy Cover Reported
Wang *et al*. 2017	Eastern Red Cedar	**8.0** A large portion of study area (pg 240) was east of LEPC range in a much higher precipitation area.
Wang *et al*. 2018	Eastern Red Cedar	Approximately 48 km^2 per year (Not enough information to calculate a rate that is in same units as other sources)

Based primarily on the information in Table 1 of Barger *et al*. (2011), we chose annual rates of encroachment. For honey mesquite, we used an annual encroachment rate (percent) of 0.2% for the low projections, and 2.3% for the high projections, and we used the midway point between the high and low rates to create a medium rate of 1.25%. Due to the fact that the information for ERC encroachment rates comes from areas east of the LEPC range with higher average annual precipitation, we modified rates (reduced) for dryer portions of the species western range (Appendix B, Part 2). For ERC in the entire Sand Sagebrush Ecoregion and the western portions of the Short-Grass/CRP and Mixed-Grass Ecoregions, we chose 0.2% for the low rate, 0.8 for the high rate, and used the intermediate point between the high and low rates to create the middle rate of 0.5%. For the eastern portions of Short-Grass/CRP and Mixed-Grass Ecoregions, we chose 1.1% for the low rate, 2.3% for the high rate, and we used the intermediate point between the high and low rates to create a middle rate of 1.7%.

Assumptions and Calculations for Woody Vegetation Encroachment

Below are the assumptions and steps we used to project encroachment of mesquite and ERC over the next 25 years.

1. As we did for the conservation efforts of tree removal (Section C.2.1.1), for the purposes of our spatial analysis and projections we assumed that all woody vegetation encroachment in the Mixed-Grass Ecoregion is ERC, even though we know some mesquite also occurs there.
2. We used the NRCS Tree Canopy cover data, LandFire Existing Vegetation Type 2014 with trees, and NRCS's Percent Canopy Cover of Conifer and Mesquite to calculate the amount of woody vegetation within each ecoregion that intersected with our classification of LEPC potential usable area[16]. These values were used as the starting point to apply the annual encroachment rates (Table C.24).
3. We acknowledge that the tree data used to calculate the starting point of encroachment are a significant underestimate of the total acres affected by trees throughout the range of the LEPC because remote sensing data is ineffective at detecting short stature and low density stands of trees that still have significant effects on LEPC space use. See Appendix B, Part 2, Threats GIS Datasets, Woody Plant Encroachment Threat, Conclusions for additional discussion of the assumption of significant underestimation.
4. Next, we projected encroachment for each ecoregion at three levels by applying the annual rates discussed above over 25 years (Table C.24).

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[16] Please see Appendix B for further information regarding the process and datasets used.

Table C.24. Projection of impacts from woody vegetation encroachment at three levels at year 25 in the LEPC ecoregions.

Ecoregion Subregion	**Total Analaysis Area Trees (Acres; non-buffered tree layer)**	**Total Trees Used to Initiate Woody Plant Enroachment (Acres; non-buffered trees*)**	**Projected Unbuffered Impact Acres of Woody Plant Encroachment at Year 25**		
			Level of Enroachment Acres (Rate)		
			Low	**Medium**	**High**
Short-Grass/CRP East 20	7,083	1,963	589 (1.1)	979 (1.7)	1,425 (2.3)
Mixed-Grass East 20	410,565	193,368	58,059 (1.1)	96,425 (1.7)	140,366 (2.3)
Short-Grass/CRP West 19	913	190	9 (0.2)	24 (0.5)	40 (0.8)
Mixed-Grass West 19	5,592	2,190	108 (0.2)	278 (0.5)	462 (0.8)
Sand Sagebrush	6,180	1,312	394 (1.1)	654 (1.7)	952 (2.3)
Sand Shinnery Oak	187,100	124,787	6,130 (0.2)	43,345 (1.25)	90,583 (2.3)
Range-wide Total	617,433	323,810	65,289	141,705	233,827

* Does not include trees in exclusion areas

5. Trees occur on the landscape differently in the four ecoregions, and we used the tree spatial data to inform the basis for incorporating woody plant expansion. To accommodate constraints of our modeling process and facilitate a streamlined process of accounting for areas indirectly affected by woody vegetation encroachment, we calculated tree relative densities (i.e., acres of impact radii acres/acre of trees; Section C.2.1.1) for each ecoregion or precipitation gradient subregion within an ecoregion (Appendix B, Part 2). The corresponding relative density was multiplied by the unbuffered impact acres of woody plant encroachment for each area to give the total area of direct and indirect effects of projected woody plant encroachment (Table C.25).

Table C.25. Projection of impacts from woody vegetation encroachment accounting for indirect effects at three levels at year 25 in the LEPC ecoregions.

Ecoregion Subregion	**Projected Buffered Impact Acres of Woody Plant Encroachment at Year 25**		
	Level of Enroachment Acres (Rate)		
	Low	**Medium**	**High**
Short-Grass/CRP East 20	38,830 (1.1)	64,489 (1.7)	93,877 (2.3)
Mixed-Grass East 20	311,768 (1.1)	517,784 (1.7)	753,739 (2.3)
Short-Grass/CRP West 19	1,390 (0.2)	3,598 (0.5)	5,963 (0.8)
Mixed-Grass West 19	874 (0.2)	2,261 (0.5)	3,748 (0.8)
Sand Sagebrush	7,650 (1.1)	12,706 (1.7)	18,496 (2.3)
Sand Shinnery Oak	11,548 (0.2)	81,660 (1.25)	170,653 (2.3)
Range-wide Total	372,060	682,498	1,046,476

C.3.3 Conversion of Grassland to Cropland

We reviewed available information to inform our efforts to project future rates of grassland conversion to croplands. These included: Peterson *et al.* (2004); Claassen *et al.* (2011); FSA (2012); Sylvester *et al.* (2013); Lark *et al.* (2015); Gage *et al.* (2016); Morefield *et al.* (2016); Wright *et al.* (2017); Lark *et al.* (2020, *accepted*); and Bigelow *et al.* (2020).

The amount of land converted varies due to a range of factors, including local land costs, farm commodity prices, and net value and availability of conservation program alternatives (e.g., Conservation Reserve Program). Publically available information is limited in documenting detailed site-specific change of land cover or land use from grassland or shrubland to cropland. Recent research (Lark *et al.* 2020 *accepted*, entire) has used available spatial data from U.S. Department of Agriculture's Cropland Data Layer (CDL; USDA NASS CDL 2020), aggregated to five classes (Table C.26) to address limitations and constraints (Lark 2017; and Lark *et al.* 2017) of the original dataset to characterize stability and change in land use/land cover types throughout the United States. We used information from Lark *et al.* (2020 *accepted*, entire) aggregated CDL data covering the time period of 2008–2016 as the initial information to develop rates of conversion for future scenarios.

Table C.26. Description of aggregated classification of cropland data layer (Lark *et al.* 2020, accepted).

Data Value	Name	Description
1	Stable non-cropland	Areas of consistent non-cropland for the duration of the study period 2008–2016.
2	Stable cropland	Areas of consistent cropland for the duration of the study period.
3	Conversion to cropland (expansion)	Areas converted to crop production between 2008 and 2016.
4	Conversion to non-cropland (abandonment)	Conversion away from crop production between 2008 and 2016.
5	Intermittent cropland	A separate category for areas that were cropped at least two years but show no clear trend towards or away from cropland. These could include areas like crop/pasture rotations, or simply areas with repeated classifier confusion. For most practical purposes, this category of intermittent cropland should be added to the category of stable cropland to map total (stable + intermittent) cropland area, or can be withheld from the analysis.

Assumptions and Calculations for Conversion of Grassland to Cropland

Below are the assumptions and steps taken to use this information to project likely future conversion of grasslands to cropland:

1. Prices for corn and soybeans peaked in 2012 at more than $8.00 and $17.00 per bushel, respectively, and wheat prices were high in 2012 at more than $9.00 per bushel (Macrotrends 2020). These high prices were a contributing factor in decision by landowners to break grassland (including CRP) out for farming in areas potentially suitable for production of these commodities. Data used to inform projections (Lark *et al.* 2020, *accepted*) includes a period, 2008–2016, that covers both high and relatively low commodity prices.

2. For defining a rate of grassland conversion for this analysis, we clipped the annual year of conversion datasets (i.e., year of Conversion to Cropland (expansion), and year of Conversion to Non-Cropland (abandonment)) from Lark (*et al.* 2020, *accepted*) to each ecoregion boundary. The net change (either expansion or abandonment) was calculated for each year, 2008–2016, and reduced by 50% because of assumption of user accuracy of CDL for grasslands is only about 50% (Lark 2017). The reduced annual values were used to calculate an 8-year annual average, and the results were multiplied by 25 to

produce the future scenario total area of conversion for the intermediate value at year 25 in the future. This process was repeated for the low and high future scenarios, but used the lowest two consecutive year's annual average net conversion, and the highest four consecutive year's annual average net conversion, respectively (Table C.26).

Table C.26. Future projected conversion of grassland to cropland, in acres, annually and at year 25 at three levels in the LEPC ecoregions and range-wide.

Projected Grassland Conversion, Annual Rate and Year 25 Total (Acres)						
	Low		Intermediate		High	
Ecoregion	Annual Rate	Year 25 Total	Annual Rate	Year 25 Total	Annual Rate	Year 25 Total
Short-Grass/CRP	3,587	89,675	5,838	145,940	7,417	185,418
Mixed-Grass	169	4,220	1,350	33,761	2,036	50,910
Sand Sagebrush	1,703	42,573	3,827	95,678	5,698	142,438
Sand Shinnery Oak	879	21,985	2,056	51,410	3,758	93,946
Range-wide Total	6,338	158,454	13,072	180,848	18,908	287,294

C.3.4 Wind Energy Development

Projecting development of wind energy is a complex task given the many factors, such as wind resource, access to transmission, financing, power purchase agreements, landowner participation, environmental compliance, and others, that affect the ultimate construction of wind energy developments.

We evaluated the implications of a range of projected effects of wind energy development as part of our assessment of the LEPC status. Decisions by developers to pursue wind energy projects are affected by numerous factors, such as the site's wind resource capacity, access to the transmission grid, funding for project development, demand for wind energy, availability of local, state and Federal financial incentives, landowner interest, and community support; all of which add complexity to developing projections of future development levels. We reviewed available information sources on wind energy developments (USDOE 2008, entire; USDOE 2015, entire; USFWS 2016a, entire; AWEA 2013, entire; AWEA 2014, entire; AWEA 2015, entire; AWEA 2016, entire; AWEA 2017, entire; AWEA 2018, entire; AWEA 2019a, entire; AWEA 2020; SPP 2020; Van Pelt *et al.* 2013; Hoen *et al.* 2020, entire), meteorological towers (FAA OEAAA 2020), and transmission projects (NREL 2015, entire; NREL 2017, entire; AWEA 2019b), to assist in projecting amounts of wind energy development.

Assumptions and Calculations for Wind Energy Development

1. The Service projections on wind energy development are based on multiple sources of information and from existing wind energy developments in or near the range of the LEPC for different aspects of development that will affect the amount and extent of wind energy within the range of the LEPC over the next 25 years. We include the following assumptions:

    a. Annual installed capacity in the United States: 6,000–8,000 megawatts (MW).

    b. The percent capacity that LEPC states will install annually: 34–45%.

   c. The percent capacity that the LEPC analysis area within a state will install annually: 11–15%

   d. The percent capacity that each ecoregion within the LEPC analysis area will install annually, based on approximate amounts already installed, or under consideration in each ecoregion, and assuming a continuation of similar proportions into the future:
      i. Short-Grass/CRP – 29%
      ii. Mixed-Grass – 46%
      iii. Sand Sagebrush – 6%
      iv. Shinnery Oak – 19%

   e. The assumed megawatts (MW) per average wind development project (250 MW)

2. We evaluated data on the parameters used above for existing wind energy developments as reported or calculated from data in the U.S. Wind Turbine Database (USWTDB; Hoen *et al*. 2020). We considered wind projects in or adjacent to the LEPC analysis area that included more than 19 turbines and had sufficient data attribution to evaluate. For each project, we calculated MW per wind turbine, wind turbines per project, project total MW, relative density of turbines, and area of projects including an 1800-m impact radius.

3. Following the analytical approach developed by the Service (USFWS 2016a, entire), we evaluated the relative density of wind energy developments in or adjacent to the LEPC analysis area. For the subset of selected projects from the USWTDB, relative density was calculated using the number of acres within the impact radius (using including the 1800-m impact radius distance from USFWS (2014)) per installed wind turbine in each project. We also calculated the total area of wind energy developments with an 1800-m impact radius. When this data was sorted and evaluated over time, the last 5 years show a substantial increase in the relative density of wind energy projects: the average area for wind development projects from 2003–2012 was 19,305 acres, while the 2014–2019 average area was 35,720 acres.

4. Due to model limitations and constraints, we modeled wind energy development by creating a geographic constraint grid, roughly approximating the typical shape of wind energy developments in or adjacent to the LEPC range, within which the model randomly selects and applies the project. The area of LEPC potential usable area occurring in the selected grid is the extent of effect. Based on the information from the analysis above, we set the geographic constraint for wind energy developments with a grid size of approximately 35,000 acres (Figure C.1; also see Appendix B, Part 2) with rectangular cells of approximately 17,550 m x 8070 m (585 x 269 30-m pixels), which equals 34,997 acres. This resulted in 927 grid cells overlapping all or part of the LEPC SSA Analysis Area. These

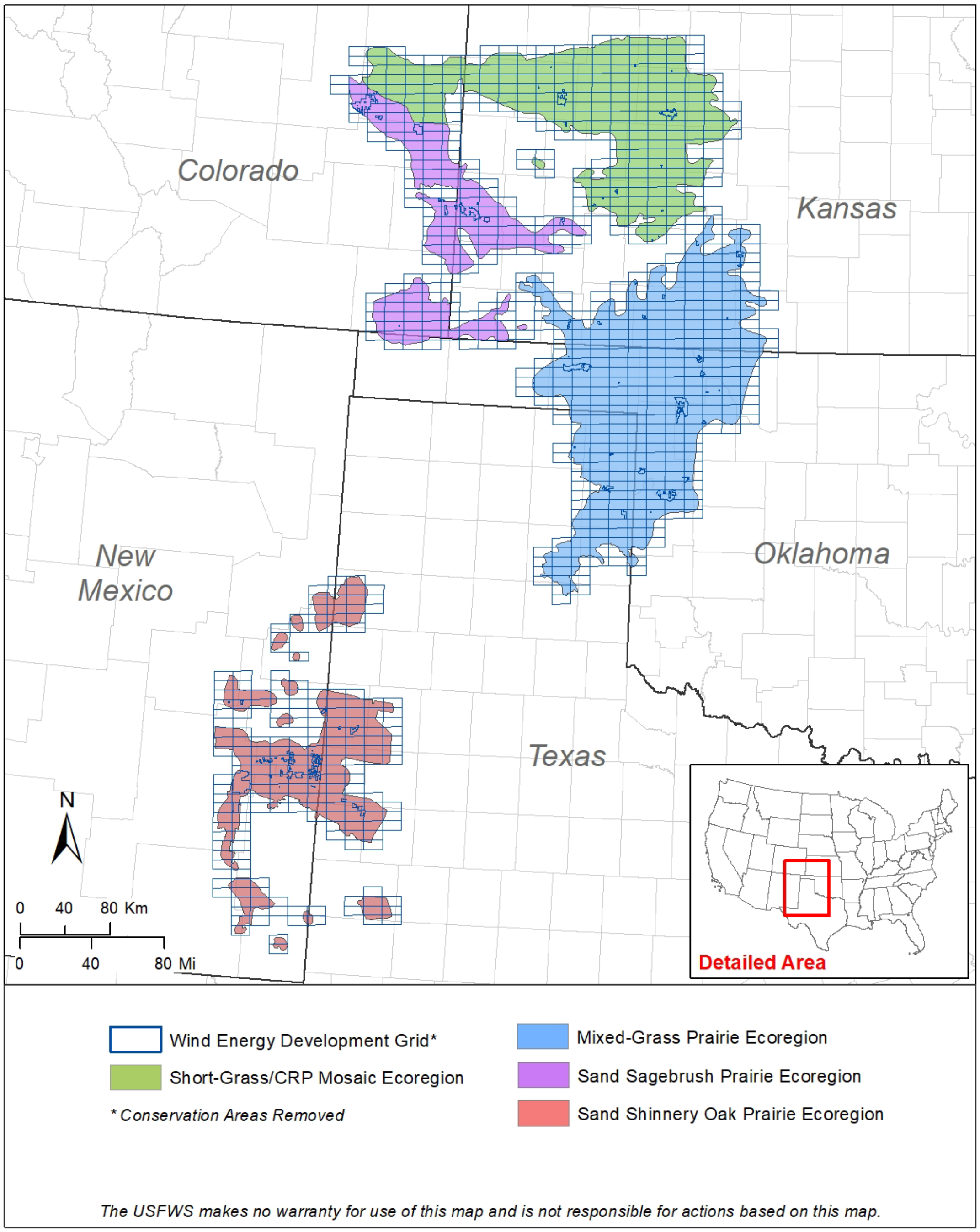


Figure C.1 Grid system used to project locations of future wind development projects.

5. There are a multitude of factors that decide if a conceptualized wind energy development ever becomes operational. Due to the complexity, we chose not to constrain wind energy development spatially within the LEPC range, except by treatment within the approximately 35,000-acre geographic constraint grid cells. Factors such as increasing wind turbine size and hub height (i.e., greater access to higher wind resource classes), placement of future transmission lines, landowner participation willingness, and market demand will dictate to a greater extent where wind energy may occur in, and out, of the LEPC range than just the wind speed classes at a given location. Additionally, it is not clear the extent to which the declining conservation status of species like the LEPC, and associated conservation recommendations, will affect the siting of wind energy developments in the range of the LEPC, given that, since 2014, 393 wind turbines have been constructed within area identified as CHAT 1 and 2 of the WAFWA LEPC RWP (USFWS unpublished analysis of WAFWA and USWTDB data).

6. Based on our experience with wind energy projects in the past, it is assumed that only a small number of the many wind projects evaluated by developers for possible construction will actually get constructed due to existing transmission lines and available capacity. However, as additional transmission lines are added to the landscape, many more future wind energy projects are likely to be completed. Expansion of the transmission grid continues to be of high priority for the wind industry (AWEA 2019b).

7. In the United States, with the annual capacity factor of onshore wind energy developments averaging only 32.2 to 34.7% (2013–2016; USEIA 2017, unpaged, Table 6.7.B) of their stated nameplate capacity, or theoretical maximum power production (i.e., not actual power production), a significant number of wind energy projects must be constructed to fulfill deliverable power production commitments.

8. We assumed many future wind energy projects will be located outside of LEPC habitat, but they will still have some indirect effects to LEPC due to the amount of habitat overlapped by the impact radius of 1,800 m extending into LEPC potential usable area.

9. The wind energy development projections process required scaling existing information or projections from the sources identified above to (1) the entire United States, (2) the entire analysis area, and (3) each specific ecoregion, to inform a range of values for each ecoregion.

    a. The low values were projected by assuming an average of 6,000 MW of annual capacity installation in the United States for the next 25 years. Using data calculated from AWEA state factsheets, we allocated 34% (2,040 MW) of the United States annual capacity installation to the five lesser prairie-chicken states for a 25-year projection of 51,000 MW. We calculated the percent of wind energy developments that occurred within or adjacent to the analysis area (39 developments) compared to the total number of projects occurring within the five lesser prairie-chicken states (286 developments). The results indicate 13.6% of existing wind energy developments were built in or adjacent to the analysis area. We adjusted this percentage down to 11%, to allow for a scenario where less development occurs than has historically occurred to date. Applying 11% to 2,040 MW (assumed annual capacity installation in LEPC states) results in an estimated 224 MW installed annual capacity in the analysis area. Assuming an average development size of 250 MW results in 0.9 developments annually in the analysis area and 22.44 developments (5,610 MW) over 25 years. The analysis area projections were subsequently allocated to each of the ecoregions based on evaluating (a) existing developments, and (b) developments under consideration within each ecoregion as a percent of the total analysis area. Resulting ecoregion-specific allocations are: Short-Grass/CRP Ecoregion 29%, Mixed-Grass Ecoregion 46%; Sand Sagebrush Ecoregion 6%; and Shinnery Oak Ecoregion 19%. All fractional values were rounded up or down, resulting in a projection of 22 total developments for the low development scenario over 25 years (Table C.27).

b. The high value estimates were projected by assuming an average of 8,000 MW of annual capacity installation in the United States for the next 25 years. Using data calculated from AWEA state factsheets, we allocated 45% (3,600 MW) of the United States annual capacity installation to the five lesser prairie-chicken states for a 25 year projection of 90,000 MW. Using the same 13.6% calculated percent of wind energy developments of the analysis area to inform the projection, we set the value to 15% to allow for a scenario where more development occurs than has historically occurred to date. Applying 15% to 3,600 MW (assumed annual capacity installation in LEPC states) results in an estimated 540 MW installed annual capacity in the analysis area. Assuming an average development size of 250 MW results in 2.16 developments annually in the analysis area and 54 developments (13,500 MW) over 25 years. We used the same ecoregion allocation and rounding process as described above, resulting in 54 total developments for the high development scenario over 25 years (Table C.27).

c. The intermediate values were generated by averaging the low and high values, and rounding up or down to whole numbers, resulting in 38 total developments over 25 years (Table C.27).

Table C.27. Projections of future wind energy development projects for the next 25 years at three levels in each LEPC ecoregion and range-wide.

	Low		Intermediate		High	
Ecoregion	**Number of Developments at Year 25**	**Total MW at Year 25**	**Number of Developments at Year 25**	**Total MW at Year 25**	**Number of Developments at Year 25**	**Total MW at Year 25**
Short-Grass/CRP	7	1,750	11	2,750	16	4,000
Mixed-Grass	10	2,500	18	4,500	25	6,250
Sand Sagebrush	1	250	2	500	3	750
Sand Shinnery Oak	4	1,000	7	1,750	10	2,500
Range-wide Total	22	5,500	38	9,500	54	13,500

Appendix D. Regulatory Mechanisms

Here we review the existing regulatory mechanisms that may be significant to LEPC conservation and the stressors that may be affected by them. Regulatory mechanisms, such as local, state, and Federal land use regulations or laws, may ameliorate or lessen some of the stressors affecting the species, provided those regulations and laws are not discretionary and that they are enforceable. We evaluate existing regulatory mechanisms for their effect on the stressors affecting the species. There may be local regulations that are significant to localized areas; however, we did not identify any local regulations that may address any of the identified stressors to the LEPC at a scale that would be significant to this range-wide assessment.

D.1 State Regulations

In 1973, the LEPC was listed as a threatened species in Colorado under the State's Nongame and Endangered or Threatened Species Conservation Act. While this designation prohibits unauthorized take, possession, and transport, which protects the species from direct purposeful mortality by humans, no protections are provided for destruction or alteration of LEPC habitat. In the remaining states, the LEPC is classified as a game species, although the legal harvest is now closed in all of those states. Accordingly, the State conservation agencies have the authority to regulate possession of the LEPC, set hunting seasons, and issue citations for poaching. For example, Texas Statute (Parks and Wildlife Code Section 64.003) prohibits the destruction of nests or eggs of game birds such as the LEPC. These authorities provide LEPCs with protection from direct mortality caused by hunting and prohibit some forms of unauthorized take, and have been adequate to address any concerns of overhunting, as evidenced by the fact that these states have closed harvest in response to low population levels. These authorities do not provide protection for destruction or alteration of the species' habitat.

All five states in the estimated occupied range have incorporated the LEPC as a species of conservation concern and management priority in their respective State Wildlife Action Plans. While identification of the LEPC as a species of conservation concern does help heighten public awareness, this designation provides no protection from direct take or habitat destruction or alteration. Additionally, most occupied LEPC habitat throughout the bird's estimated occupied range occurs on private land, where state conservation agencies have little authority to protect or directly manage the species' habitat.

The states in the LEPC range have laws and regulations that address use of state-owned lands held in trust to generate revenues to support public schools. These lands are managed primarily to maximize financial return from operations such as leasing for agricultural use, mineral extraction, or energy production. The scattered nature of these lands and requirement to maximize financial returns minimize the likelihood that these lands will be managed to reduce degradation and fragmentation of habitat and ensure the conservation of the species.

One exception may be the recent efforts of the Colorado Oil and Gas Conservation Commission (COGCC) to explicitly consider wildlife resources in new oil and gas permitting. SB19-181 was signed in 2019 and changed the mandate of the COGCC from fostering oil and gas development to regulating oil and gas development "in a reasonable manner to protect and minimize adverse impacts to public health, safety, and welfare, the environment and wildlife resources." §34-60-106(2.5)(a), C.R.S. LEPC habitats are included in the list of High Priority Habitats for which actions must be taken to avoid, minimize, and mitigate for impacts to wildlife resources. In November 2020, COGCC approved new regulations to finalize the wildlife rules included in the 1200 Series, which include actions pertaining to LEPC habitats including focal areas, connectivity areas, and lek sites (https://cogcc.state.co.us/#/home). These rules should reduce some of the potential effects on LEPC of future oil and gas development in Colorado.

D.2 Federal Regulations

LEPCs are not covered or managed under the provisions of the Migratory Bird Treaty Act (16 U.S.C. 703–712) because they are considered resident game species.

D.2.1 U.S. Forest Service

National Grasslands are a classification of Federal land managed for sustainable multiple uses by the U.S. Forest Service. There are six National Grasslands located within the estimated historical range of the LEPC (see Table D-1). Two of the six, the Comanche National Grassland in Colorado and the Cimarron National Grassland in Kansas, occur within the estimated occupied range and breeding populations of LEPC are known from these areas. The remaining four Grasslands occur within or adjacent to counties that are occupied with LEPC, but the National Grasslands themselves are not within the delineation of the estimated occupied range and no breeding populations of LEPC are known to occur on these holdings.

Table D-1. National Grasslands within Lesser Prairie-Chicken estimated historical range.

National Grassland	Size in hectares (acres)	Location	Administration
Comanche National Grassland	179,586 (443,765)	Baca, Las Animas, and Otero Counties, CO	Pike and San Isabel National Forest
Cimarron National Grassland	43,777 (108,175)	Morton and Stevens Counties, KS	Pike and San Isabel National Forest
Kiowa	55,659 (137,537)	Mora, Harding, Union, and Colfax Counties, NM	Cibola National Forest
Rita Blanca	37,631 (92,989)	Dallam County, TX and Cimarron County, OK	Cibola National Forest
Black Kettle	12,661 (31,286)	Roger Mills County, Oklahoma, and Hemphill County, TX	Cibola National Forest
McClellan Creek	586 (1,449)	Gray County, TX	Cibola National Forest

The National Forest Management Act of 1976 and the associated planning rule in effect at the time of planning initiation are the principal law and regulation governing the planning and management of National Grasslands. The Kiowa, Rita Blanca, Black Kettle, and McClellan Creek National Grasslands (collectively known as the Cibola Grasslands) have a Grasslands

Plan, which became effective October 16, 2012. The Cibola National Forest and Grasslands used the guidance of the 2012 National Forest System land management planning rule (Planning Rule) (77 FR 21162) transition language allowing the provisions of the 1982 Planning Rule, including the requirement to prepare an Environmental Impact Statement, to complete the 2012 plan for these National Grasslands. The management strategies for management of these National Grasslands provide a strategic, outcome-oriented, programmatic framework for future activities and will be implemented at the District level through the application of certain Desired Conditions, Objectives, Standards, and Guidelines. The Environmental Impact Statement highlights that the new plan will allow for enhancement of LEPC habitat by moving vegetation types toward the species' desired vegetation structures and species composition, in addition to reducing mortality caused by fence collision. As explained above, the transition provisions (36 CFR 219.17(b)(3)) of the 2012 planning rule allow the use of the provisions of the 1982 planning rule, including the requirement that management indicator species be identified as part of the plan. Management indicator species serve multiple functions in forest planning: focusing management direction developed in the alternatives, providing a means to analyze effects on biological diversity, and serving as a reliable feedback mechanism during plan implementation. The latter often is accomplished by monitoring population trends in relationship to habitat changes.

Although suitable habitat is present, no breeding populations of LEPCs are known from the Kiowa, Rita Blanca, Black Kettle, and McClellan Creek National Grasslands. Consequently, the LEPC is not designated as a management indicator species in the plan. Instead, the LEPC is included on the Regional Forester's sensitive species list and as an At-Risk species. A sensitive species is one for which population viability is a concern as a result of significant current or predicted downward trends in (1) population numbers or density or (2) habitat capability that would reduce a species' existing distribution.

The Pike and San Isabel National Forests currently uses the 1984 Land and Resource Management Plan (USFS 1984, entire) to inform its management of the Cimarron and Comanche National Grasslands. The USFS released a Lesser Prairie-Chicken Management Plan for the Cimarron and Comanche National Grasslands on May 1, 2014; this plan provides a framework for management of LEPC habitat (USFS 2014, entire). The plan tiers to WAFWA's Lesser Prairie-Chicken Range-Wide Conservation Plan. Threats to the LEPC are identified in the plan, as well as conservation measures to avoid, minimize, or mitigate these threats. The plan provides separate population and habitat recovery goals for the Cimarron and Comanche National Grasslands. For example, the plan identifies a goal of 149 birds on leks in the Comanche National Grasslands and 131 birds on leks in the Cimarron National Grasslands. These population goals are derived from past lek counts during peak periods on both Grasslands. Vegetation surveys will be completed at both the Cimarron and Comanche National Grasslands and inform ongoing and future monitoring efforts of suitable habitat and lek activities occurring on the Grasslands. Because National Grasslands are managed for multiple uses, the plan includes guidelines for prescribed fire and grazing.

The Comanche and Cimarron National Grasslands currently manage the Comanche LEPC Habitat Zoological Area, now designated as a Colorado Natural Area, which encompasses an area of 4,118 ha (10,177 ac) that is managed to benefit the LEPC. Colorado Parks and Wildlife documented lesser-prairie chicken leks in this area from 1960 until 2012. In 2013, no leks were found within or in close proximity to the Zoological Area. The last documented lek of native LEPC (not translocated from another ecoregion) on the Comanche National Grasslands was in spring of 2016. Due to translocation efforts, three new leks were documented on the Comanche National Grasslands between 2018 and 2020. Most of the translocated birds have been found outside of the Zoological Area, but several birds have been found there, and nesting was documented there in 2019. Current conditions on this area include existing oil and gas leases, two-track roads, utility corridors, and livestock grazing. Wildfires on the area have been suppressed over the last 30 years. The area provides a special viewing area for the LEPC, which has been closed to protect lekking activities. The 1984 plan specifies that the condition of the area should meet the special habitat needs of the LEPC, specifically protection of leks from all surface disturbance, protection of nesting habitat from surface disturbance during the nesting period (April 15 to June 30) and limiting forage use by livestock and wild herbivores to no more than 40 percent.

D.2.2 U.S. Bureau of Land Management

The other primary Federal surface ownership of lands occupied by the LEPC is administered by the BLM in New Mexico. In New Mexico, roughly 41 percent of the known historical and most of the estimated occupied LEPC range occurs on BLM land. The BLM currently manages approximately 342,969 ha (847,491 ac) within LEPC range in eastern New Mexico. They also oversee another 120,529 ha (297,832 ac) of Federal minerals below private surface ownership. The core of currently occupied LEPC habitat in New Mexico is within the Roswell BLM Resource Area. However, the Carlsbad BLM Resource Area comprised much of the historical southern periphery of the species' range in New Mexico.

The BLM established the 23,278-ha (57,522-ac) Lesser Prairie-Chicken Habitat Preservation Area of Critical Environmental Concern (ACEC) upon completion of the Resource Management Plan Amendment (RMPA) in 2008; the purpose of the ACEC is to maintain and enhance habitat for the LEPC and the dunes sagebrush lizard (BLM 2008, p. 1). The management goal for the ACEC is to protect the biological qualities of the area, with emphasis on the preservation of the shinnery oak-dune community to enhance the biodiversity of the ecosystem, particularly habitats for the LEPC and the dunes sagebrush lizard. The ACEC not only includes 20,943 ha (51,751 ac) public land surface acres, in addition to State trust land and private land, but also includes 18,981 ha (46,902 ac) of Federal mineral estate (BLM 2008, p. 30). Upon designation, the ACEC was closed to future oil and gas leasing, and existing leases would be developed in accordance with prescriptions applicable to the Core Management Area as described below (BLM 2008, p. 30). Additional management prescriptions for the ACEC include designation as a right-of-way exclusion area, vegetation management to meet the stated management goal of the area and limiting the area to existing roads and trails for off-highway vehicle use (BLM 2008, p. 31). All acres of the ACEC have been closed to grazing through relinquishment of the permits except for one 1393-ha (3,442-ac) allotment.

The BLM's approved RMPA (BLM 2008, pp. 5–31) provides some limited protections for the LEPC in New Mexico by reducing the number of drilling locations, decreasing the size of well pads, reducing the number and length of roads, reducing the number of power lines and pipelines, and implementing best management practices for development and reclamation.

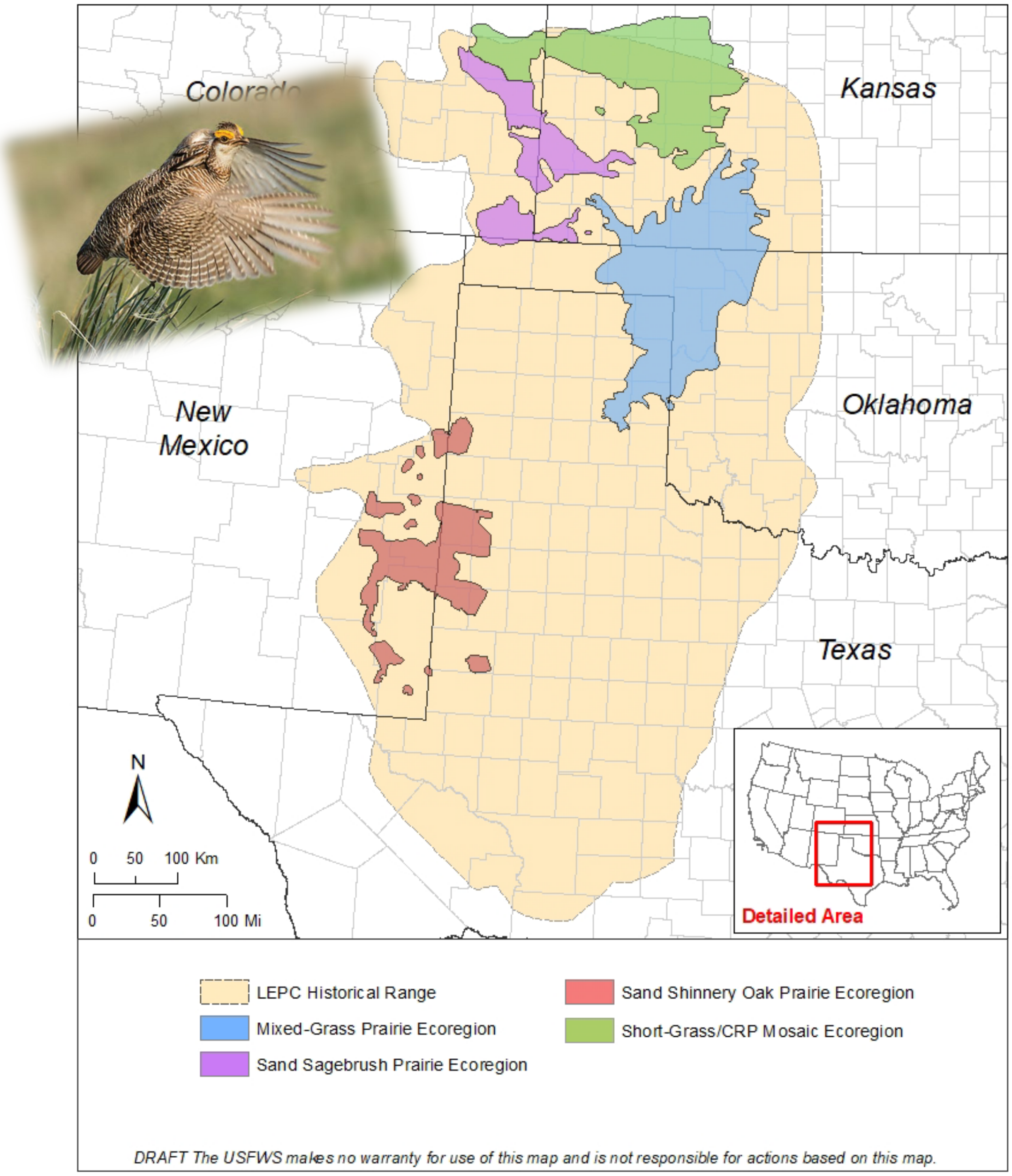
Implementation of these protective measures, particularly curtailment of new mineral leases, would be greatest in the Core Management Area and the Primary Population Area habitat management units (BLM 2008, pp. 9–11). The Core Management and Primary Population Areas are located in the core of the LEPC estimated occupied range in New Mexico. The effect of these best management practices on the status of the LEPC is unknown, particularly considering about 33,184 ha (82,000 ac) have already been leased in those areas (BLM 2008, p. 8). The effectiveness of the amended RMPA is hampered by a lack of explicit measures designed to improve the status of the LEPC, limited certainty that resources will be available to carry out the management plan, limited regulatory or procedural mechanisms in place to carry out the efforts, lack of monitoring efforts, and provision for exceptions to the best management practices under certain conditions, which could negate the benefit of the conservation measures.

The approved RMPA stipulates that implementation of measures designed to protect the LEPC and dunes sagebrush lizard may not allow approval of all spacing unit locations or full development of a lease (BLM 2008, p. 8). In addition, the RMPA prohibits drilling and exploration in LEPC habitat between March 1 and June 15 of each year (BLM 2008, p. 8). No new mineral leases will be issued on approximately 32 percent of Federal mineral acreage within the RMPA planning area (BLM 2008, p. 8), although some exceptions are allowed on a case-by-case basis (BLM 2008, pp. 9–11). Within the Core Management Area and Primary Population Area, new leases will be restricted in occupied and suitable habitat; however, if there is an overall increase in reclaimed to disturbed acres over a 5-year period, new leases in these areas will be allowed (BLM 2008, p. 11). The RMPA allows lease applicants to voluntarily participate in a power line removal credit to encourage removal of idle power lines (BLM 2008, pp. 2–41). In the southernmost habitat management units, the Sparse and Scattered Population Area and the Isolated Population Area, where LEPCs are now far less common than in previous decades (Hunt and Best 2004), new leases will not be allowed within 2.4 km (1.5 mi) of a lek (BLM 2008, p. 11).

D.3 Summary

Existing regulatory mechanisms at the Federal and state level have ameliorated the effects of some risk factors for the species to a very limited extent. Because only about 4% of the LEPC estimated occupied range occurs on Federal lands, management of private lands are the most important way for the range-wide conservation of the LEPC and its habitat. However, no laws or regulations currently protect LEPC habitat on private land, aside from state harvest restrictions. Since most occupied LEPC habitat occurs on private land, conservation agencies have little authority to protect LEPC, or facilitate and monitor management of LEPC habitat, beyond regulating recreational harvest. Because most LEPC habitat destruction and modification on private land occurs through otherwise lawful activities such as agricultural conversion, energy development, and fire suppression, virtually no regulatory mechanisms exist to substantially alter human land uses at a large enough geographic scale to protect LEPC populations and their habitat. In conclusion, existing regulatory mechanisms have minimal influence on the range-wide trends of LEPC habitat loss and fragmentation.

Appendix E. LEPC SSA Maps, Figures, and Tables



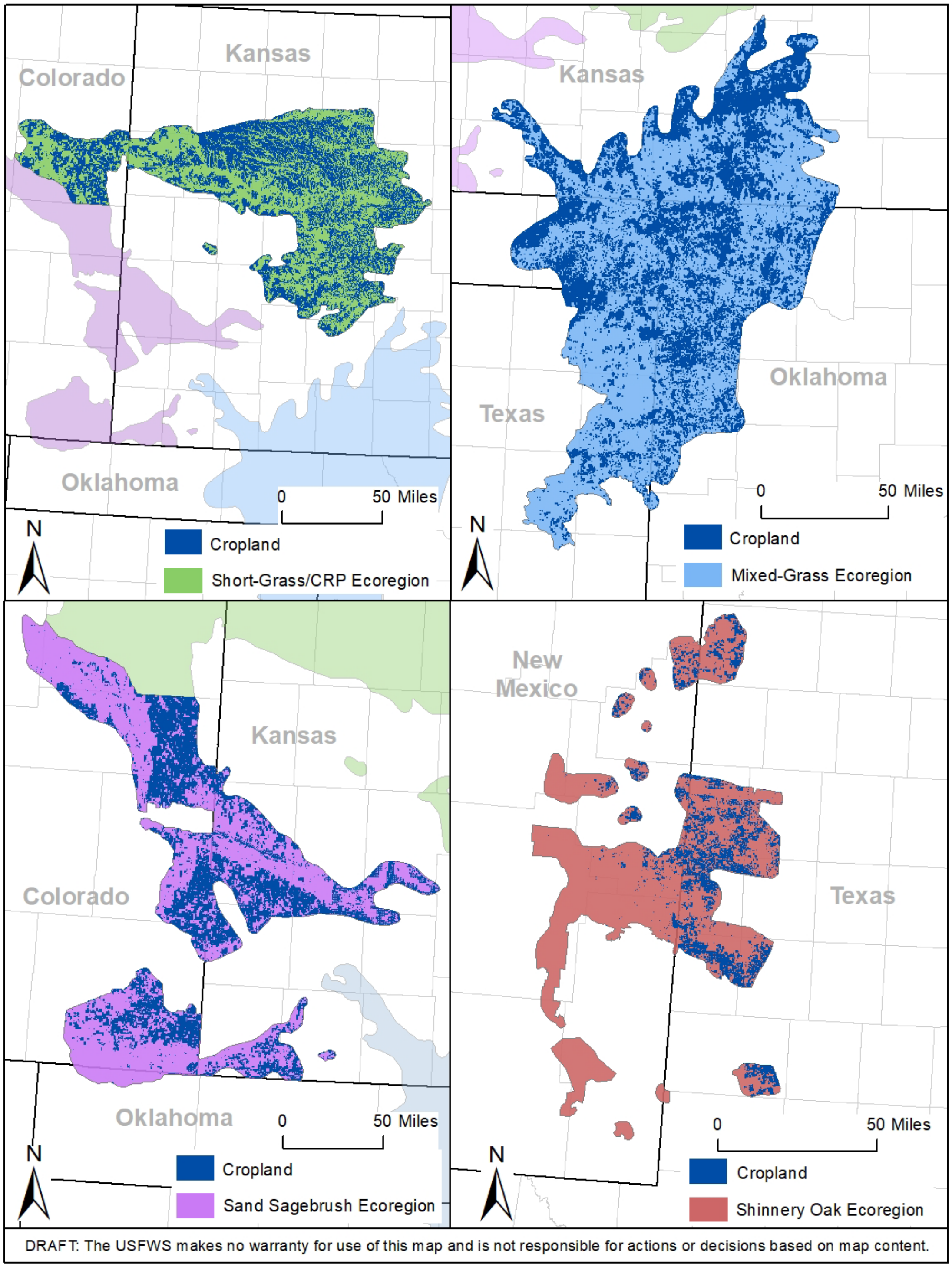


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Figure E.1 Estimated impacts of cropland conversion in the four lesser prairie-chicken ecoregions.

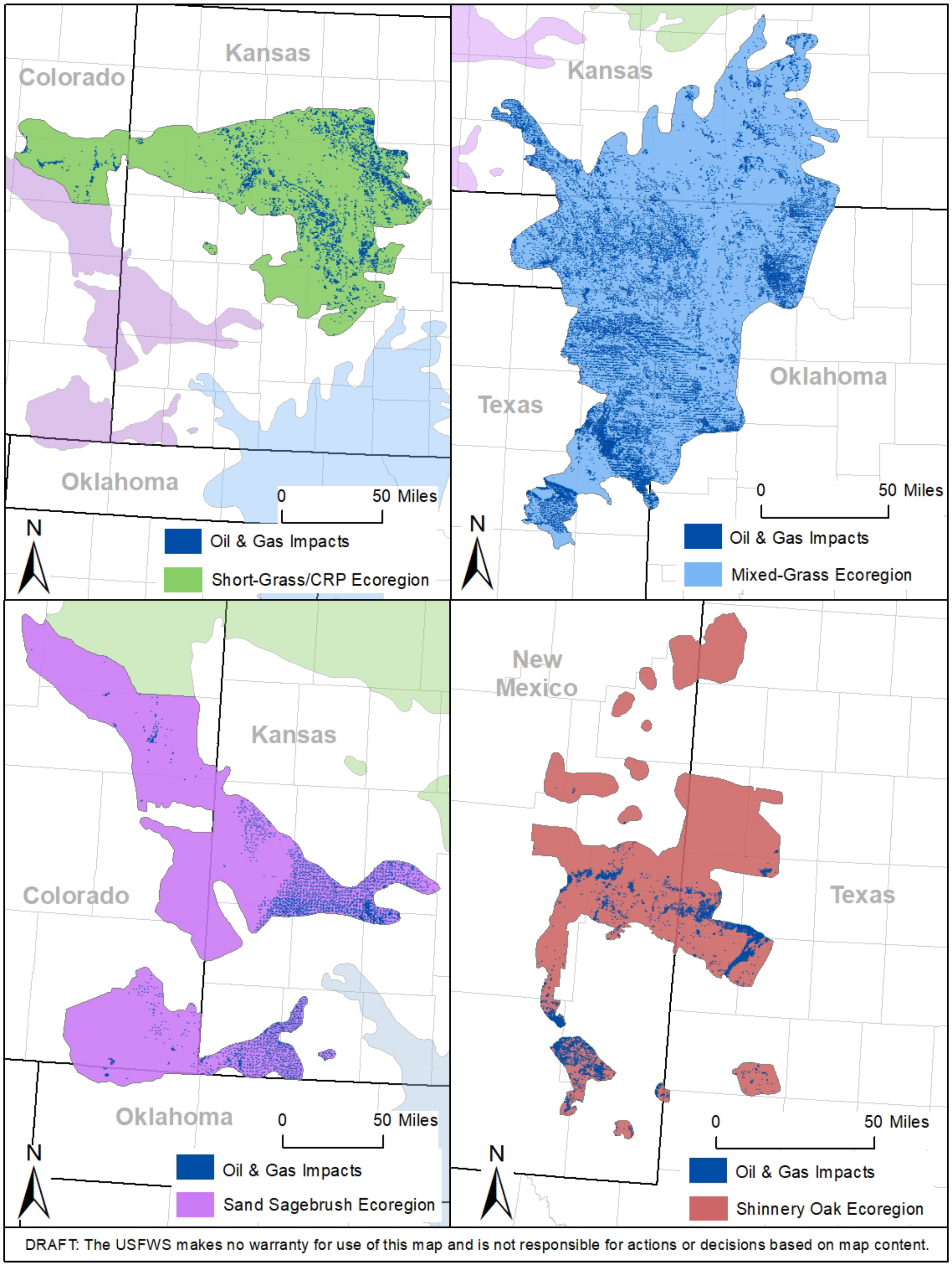

Figure E.2 Estimated impacts of oil and gas (petroleum production) in the four lesser prairie-chicken ecregions.

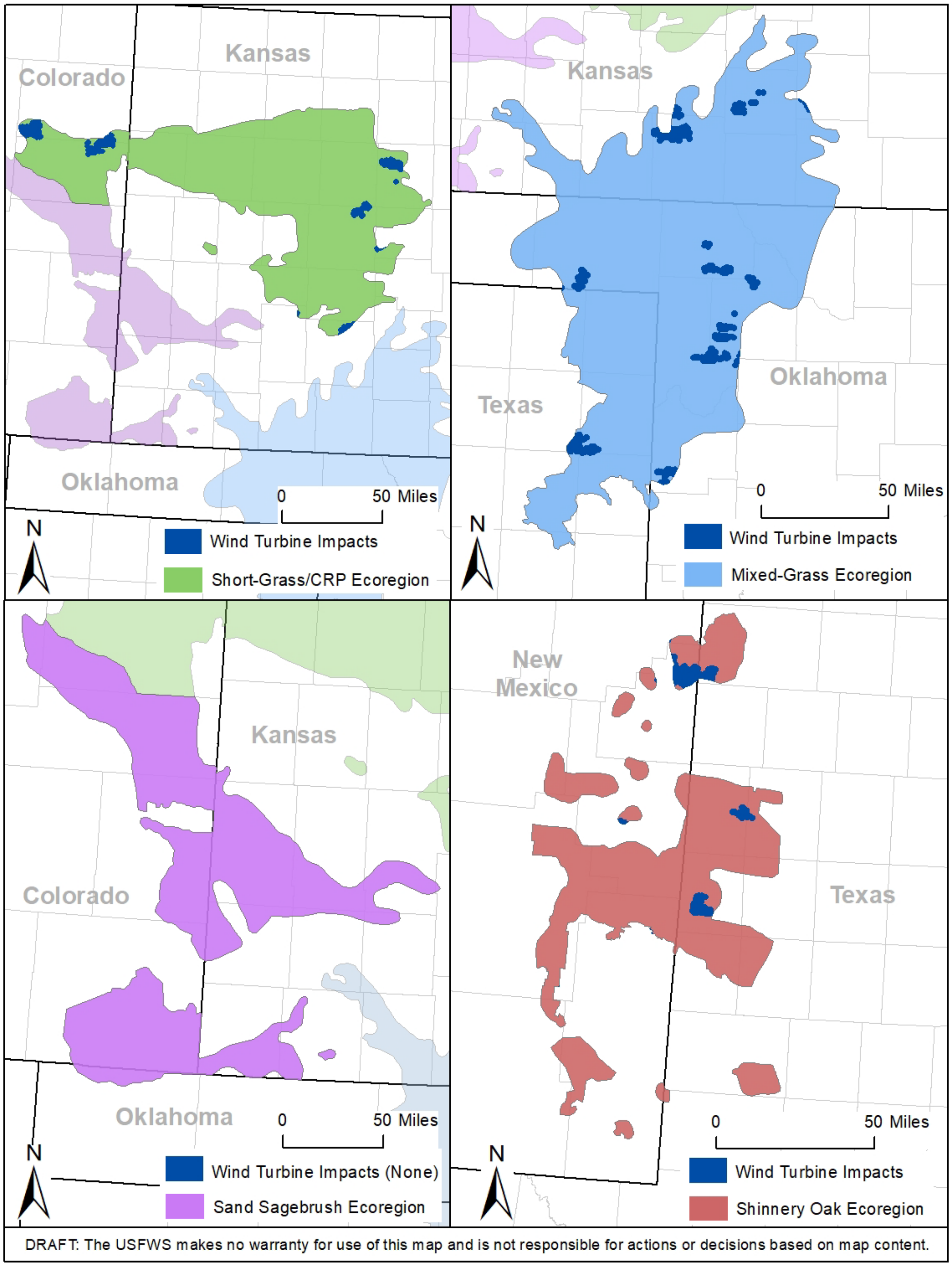

Figure E.3 Estimated impacts of wind energy development in the four lesser prairie-chicken ecoregions.

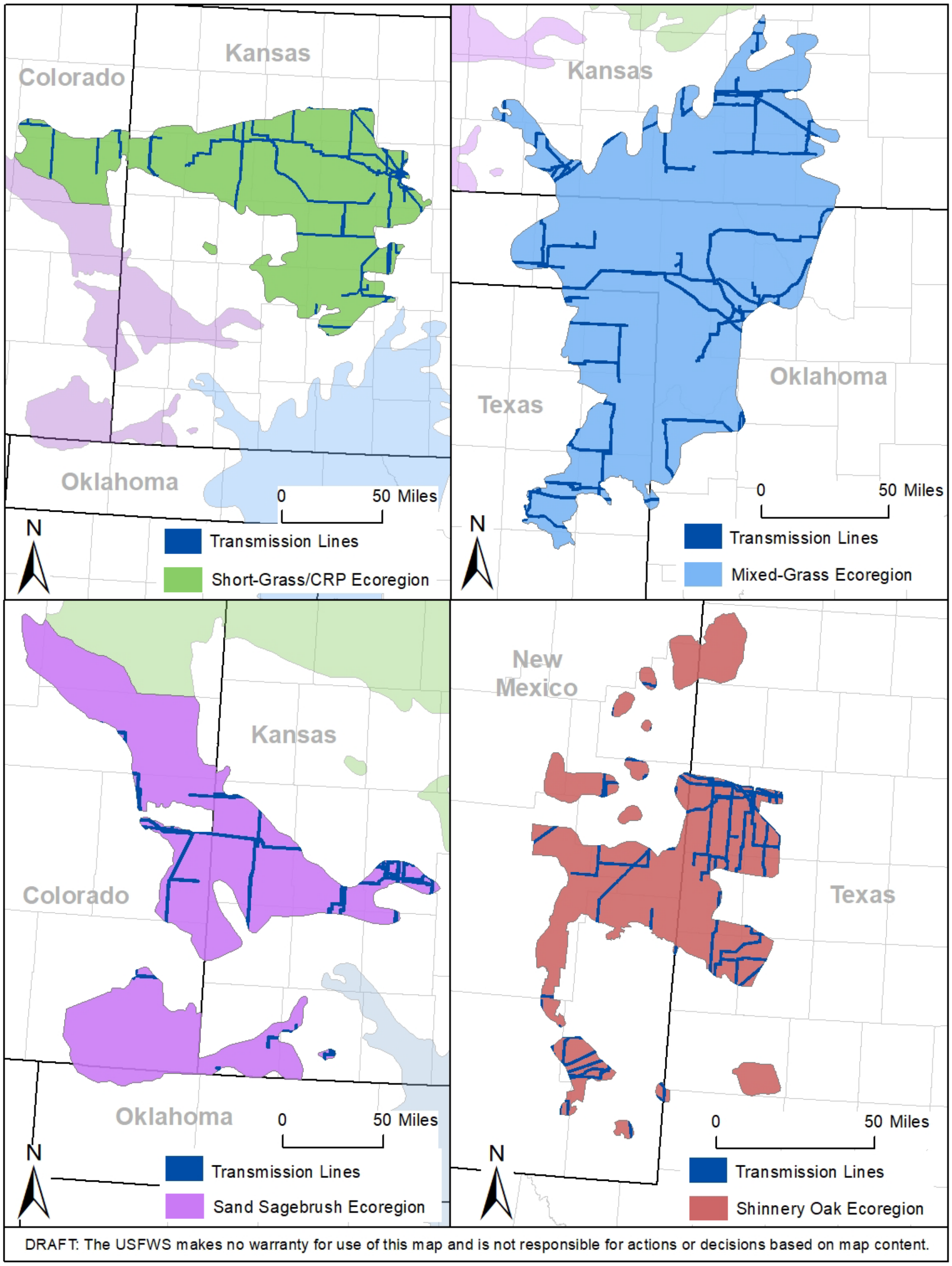

Figure E.4 Estimated impacts of transmission lines in the four lesser prairie-chicken ecoregions.

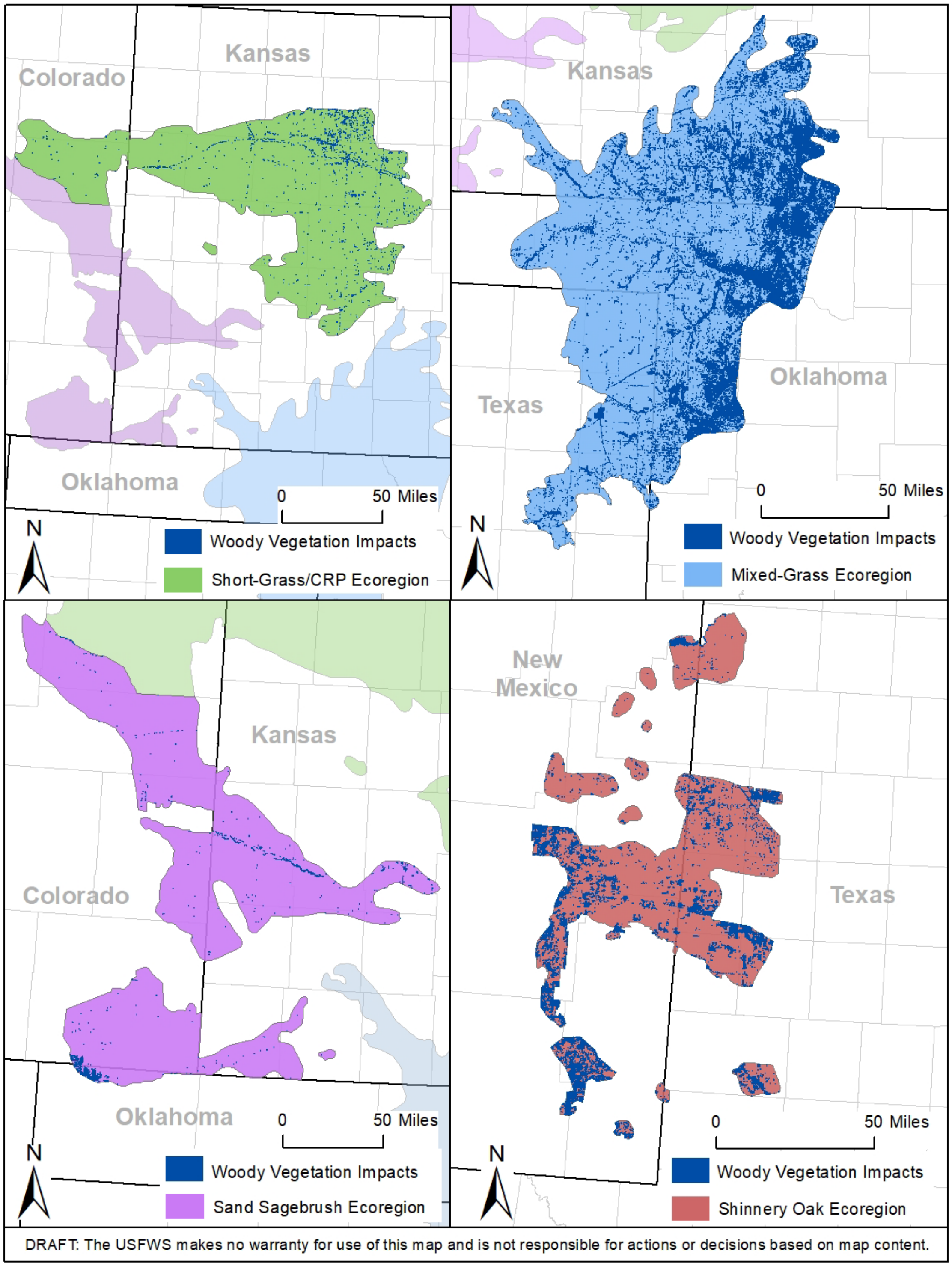

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Figure E.5 Estimated impacts of woody vegetation encroachment in the four lesser prairie-chicken ecoregions.

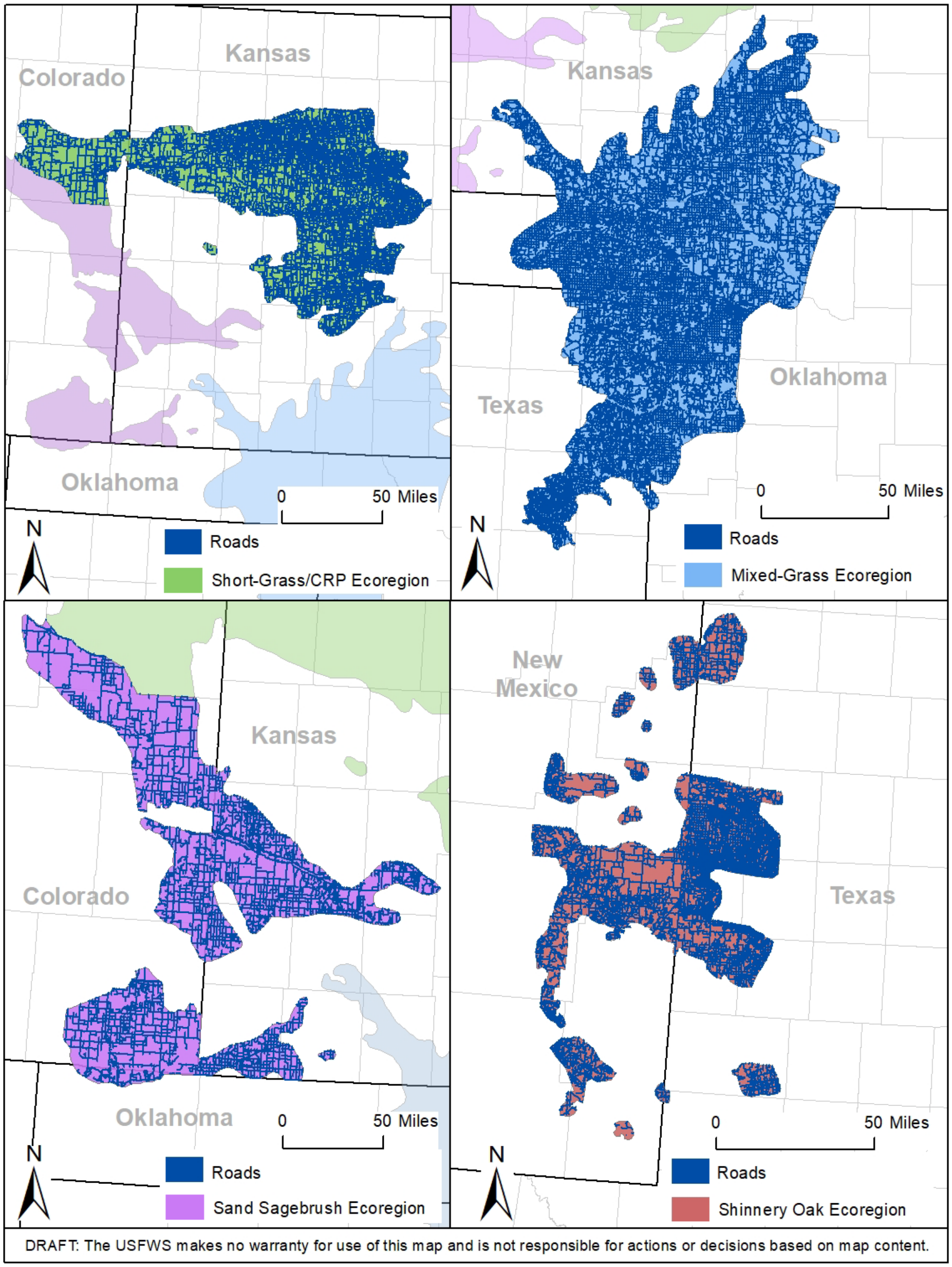

Figure E.6 Estimated impacts of roads in the four lesser prairie-chicken ecoregions.

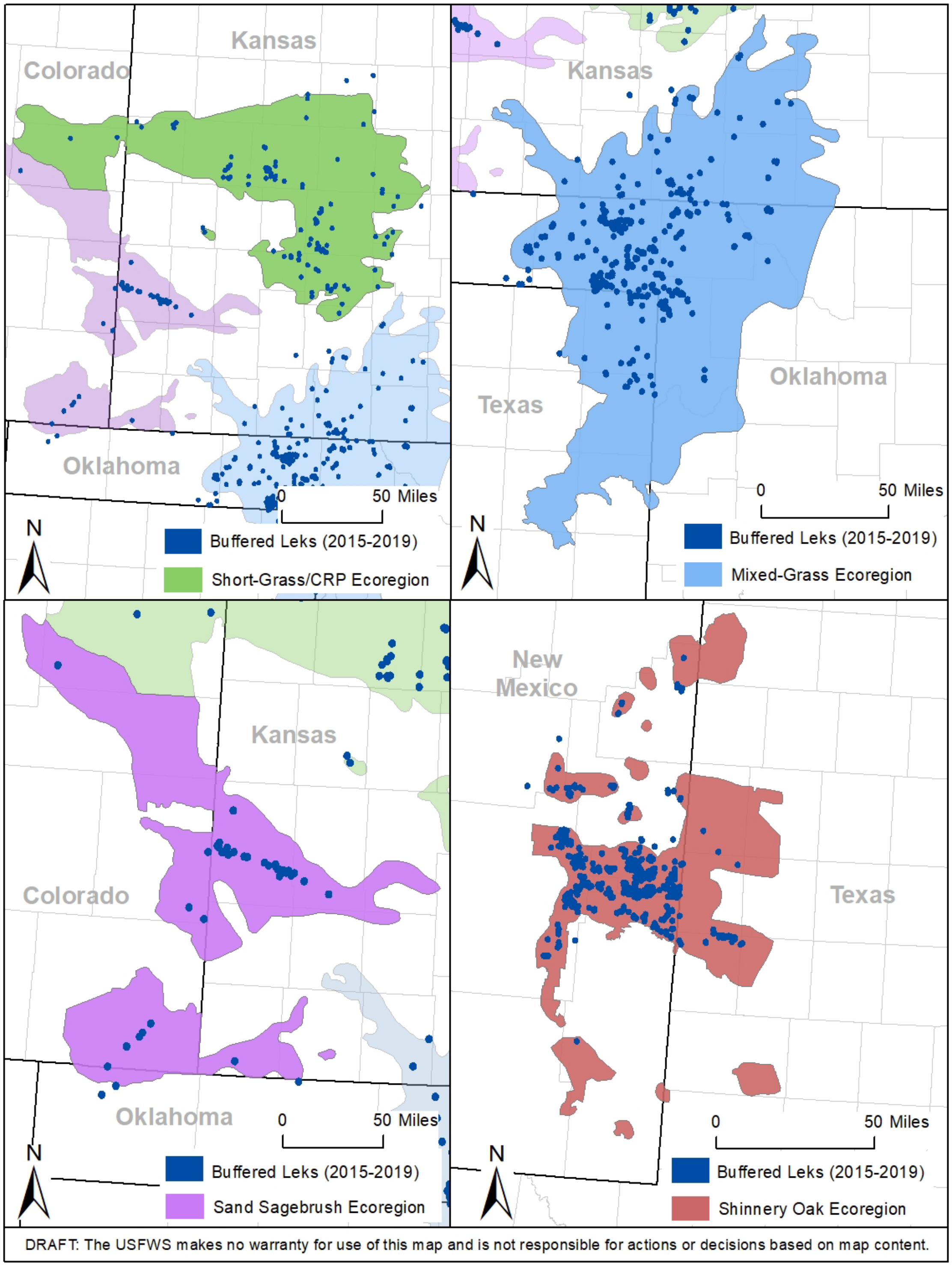

Figure E.7 Locations of lesser prairie-chicken leks documented at least once between 2015 and 2019 as reported by WAFWA (www.sgpchat.org, accessed in July 2020) in or near each of the four ecoregions. Note that lek locations are buffered by a 1.25-mile radius.

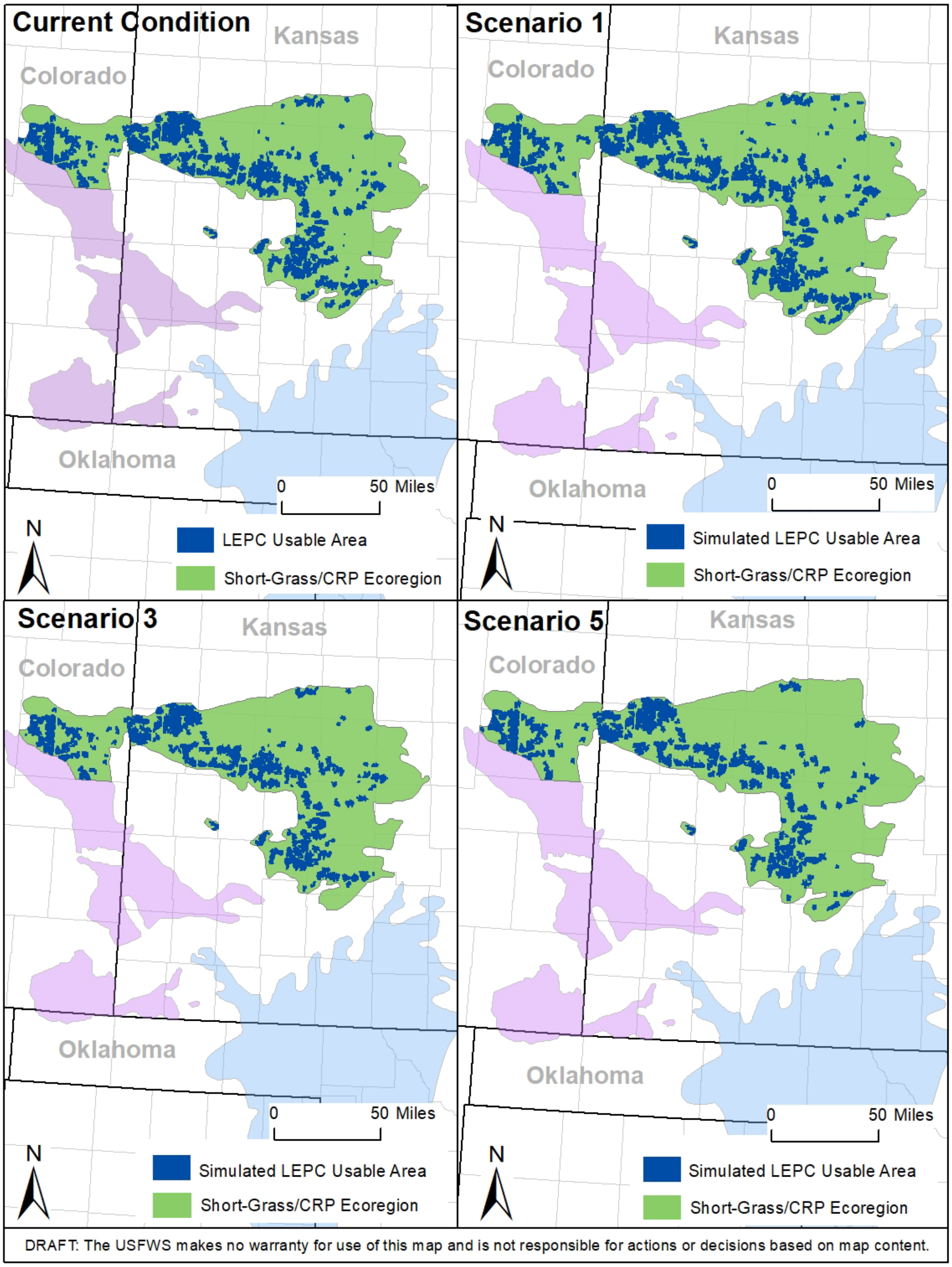

Figure E.8 Maps of current condition and modeled future simulations of lesser prairie-chicken potential usable area blocks in the Short-Grass Prairie/CRP Ecoregion. Future projection maps are of the median output of 20 simulation for three future scenarios (1, 3, 5).

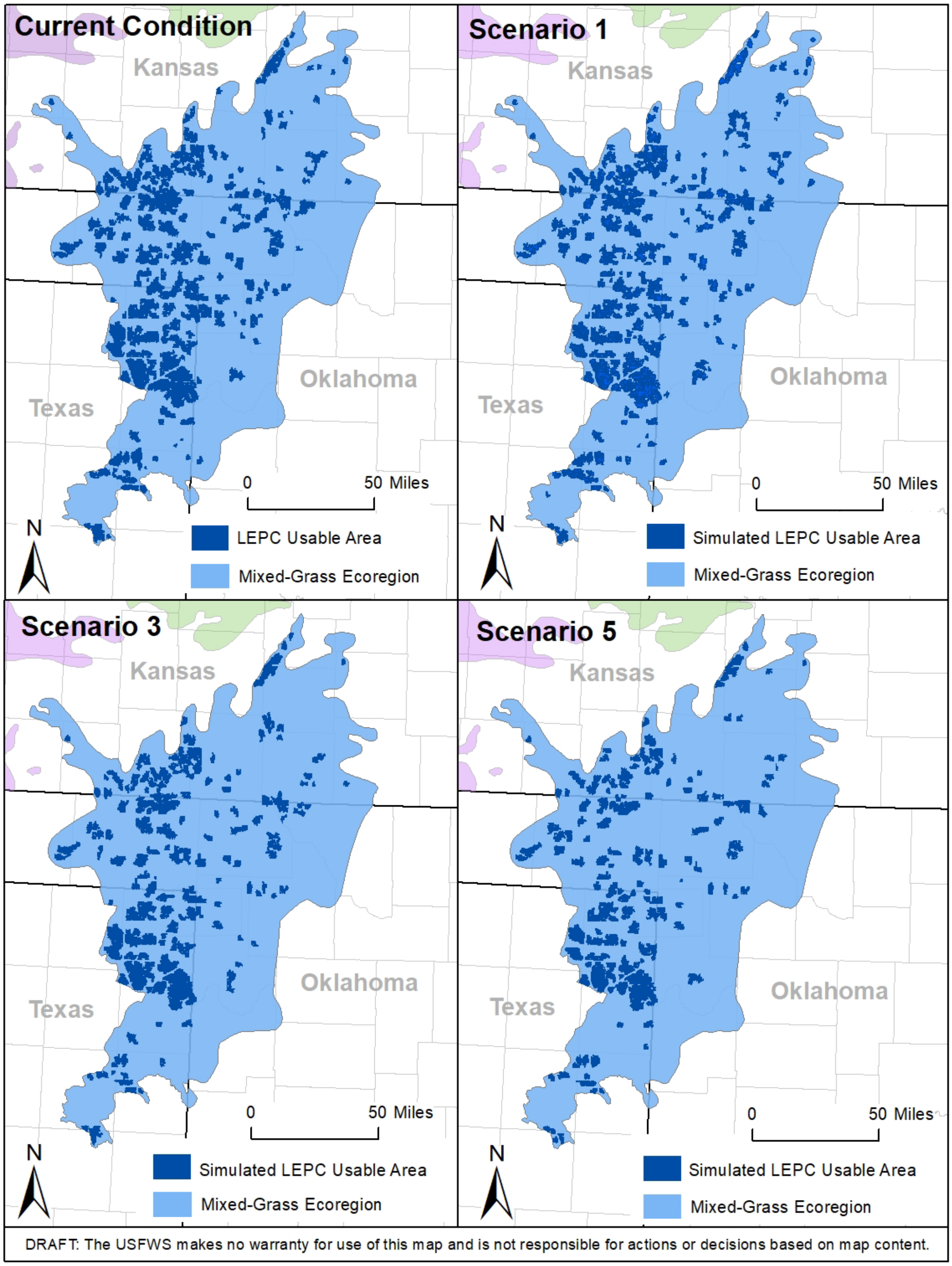

Figure E.9 Maps of current condition and modeled future simulations of lesser prairie-chicken potential usable area blocks in the Mixed-Grass Ecoregion. Future projection maps are of the median output of 20 simulation for three future scenarios (1, 3, 5).

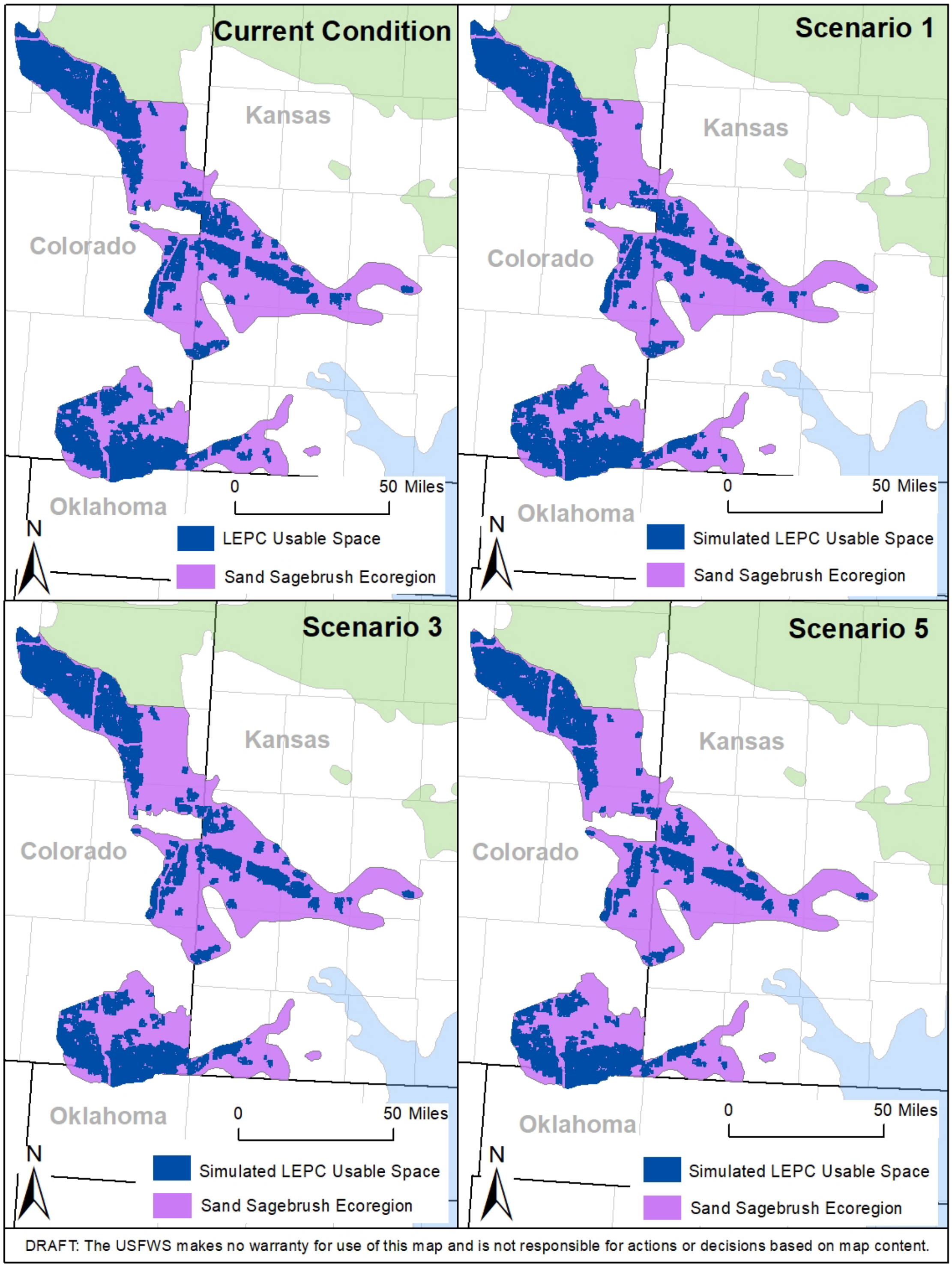

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Figure E.10 Maps of current condition and modeled future simulations of lesser prairie-chicken potential usable area blocks in the Sand Sagebrush Ecoregion. Future projection maps are of the median output of 20 simulation for three future scenarios (1, 3, 5).

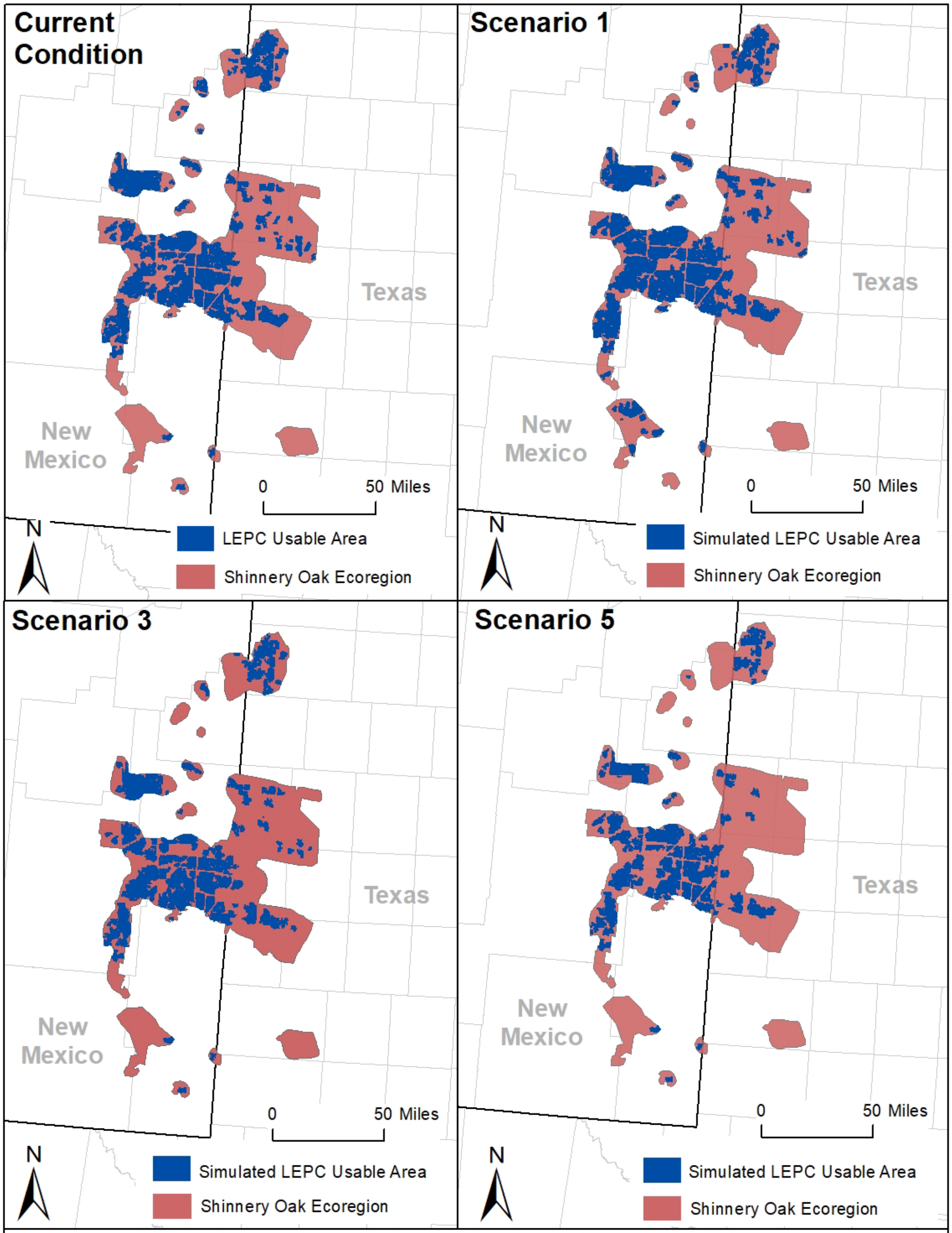

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Figure E.11 Maps of current condition and modeled future simulations of lesser prairie-chicken potential usable area blocks in the Shinnery Oak Ecoregion. Future projection maps are of the median output of 20 simulation for three future scenarios (1, 3, 5).

Table E.1 Current condition and future scenarios of projected acreage of lesser prairie-chicken potential usable area blocks in the four ecoregions. Each modeled future scenario included 20 simulation iterations. We report the median, maximum, minimum, mean, and standard deviation of the acreage for the simulation results of the 20 projections.

Short-Grass/CRP Ecoregion

		Median	Maximum	Minimum	Mean	Standard Deviation
Current Condition		1,023,894				
Future Scenarios	1	975,047	996,898	951,618	975,355	11,707
	2	956,190	979,128	921,929	955,011	14,817
	3	877,663	904,241	828,801	874,446	19,441
	4	808,152	845,027	775,625	815,772	19,226
	5	776,111	807,275	731,566	775,026	19,390

Mixed-Grass Ecoregion

		Median	Maximum	Minimum	Mean	Standard Deviation
Current Condition		994,483				
Future Scenarios	1	974,200	995,713	955,828	974,674	11,694
	2	864,780	896,238	836,087	867,591	15,721
	3	742,855	766,503	717,268	743,758	14,126
	4	649,227	672,458	601,381	644,873	15,510
	5	630,633	651,825	562,258	625,171	24,105

Sand Sagebrush Ecoregion

		Median	Maximum	Minimum	Mean	Standard Deviation
Current Condition		1,028,523				
Future Scenarios	1	992,632	1,004,236	969,626	991,764	8,469
	2	980,302	995,973	957,166	981,428	8,934
	3	932,477	948,557	912,885	932,899	9,950
	4	887,224	909,014	865,580	887,069	12,678
	5	884,851	911,993	871,602	888,035	9,487

Shinnery Oak Ecoregion

		Median	Maximum	Minimum	Mean	Standard Deviation
Current Condition		1,023,572				
Future Scenarios	1	1,149,759	1,178,039	1,112,052	1,149,281	18,594
	2	988,072	1,027,717	959,206	992,418	19,054
	3	868,761	916,446	831,533	871,199	25,925
	4	771,923	807,518	739,444	773,288	19,424
	5	711,933	736,787	666,983	704,921	22,294

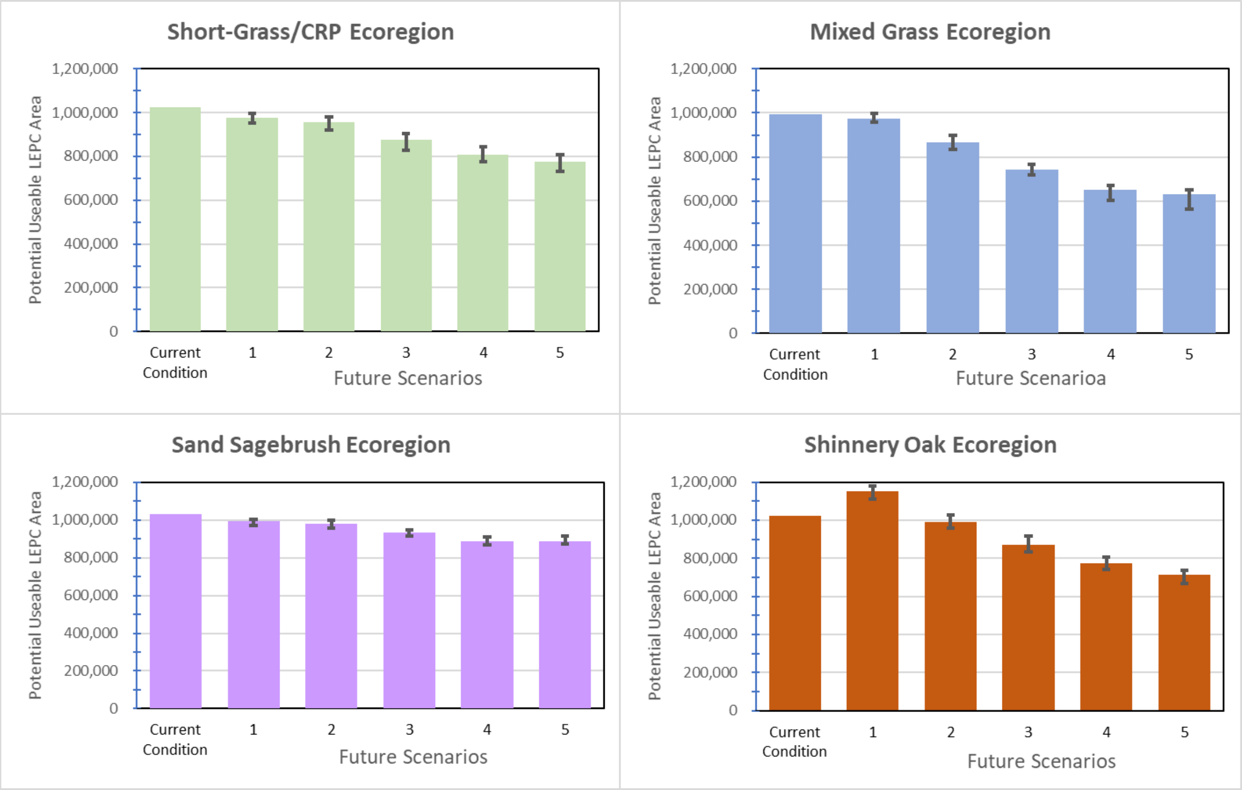

Figure E.12 Current condition and median acreage projections from five future scenarios of lesser prairie-chicken potential useable blocks in the four ecoregions. Error bars represent the maximum and minimum results from the 20 simulation iterations for each scenario.

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