APPENDICES

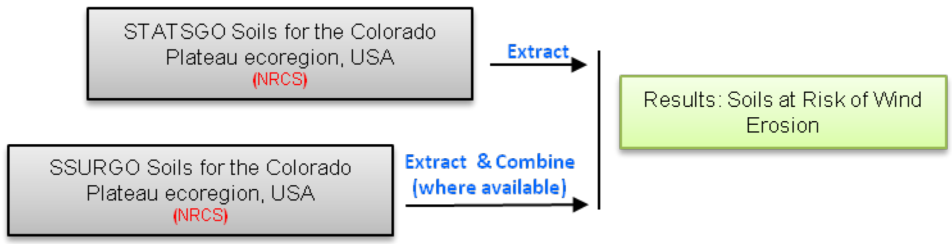
Appendix A – Colorado Plateau Management Questions

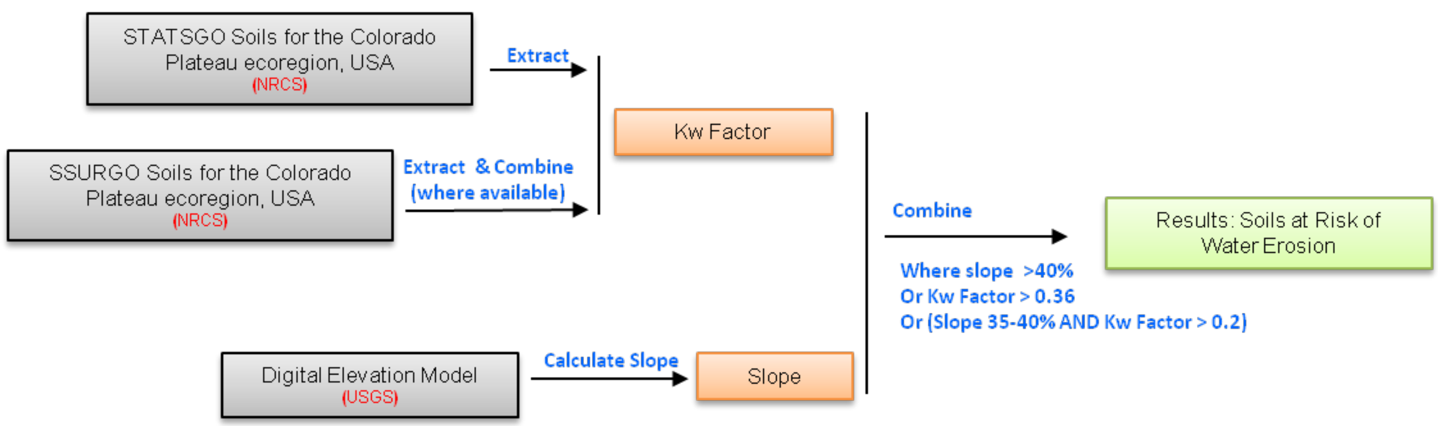
Organization of Appendix A

The following sources and results are provided for each management question: a conceptual model and/or a Process Model and a description of the analytical process (including source data) for each management question and results in the form of maps and other supporting graphics. Access to a data portal to examine the results in greater detail is available at the BLM website: http://www.blm.gov/wo/st/en/prog/more/climatechange.html.

A. Soils, Biological Crust, and Forage Management
MQ A1. Where are soils susceptible to wind and water erosion?

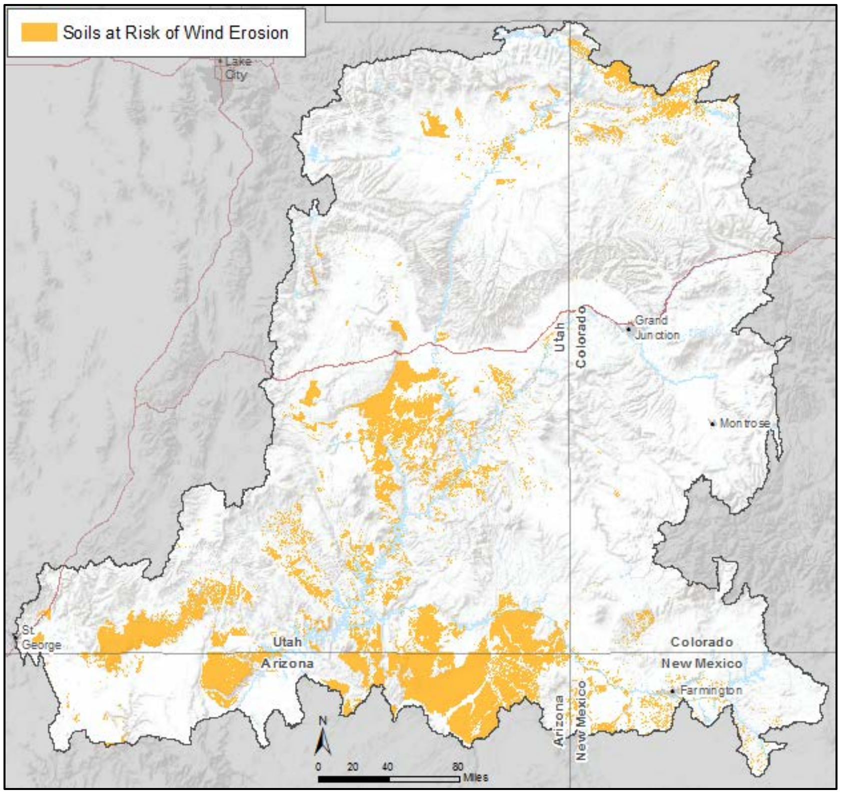
Process Model or Description

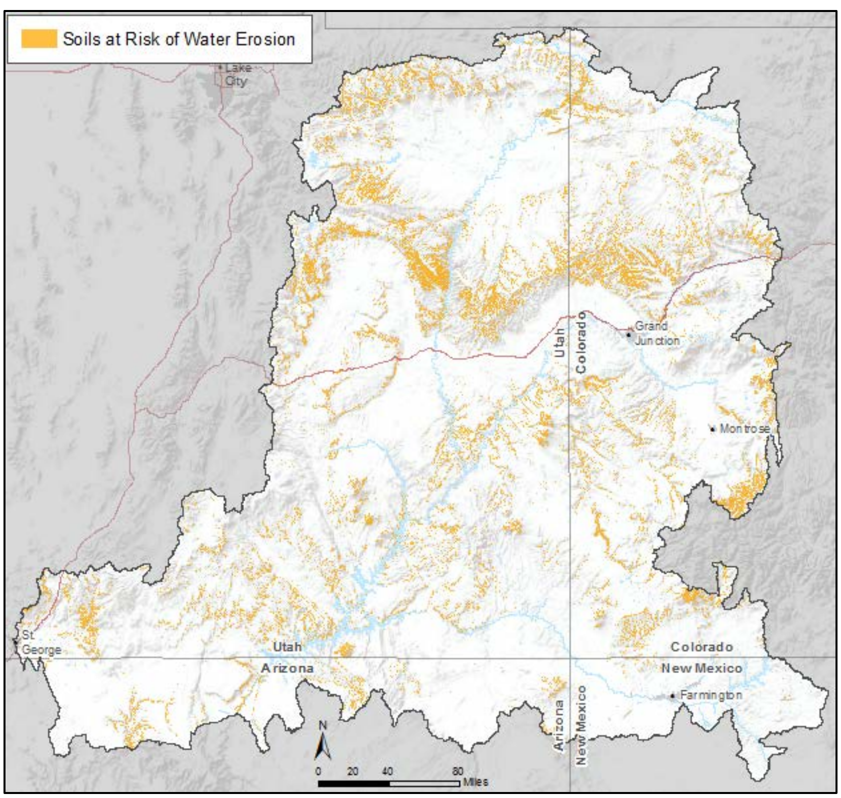




Results

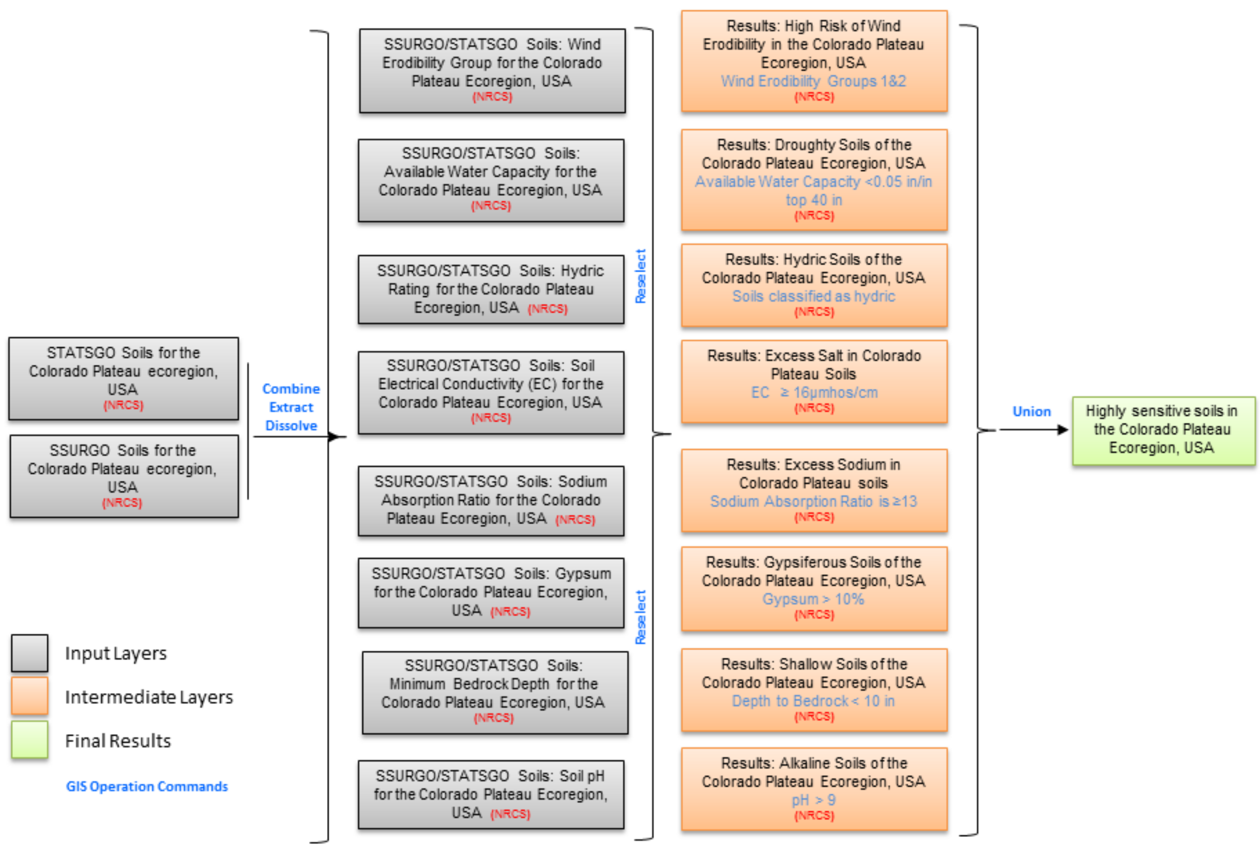
MQ A1. Where are soils susceptible to wind and water erosion?





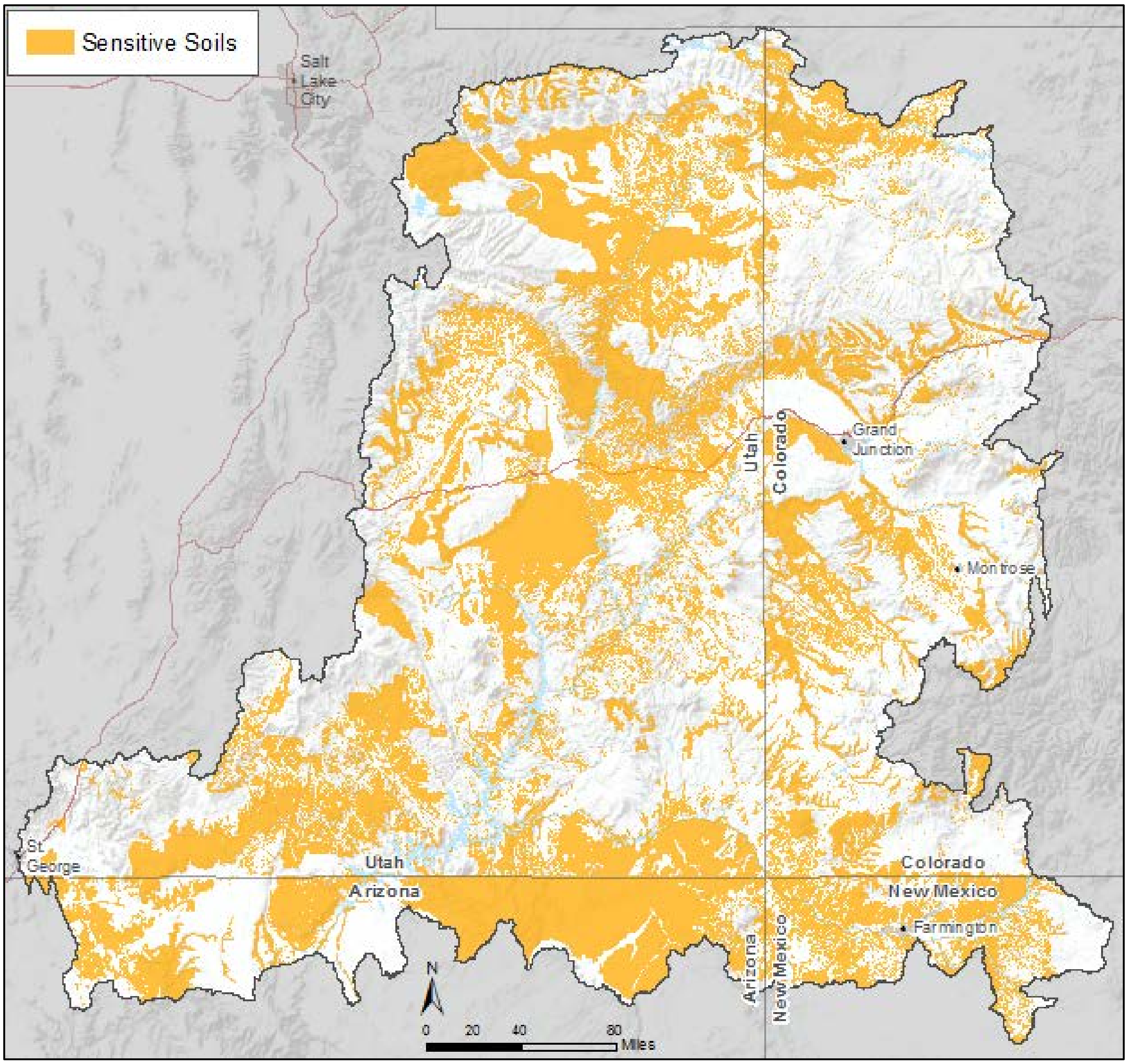
A. Soils, Biological Crust, and Forage Management
MQ A2. Where are sensitive soils (including saline, sodic, gypsiferous, shallow, low water holding capacity)?

Process Model



Results

MQ A2. Where are sensitive soils (including saline, sodic, gypsiferous, shallow, low water holding capacity)?



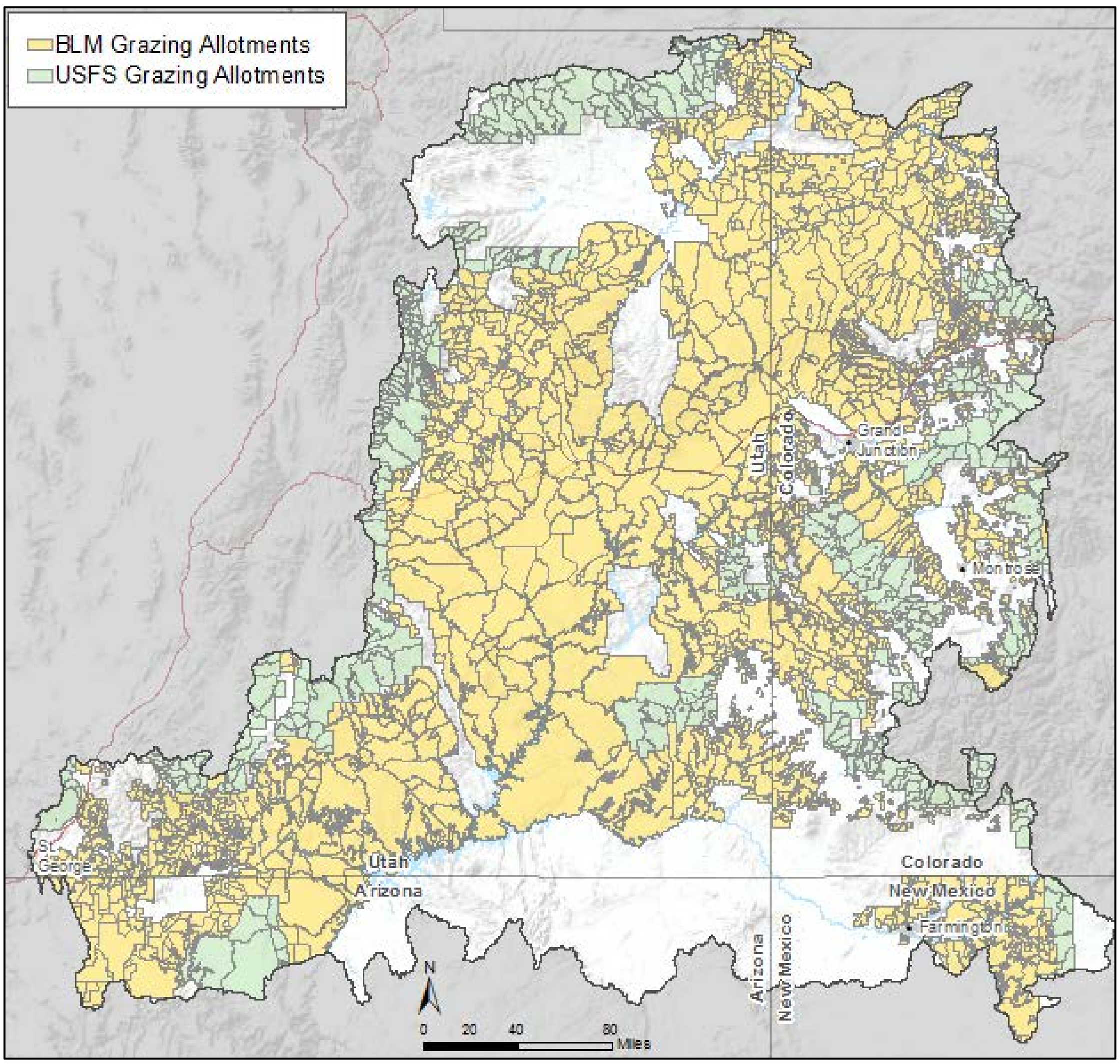
Note: Any individual soil type may be viewed individually as source data on date portal.

A. Soils, Biological Crust, and Forage Management
MQ A3. Which HMAs and allotments may experience significant effects from change agents including climate change?

Process Description

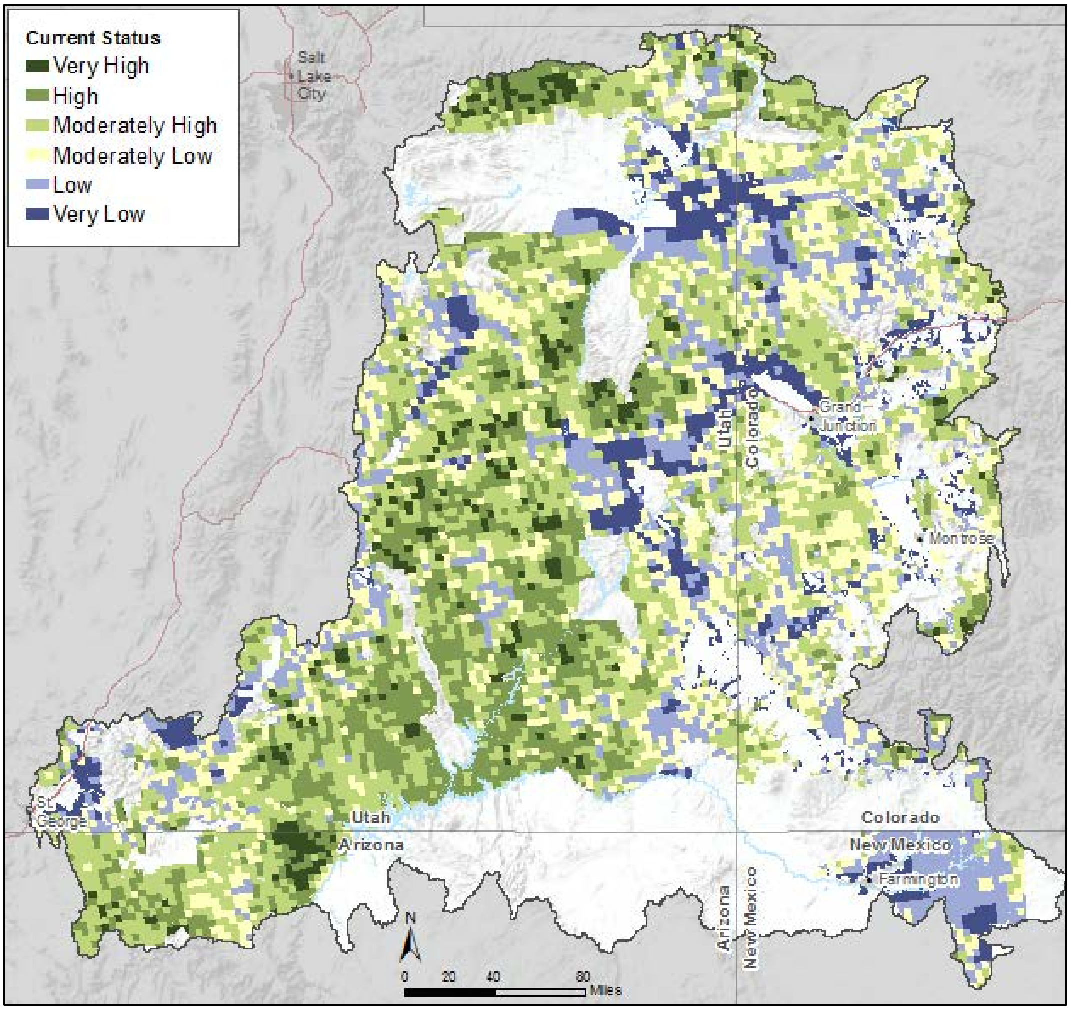
Allotments and HMAs were intersected with the combined results of current and near-term terrestrial intactness and long-term potential for climate change and energy development (see Appendix D for logic models).

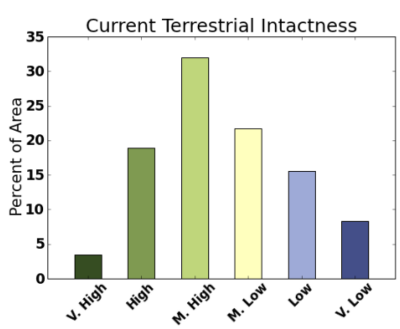
Results



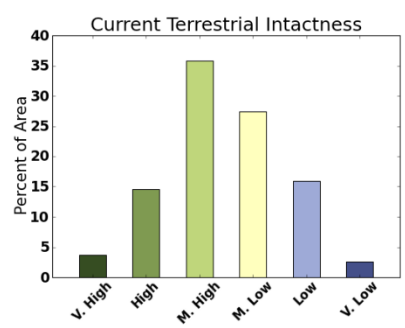
MQ A3. Which HMAs and allotments may experience significant effects from change agents including climate change?

Current Status of Allotments





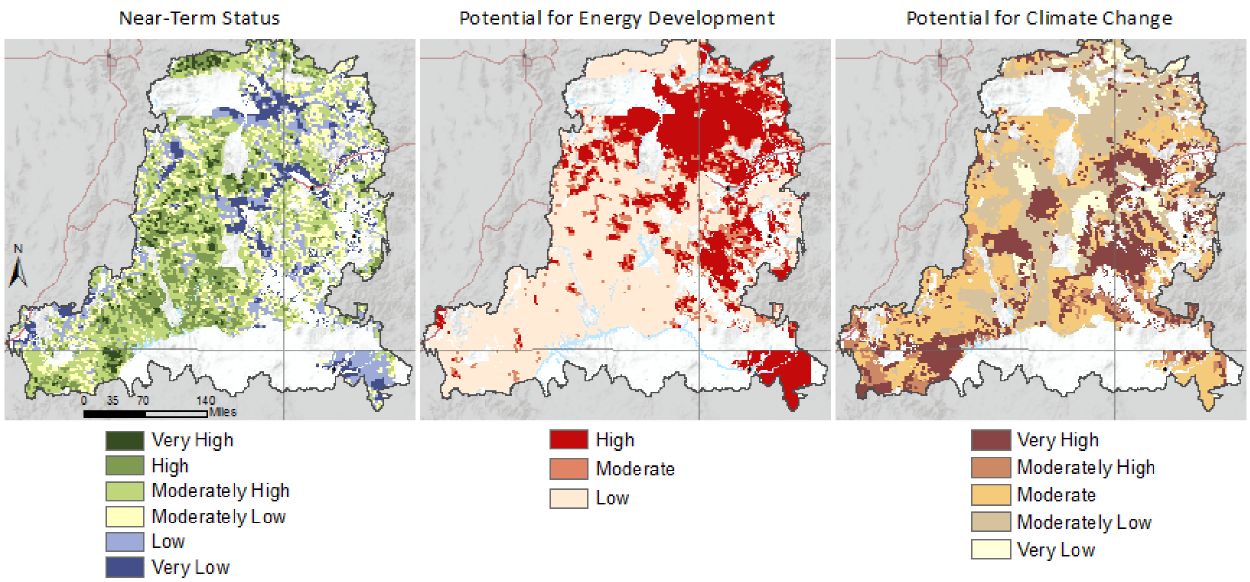
BLM Allotments



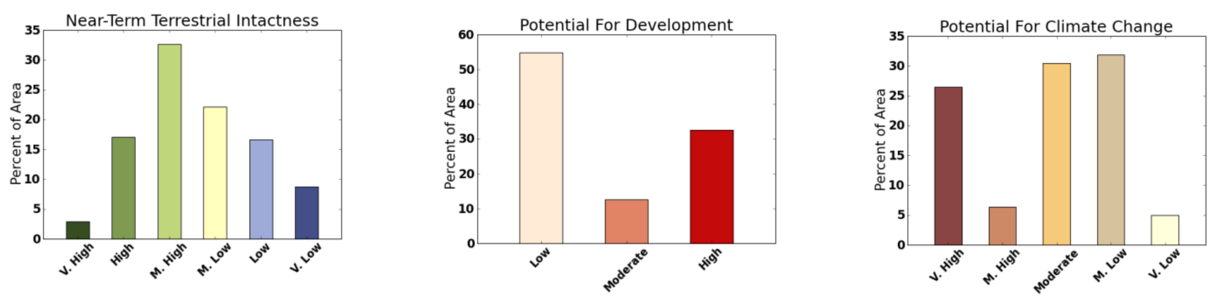
Forest Service Allotments

MQ A3. Which HMAs and allotments may experience significant effects from change agents including climate change?

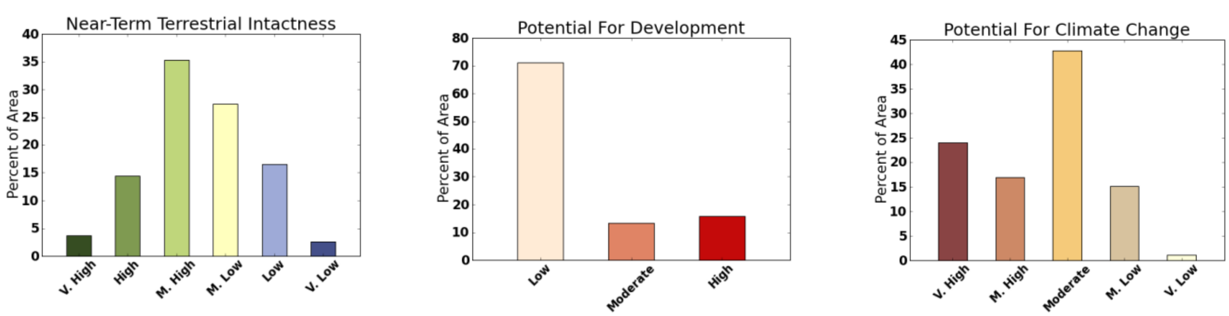
Allotments near-term future (2025) status, long term maximum potential energy development and potential for climate change (2060):



BLM Allotments

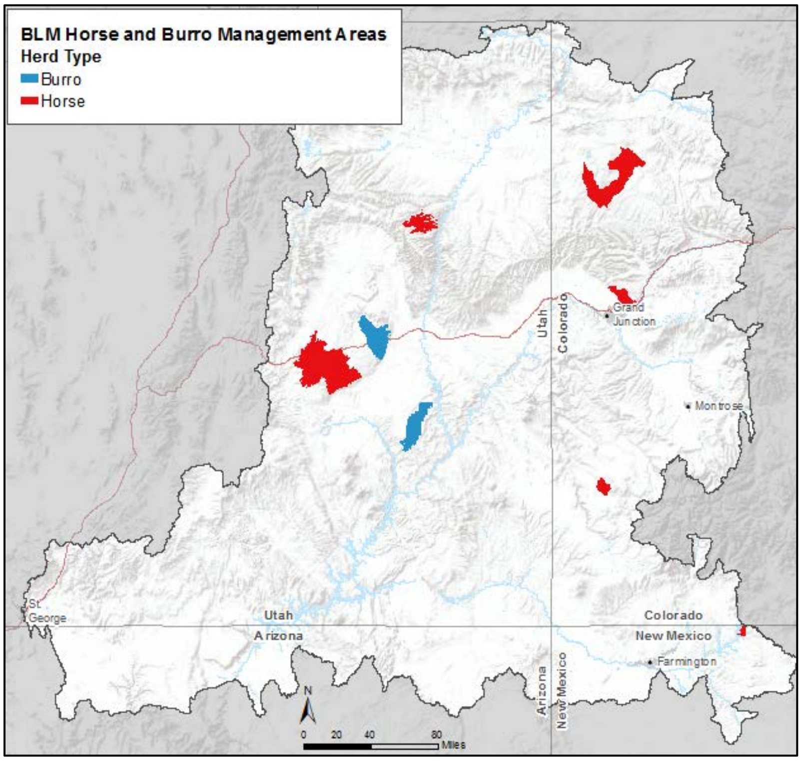


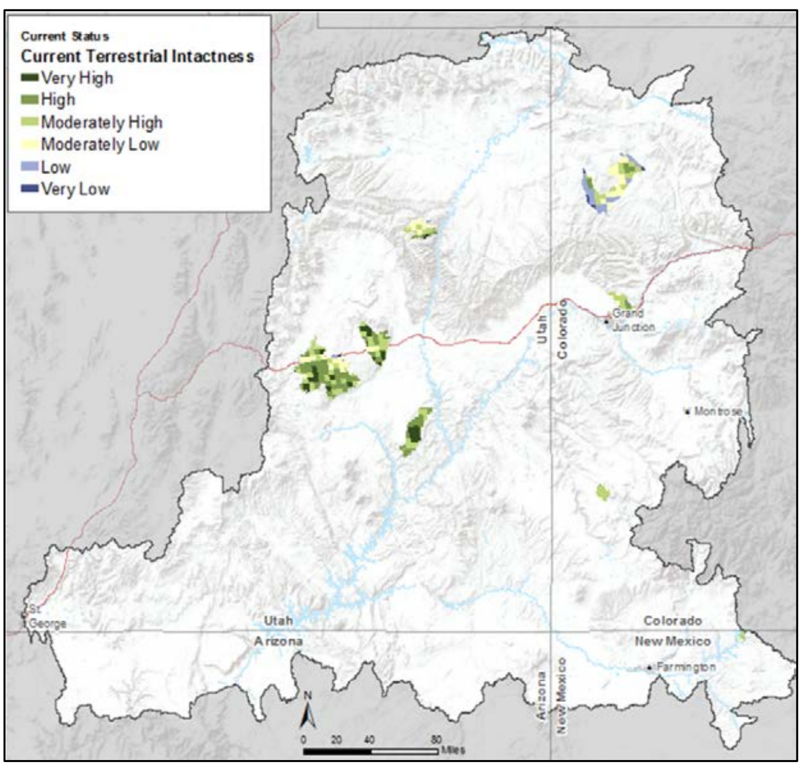
Forest Service Allotments

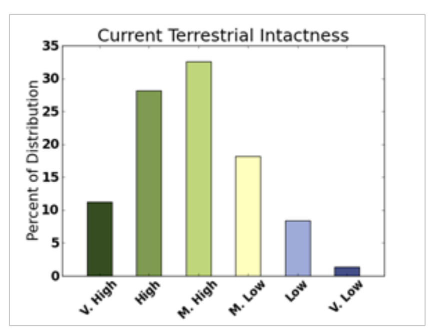


MQ A3. Which HMAs and allotments may experience significant effects from change agents including climate change?

Current Distribution and Status of Herd Management Areas (HMAs)

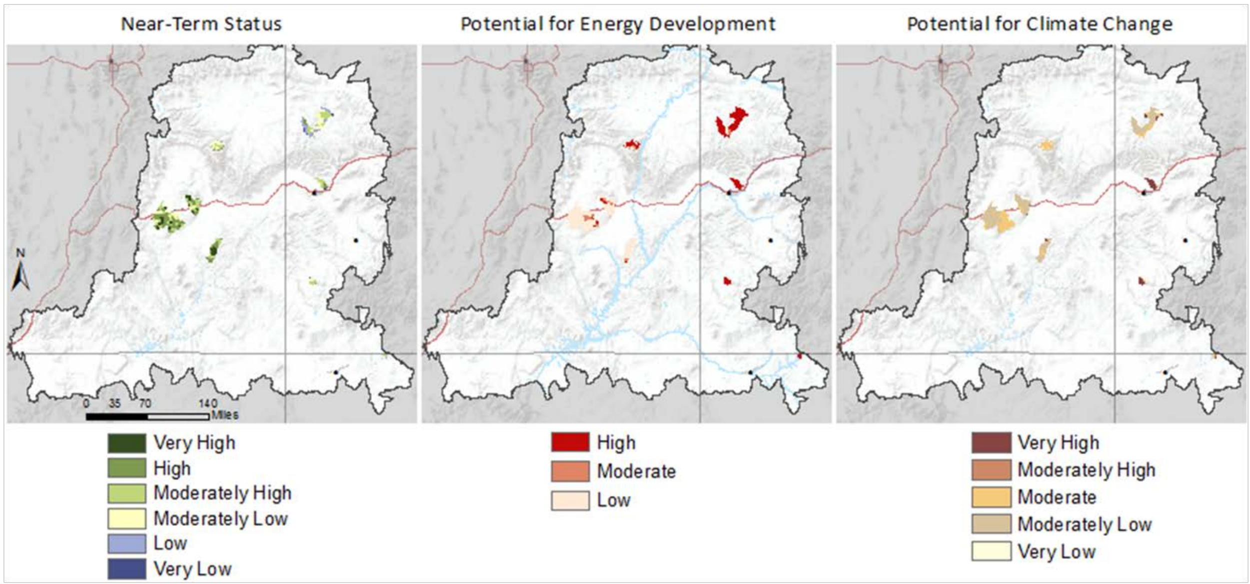


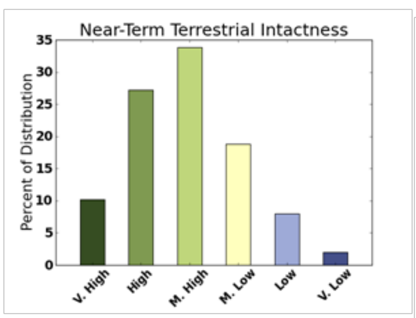


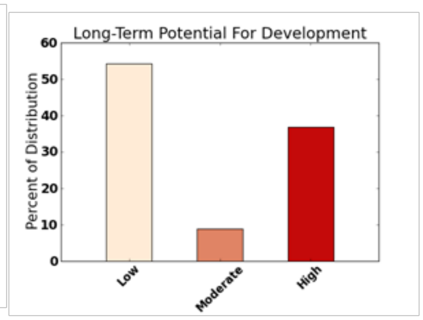


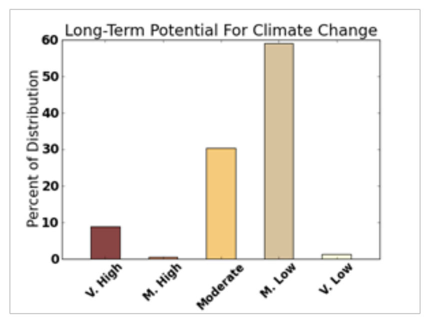
MQ A3. Which HMAs and allotments may experience significant effects from change agents including climate change?

HMAs near-term future (2025) status, long term maximum potential energy development and potential for climate change (2060):

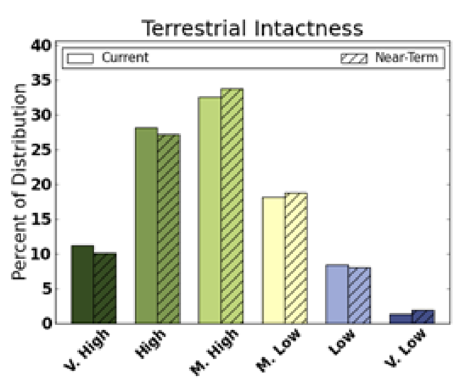








Current and Near-term future intactness



A. Soils, Biological Crust, and Forage Management
MQ A4. Where are soils that have potential to have cryptogamic soil crusts?

Soil Crust Conceptual Model

Biological crust forms in most ecological systems throughout the Colorado Plateau. There are five primary natural drivers (cyan boxes) that determine the extent and composition of biological crust including soil characteristics, precipitation, temperature, wind erosion, and condition and extent of natural vegetation. Biological soil crust stabilize the soil surface as the combined community of cyanobacteria, mosses, lichens, and other organisms reduce or prevent soil surface erosion (Jones et al. 1997). Biological crusts serve as an important source of fixed carbon (Beymer and Klopatek 1991); crusts also fix nitrogen (Belnap 1995), inhibit invasive seed germination (Larsen 1995), help retain soil moisture (Belnap and Gardner 1993), and stabilize soils (Belnap and Warren 1998). Loss of soil crust is both a component of and accelerator of desertification (Belnap 1995). Biological crusts are sensitive to even relatively minor soil disturbances. Surface disturbance by humans, livestock, and machines have affected a large proportion of crust cover throughout the Colorado Plateau. Biological crust disturbance leads to increased soil erosion from wind and water, which adds to the difficulty for crust reestablishment as soil crust is sensitive to burial. Besides mechanical disturbance, biological soil crust responds to the condition of the native vegetation—degraded natural ecosystems usually means degraded soil crust—and it does not effectively resist the expansion of non-native invasive species.

The major change agent affecting this ecological system covered in the REA process is Development (based on current and projected future extent of urban land cover). Overall landscape intactness, which includes development from all sources (urban, agriculture, energy, roads, and recreation), invasive species, and habitat fragmentation, is used to describe the regional environment that contains this ecosystem type. Climate change projections (including precipitation and temperature changes as well as MAPSS modeling outputs are also used to predict where natural plant communities that may contain biological crust may be under significant climate stress.

References

Belnap, J. 1995. Surface disturbances: Their role in accelerating desertification. *Environmental Monitoring and Assessment* 37:39–57.

Belnap, J., and J.S. Gardner. 1993. Soil microstructure of the Colorado Plateau: the role of the cyano-bacterium *Microcoleus vaginatus*. *Great Basin Naturalist* 53:40–47.

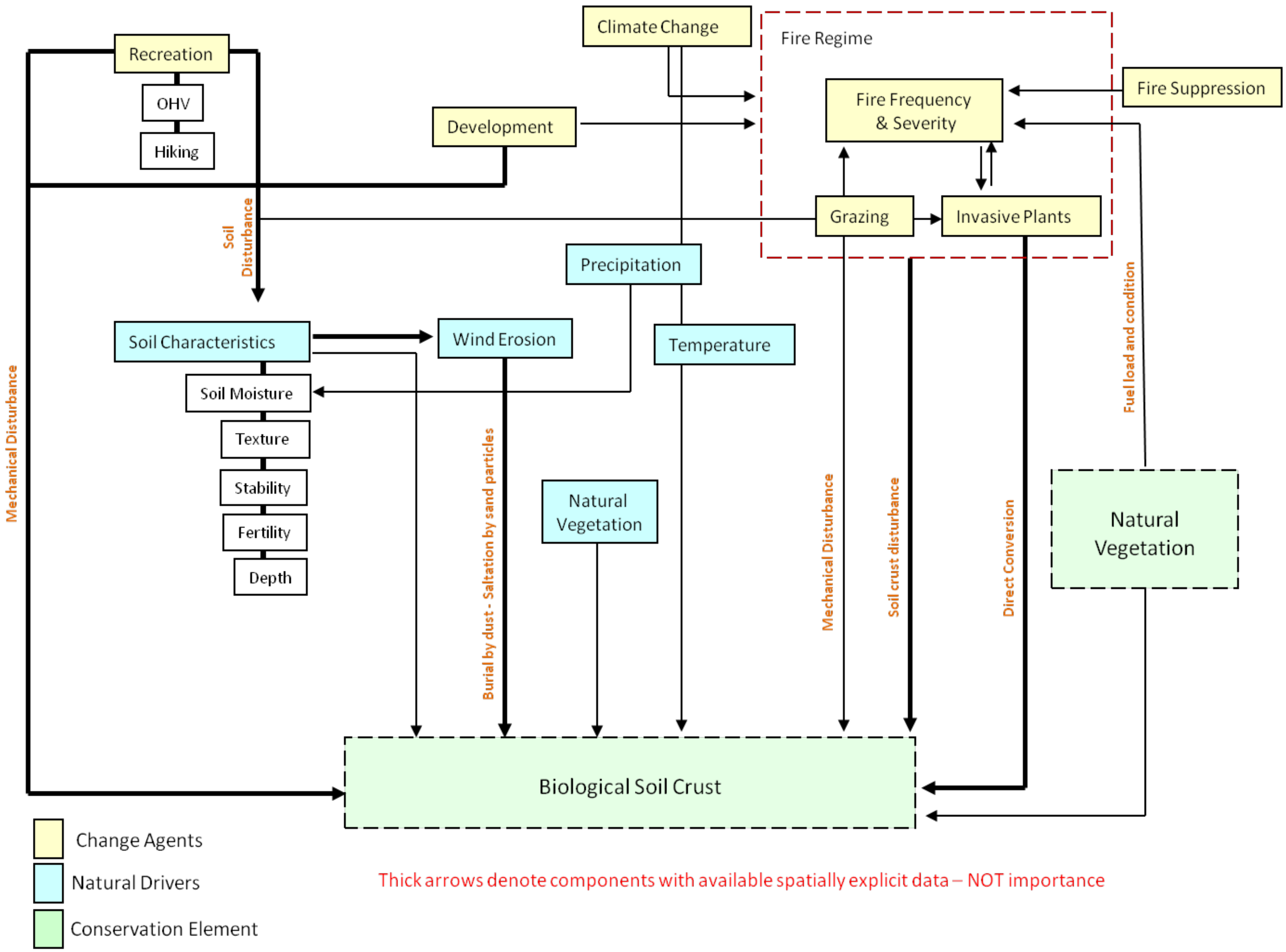
Belnap, J., and S. Warren. 1998. Measuring restoration success: a lesson from Patton's tank tracks. *Ecological Bulletin* 79: 33.

Beymer, R.J., and J.M. Klopatek. 1991. Potential contribution of carbon by microphytic crusts in pinyon-juniper woodlands. *Arid Soil Research and Rehabilitation* 5:187–198.

Jones, C.G., J.H. Lawton, and M. Shachak. 1997. Positive and negative effects of organisms as physical ecosystem engineers. *Ecology* 78: 1946–1957.

Larsen, K.D. 1995. Effects of microbiotic crusts on the germination and establishment of three range grasses. Unpublished thesis, Boise State University, Boise.

Biological Soil Crust Conceptual Model



Biological Soil Crust Model Description

A potential biological crust model was generously provided to this REA by M.A. Bowker, U.S. Geological Survey. Predictor variables included: annual precipitation and seasonality (PRISM), annual maximum and minimum temperature (PRISM), soils data (Natural Resources Conservation Service), surficial geology data, and Digital Elevation Model (DEM) data. Model outputs were generated at 800 m resolution.

For REA final results, we removed impervious surfaces (from NLCD Impervious Surfaces 2006) and developed and intensive agriculture (from LANDFIRE EVT v1.1) from early and late successional crust potential predicted by Matt Bowker.

Below is an insert by Matt Bowker and Terry Arundel describing the predicted surface for the soil crust model:

Maps of Potential Biological Crust Abundance on the Colorado Plateau

Matthew A. Bowker and Terry Arundel
US Geological Survey, Southwest Biological Science Center, Flagstaff, Arizona

Introduction

These data layers indicate the *potential* quantitative cover of biological crusts, and major constituents (mosses, lichens, dark cyanobacterial crusts) across the entire Colorado Plateau. The product is intended to assist BLM and its contractor, Dynamac Inc., in treating biological crusts as a conservation element in the Colorado Plateau Rapid Ecoregional Assessment.

What this work <u>will</u> do:

At the scale of the entire Colorado Plateau, we provide a spatially explicit estimate of the crust abundance that would likely exist if the site were in a "least-disturbed" state. Least-disturbed indicates an ecosystem state existing under current or recent climate conditions, that has been as minimally affected by disturbance as possible, given the context of widespread current and historical grazing. This state may or may not be equivalent to a historical reference condition; there is simply no information to know. Examples of least-disturbed sites include: 1) sites in National Parks where grazing has been excluded for some time, 2) never-grazed relicts, 3) Range exclosures, 3) Sites within grazed landscapes which are distant from water and/or high quality forage, or are geographically isolated.

What this work <u>will not</u> do:

This work will estimate and map the <u>potential</u> crust abundance, but will not map the current, existing crust abundance. Remote sensing is the only practical way to conduct the latter at such a large scale.
This work will be useful for regional scale analyses but may or may not provide a reliable basis for determining the status of a particular location (e.g. a hectare plot). Due to time and budgetary constraints, we are forced to partially rely on relatively low resolution model inputs (e.g. PRISM climate data). This may compromise the accuracy of model predictions at finer spatial scales.

Materials and Methods

Ecoregional biocrust database

An integrated dataset of samples from around the Colorado Plateau, and its northern, southern and eastern ecotones was assembled (Table 1). All sites were in least-disturbed condition at the time of sampling. Seven data sources were used. Sites from datasets by Bowker et al. were carefully selected based upon known or inferred disturbance history. Other data sources are from currently ungrazed areas in National Park Service units. In addition to being ungrazed we screened out sites which may be in a persistent annualized state (>5% exotic annuals) and interviewed data collectors about the reasonability of including these sites. There are 682 total records in all—593 contain data on total crust cover, and 502 contain data on soil stability. In addition, 259 contain primary soil data collected in association with the crust surveys; these data include soil texture, $CaCO_3$ and gypsum content.

We compiled 681 individual records from 5 different datasets to construct models of potential biocrust abundance. All datasets met the following requirements for inclusion: 1. data represented ecosystems in a low disturbance state. These included samples from National Parks, retired grazing allotments, geographically isolated areas including mesa tops, and samples within a more heavily grazed matrix that had escaped recent disturbance due to distance from water, roads, or adequate forage; 2. datasets were favored that had one of the authors personally involved (Bowker et al. 2005, Bowker et al. 2006, Bowker & Belnap 2007) or sufficiently familiar to be confident in the data.

Table 1. Summary of integrated dataset of quantitative biological crust data. Numbers refer to number of samples in each category. (M) denoted that soils stability values were modeled based on crust and other site characteristics; otherwise they are measured on site.

Data source	Location	Soil data	Dk. cyano	Moss	Lichen	Total crust	Chlor. a	Soil stability
Bowker et al. 2006	Grand Staircase-Escalante NM & vicinity	114	114	114	114	114	113	113(**M**)
Bowker & Belnap 2007	Walnut Cyn NM & vicinity	11	11	11	11	11	11	11
	Wupatki NM	25	25	25	25	25	25	25
	Sunset Crater NM	4	4	4	4	4	4	4
	Verde Valley, Arizona	11	11	11	11	11	11	11
	Other N. Arizona	13	13	13	13	13	13	13
Bowker et al. 2005	Canyonlands & vicinity	38		38	38			
	Dinosaur NM	8		8	8			
	Natural Bridges NM	8		8	8			
	Glen Canyon NRA	23		23	23			
	Other (Hovenweep NM Arches NP)	4		4	4			
Coles et al. 2010	Arches NP		90	90	90	90		
Miller et al. unpub	Canyonlands NP					101		101
NPS I&M								
NCPN	Canyonalnds NP		62	62	62	62		62
	Capitol Reef NP (retired allot's)		21	21	21	21		21
	Black Canyon/Curecanti (retired allot's)		17	17	17	17		17
	Dinosaur NM (retired allot's)		16	16	16	16		16
SCPN	Chaco Cyn CP		16	16	16	16		16
	Mesa Verde NP		20	20	20	20		20
	Petrified Forest NP		62	62	62	62		62
	Grand Canyon NP		10	10	10	10		10
Totals		259	492	573	573	593	177	502

Modeling

Using these existing data, we prepared regression tree models (CART) that estimate potential abundance of biological crusts on the Colorado Plateau landscape.

Predictors:

Annual precipitation and seasonality: The PRISM model provided information at an 800m grid cell size regarding long-term (1971–2000) annual average precipitation. Using their monthly normals, we derived the proportion of the total that falls from July–September, an index of the relative import of the summer monsoon.

Annual maximum and minimum temperature: The PRISM model also provided information at an 800m grid cell size regarding annual average maximum and minimum temperature, the July maximum, and the January minimum as descriptors of temperature extremes.

Soils data: The Natural Resource Conservation Service (NRCS) in Utah, and private contractor Dynamac, Inc. oversaw the production of an ecoregional soil survey map based upon NRCS SSURGO data. This entailed joining numerous individual surveys into a single shapefile and database. The process was conducted by NRCS for the state of Utah, and Dynamac's subcontractors oversaw the same process in Arizona, New Mexico, and Colorado. Another, lower resolution national database, STATSGO, was used to fill holes in the SSURGO coverage. Because soils vary on such fine scales, reliance on higher resolution information was key. One cost of this approach is that soil surveys are conducted and mapped in a piecemeal fashion over decades, and outputs do not edgematch. Nonetheless it is the best high resolution soil data available.

From this database, we extracted and mapped 6 soil property indicators: $CaCO_3$, % gypsum, sodium adsorption ratio, % sand, % clay, and the plasticity index. These data were rasterized at a 30m resolution.

Geology Data: We also used a seamless geology map initially prepared by Dynamac, Inc. Because geological codes differ by state, we reclassified them into a simpler system based upon geological substrates represented in the integrated dataset. Groupings are based upon composition of rock (e.g. limestone, shales, sandstones, etc.), age (e.g. Permian, Jurassic, etc.) and were also informed by past experience (e.g. distinction of Kaiparowits from other cretaceous sandstones).

Geology data aggregations:

Alluvial = Qa, Qs, Qao

Basalt = QTb, Qtv, Qb

Chinle = TR2, TRc

Cretaceous SS = Kch, K1, Kjdj, Kjdw, Kdb

Cretaceous SH = Kls, K2, Km

Eolian = Qe

Jurassic SS = J1, J2, Jmwe

Kaiparowits = K3

Moenkopi = TRm, TR1

Navajo = JTR, JTRgc

Permian LS = Pkt, Pp

Permian SS = Pc, Pct, PNP

If a geological substrate was not encountered in the training data, it was treated as "other" in the modeling and mapping process.

DEM data:

We acquired 30m resolution digital elevation models, and derived slope and aspect from them.

Resolution:

Although there were two original data resolutions, 30m and 800m, we snapped all rasters to a common grid (that of the DEMs) to avoid topological problems. The higher resolution was necessary to avoid losing important detail in many datasets, and regrettably the 800m resolution is the best available for climate data. Resampling 30m data to 800m in nonsensical in this case.

Regression trees:

Using these input data, we constructed CART models of various types of crust cover. Crusts organisms can be conveniently grouped into dark cyanobacterial crust cover, moss cover, and lichen cover. It can be instructive to group these data in various ways such as total late successional crusts, which is the sum of all three, and total moss and lichen cover. We also modeled light crusts which refers to physical crusting (with some biological colonization) to biological crusting by non-pigmented cyanobacteria. Whereas moss and lichen cover is fairly unambiguous, we expected some observer bias in the other variables in the various datasets. Chlorophyll *a* (a cyanobacterial biomass indicator) was available for some of the data. Finally, soil stability using the Herrick soil stability kit which measures water stable aggregation on a scale of 0–6, was available in many cases.

We attempted to model all of the crust variables as a function of all of the above predictor data. Soil stability was modeled as a function of the various classes of crust cover, geology, and the six soil properties. We used one surrogate, which allows splits to be made on alternatives if a case is lacking a measurement of a predictor. We allowed the minimum size of a parent node to be 30 cases. To select the best tree we conducted a 25-fold cross validation, and pruned based upon the standard error rule. Cross validation allows an estimate of “cost”, and a pseudo-R^2 estimating the proportion of variance the model would explain if confronted with new data. The standard error rule selects the simplest tree which has a cost within 1 standard error of the lowest cost tree. Another measure of model quality is the internal R^2, which measures how much variance the model explains in the training data. In the case of dark cyanobacteria, no splits were found using the standard error rule, thus we relaxed this constraint and built the lowest cost 2-node model. Because this modeling procedure is hierarchical, initial splits partially define which subsequent splits are selected; the saturated model may or may yield the best model. We systematically withheld related predictors (e.g. geology vs. the soil variables, annual temperature extremes vs. monthly temperature extremes) in an attempt to find lower cost models without greatly increasing complexity.

When our best tree was selected we considered this our “primary” model. Primary models were selected for total late successional crusts (moss + lichen + dark cyanobacteria), moss + lichen, lichens, mosses, dark cyanobacteria, light cyanobacteria, and soil stability. Several of our response variables can be estimated in more than one way, either directly through regression tree modeling, or indirectly using simple raster calculations based upon multiple mapped regression tree outputs. For example, it is possible to model late successional crusts (total moss + lichen + dark cyanobacteria) directly using regression tree analysis. Another approach might be to model these three components independently and sum the outputs. A third approach might model dark cyanobacterial crusts and total macrophytes (moss + lichens) directly and sum these outputs. *A priori*, there is no way of knowing which approach would yield the best predictions. For total late successional crusts (moss + lichen + dark cyanobacteria), moss + lichen, lichens, mosses, and dark cyanobacteria we produced 2 alternative models each based upon these simple arithmetic operations. We consider these “secondary” models. No secondary models were produced for light cyanobacteria or soil stability.

Multi-model inference:

Again, for total late successional crusts (moss + lichen + dark cyanobacteria), moss + lichen, lichens, mosses, and dark cyanobacteria, we devised a way of using primary and secondary models together to draw inference. All models contain some semblance of "truth" and different models may contain unique information (Burnham and Anderson 2002). We used multiple models as terms in multiple regression models, obtaining slope estimates for each of them. To select the best regression model we selected from all 8 possible models using Akaike's Information criterion. The best models always used the primary model in addition to at least one secondary model as terms. This can be considered a simplistic form of "boosting" (Elith et al. 2008). These multi-model outputs are considered our "final" models.

Results

We deliver twelve raster products. The following naming conventions are used:

li = light cynaobacteria

d = dark cyanobacteria

m = mosses

l = lichens

ml = mosses + lichens

mld = mosses + lichens + dark cyanobacteria

stability = soil stability

Both primary and final grids are provided, the final grids being preceded by "fin". In the cases where they are available we recommend use of final models over primary models. Secondary models are not provided to avoid confusion among users, and because they are less useful, and could easily be produced from primary models if desired. They can be provided on request.

Overall our approach was able to generate useful models for several parameters related to biocrust development and function. Predictive value of the models ranged from very high (light cyanobacterial cover and surface soil stability), to moderate (late successional crusts, total moss, total lichen, and total moss + lichen), to poor (dark cyanobacterial crusts).

Primary models:

Late successional crust cover *(moss + lichen + dark cyanobacterial cover):*

We constructed a 9 node model for late successional crust elements, primarily based upon monsoon importance, soil gypsum, and geology (**Figure 1f**). Our model explained 47% of the variation in the data. Based on cross-validation our best estimate of predictive power in new data is R^2 = 0.27.

Total moss + lichen cover:

Total moss + lichen cover was also described in a somewhat more successful 7 node model (**Figure 1e**) based primarily on soil gypsum and monsoon importance. Our model explained 46% of the variance in the data, and 36% when confronted with new data during cross validation.

Total moss

A four node model predicts total moss cover (**Figure 1c**). Variables related to temperature extremes were the most important predictors. This model explained 26% of the variation in the training data, and 20% when confronted with new data during cross-validation.

Total lichen

An equally simple but somewhat more successful model used four nodes to predict total lichen cover (**Figure 1d**). In descending order, the splits were based upon soil gypsum, temperature minimums, and monsoon importance. This model explained 36% of the variation in the training data, and attained an R^2 of 0.28 based on cross-validation.

Dark cyanobacterial crust cover

Based on an analysis of cost versus complexity and the 1 standard error pruning rule, we failed to generate even a single split in the dark cyanobacteria data. To ensure that we had a model with some weak predictive power, we forced a two node solution (**Figure 1b**). This split was based upon geology. Only 10% of variance was explained in training data, and 7% in validation data. Weak performance may be related to observer differences in the various datasets.

Early successional crusts (light cyanobacterial and some physical crust cover)

In contrast, our 9 node model of light cyanobacterial cover (**Figure 1a**) performed exceptionally well. Again monsoon importance was crucial, the first split, but this model also invoked 4 other predictors. About two thirds of the variance (67%) in the training data was explained. Validation performance was exceptionally good, capturing 53% of the variation in withheld data. We noted one idiosyncrasy of this model, that substrates coded as “chinle” in the geology dataset displayed relatively high values. “Chinle” encompasses bentonitic shales that support little true cyanobacterial crusting, in addition to sandier substrates that do support cyanobacteria. These bentonitic surfaces do tend to exhibit a thin physical crust which may be recorded by some observers as biocrust. Overall this appears to be a good model but users should note that predictions for chinle shales may be inflated.

Surface soil stability

The soil stability model was another of our most successful models. It is based upon eight nodes (**Figure 1g**). Late successional crust cover is the most important predictor, being invoked in the first split, and in three of the other splits. Variance explained in both training and validation is high, at 63% and 50%, respectively.

Multi-model inference

Several response variables can be modeled using more than one approach. A user could use the best performing model, the most direct modeling procedure, or draw information from multiple models simultaneously. Multi-model inference is powerful because the samples of one model that are difficult to explain may be explainable by another model.

In the case of the various types of biocrust cover, the direct approach to modeling was the most informative in all cases, but modeling only with the primary model was never selected as the best model; secondary models were invoked in all cases. In three of five cases the saturated model (using one primary term and two secondary terms) was the best model. Most cases exhibit substantial improvement in the variance explained in the training data. Users will note that in some of these final models, negative values are possible. These values should be interpreted as ones very near zero, and in any case are expressed only in very small portions on the output maps.

The equations appear below:

1. Response MLD

Intercept: -2.956984

Slope (mld primary model): 0.7125703

Slope2 (m + l + d): 0.5700944

Internal R^2 = 0.46

IF IT IS DESIRABLE TO REDUCE CRUST COVER TO ONE VARIABLE, we recommend using this model (finmld);. These are the most visible and highly functional crusts.

2. Response ML

Intercept: -0.578821

Slope (ml primary model): 0.4868865

Slope2 (m + l): 0.326629

Slope3 (mld – d): 0.2549641

Internal R^2 = 0.48

3. Response L

Intercept: 0.1215443

Slope (l primary model): 0.5048521

Slope2 (mld – m - d): 0.1638832

Slope 3 (ml – m): 0.2476273

Internal R^2 = 0.42

4. Response M

Intercept: -0.315065

Slope (m primary model): 0.7102625

Slope2 (mld – l - d): 0.1118507

Slope3 (ml – l): 0.1987241

Internal R^2 = 0.36

5. Response D

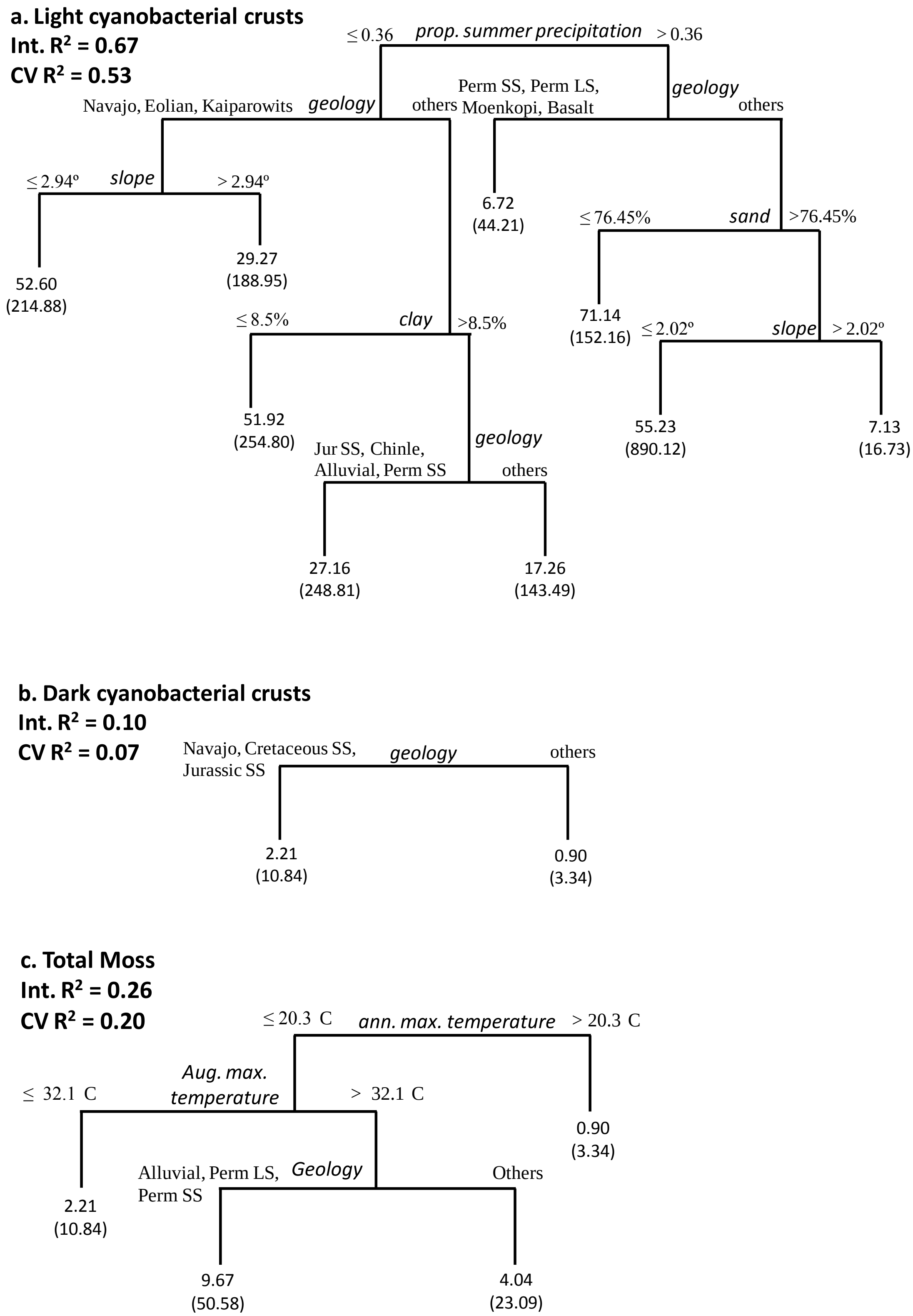
Intercept: -0.9187871

Slope (d primary model): 0.8590865

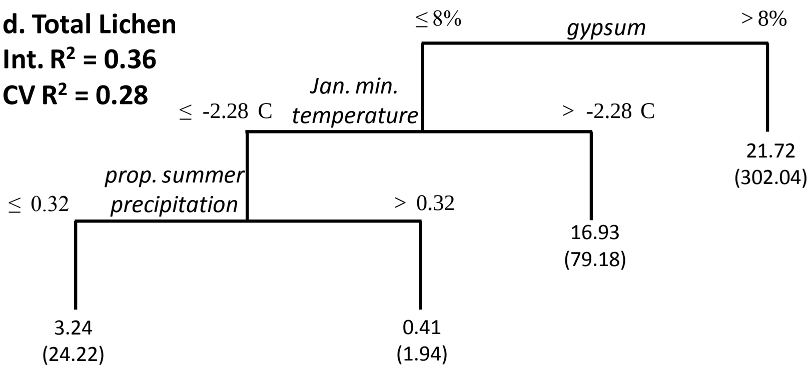
Slope2 (mld – l - m): 0.3137156

Internal R^2 = 0.19

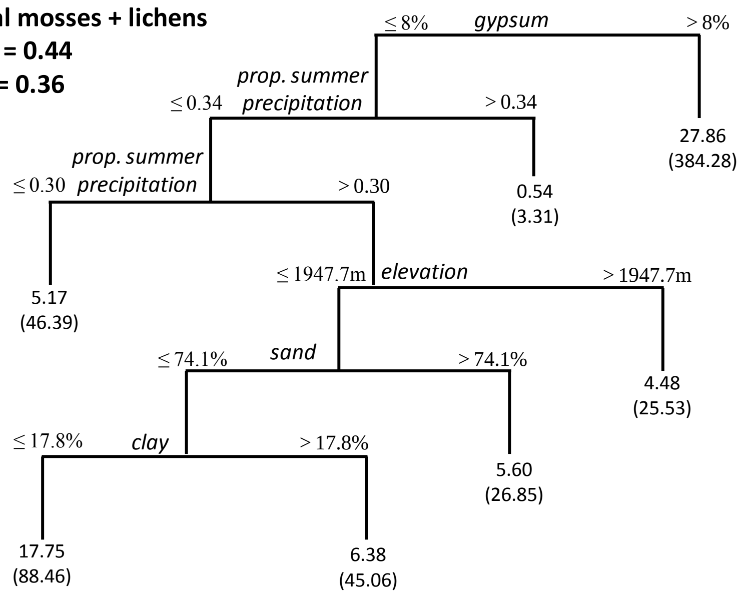
Figure 1. Primary regression tree models produced for the BLM Colorado Plateau REA. Models are read from top to bottom like a decision tree. Italicized text and associated values indicate split criteria. Predicted mean and variance of the response variable are presented at end nodes.



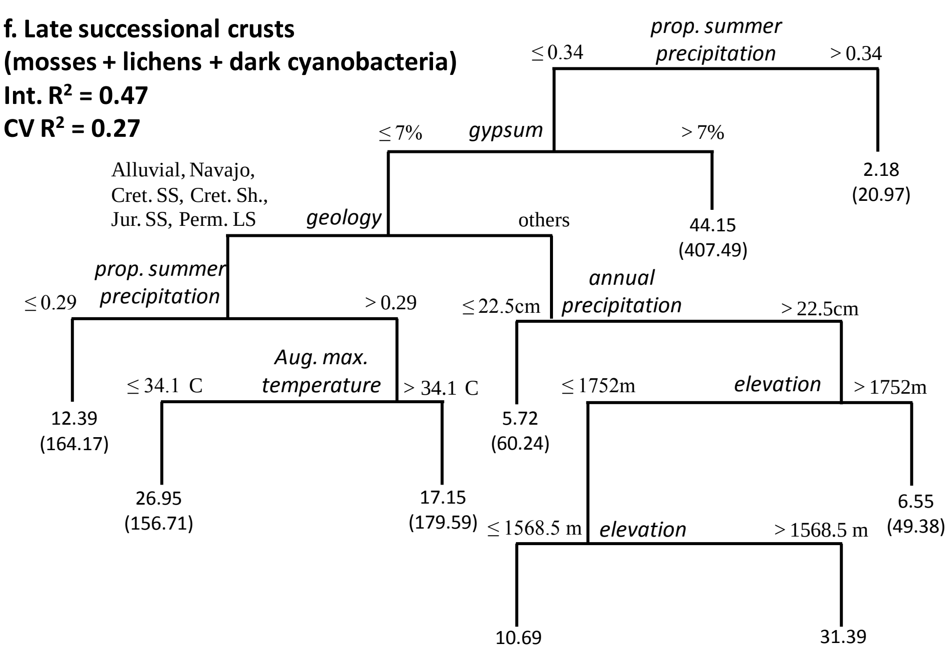
d. Total Lichen
Int. R^2 = 0.36
CV R^2 = 0.28



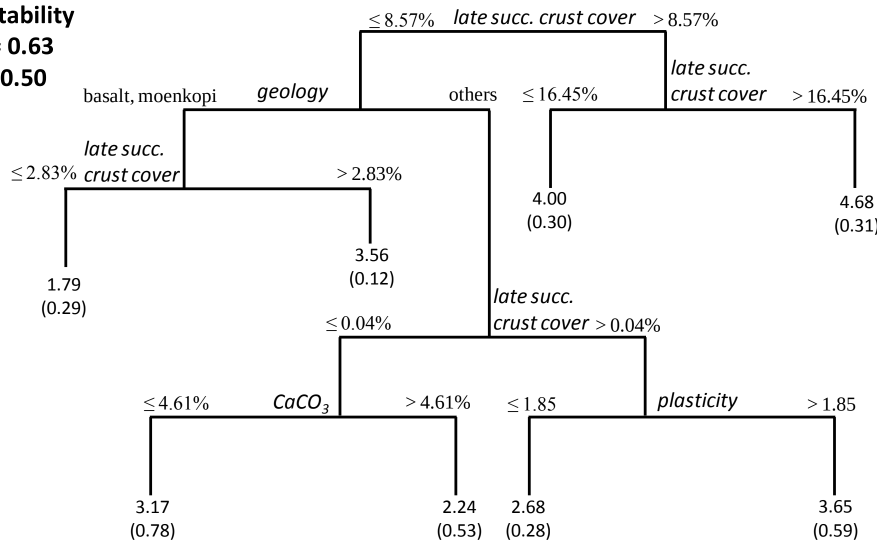
e. Total mosses + lichens
Int. R^2 = 0.44
CV R^2 = 0.36



f. Late successional crusts
(mosses + lichens + dark cyanobacteria)
Int. R^2 = 0.47
CV R^2 = 0.27



g. Soil stability
Int. R^2 = 0.63
CV R^2 = 0.50



References Cited

Bowker, M.A., J. Belnap, D.W. Davidson, and S.L. Phillips. 2005. Evidence for micronutrient limitation of biological soil crusts: Importance to arid-lands restoration. *Ecological Applications* 15:1941–1951.

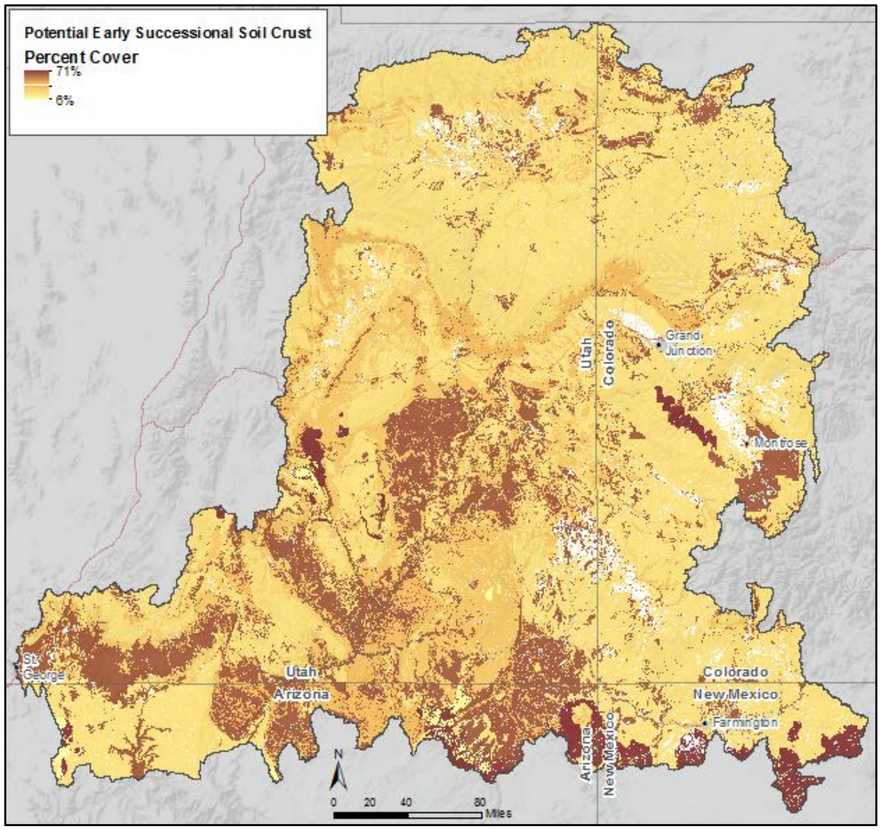
Bowker, M.A., and J. Belnap. 2007. Spatial modeling of biological soil crusts to support land management decisions: Indicators of range health and conservation and restoration value based upon the potential distribution of biological soil crusts in Montezuma Castle, Tuzigoot, Walnut Canyon, and Wupatki National Monuments, Arizona.

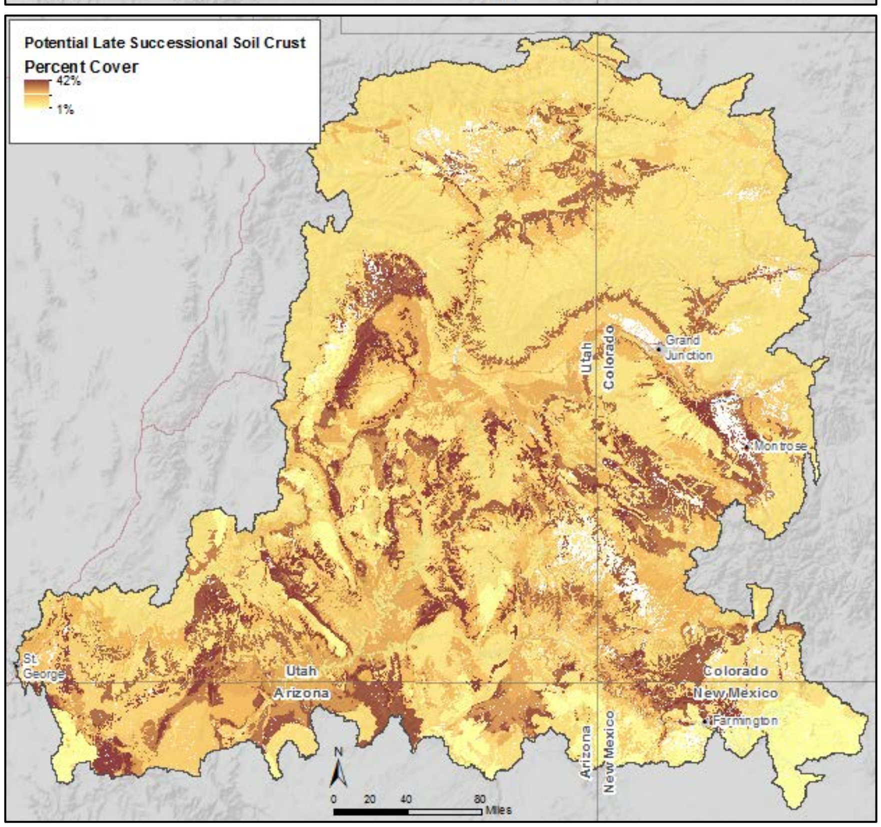
Bowker, M.A., J. Belnap, M.E. Miller. 2006. Spatial modeling of biological soil crusts to support rangeland assessment and monitoring. Rangeland Ecology and Management 59: 519-529

Burnham, K.P., and D.R. Anderson. 2002. Model selection and multi-model inference: A practical information-theoretic approach. Springer, New York.

Elith, J., J.K. Leathwick, T. Hastie. 2008. A working guide to boosted regression trees. *Journal of Animal Ecology* 77: 802–813.

Results: Modeled Early and Late Successional Biological Soil Crust



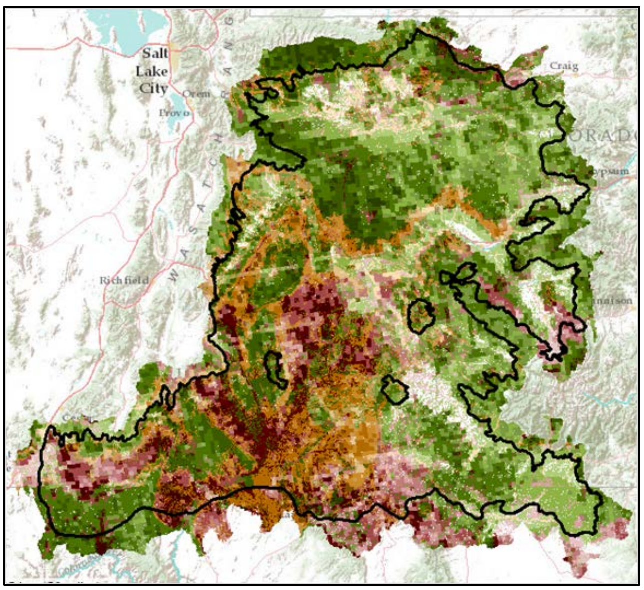


A. Soils, Biological Crust, and Forage Management
MQ A5. What/where is the potential for future change to the cryptogamic crusts?

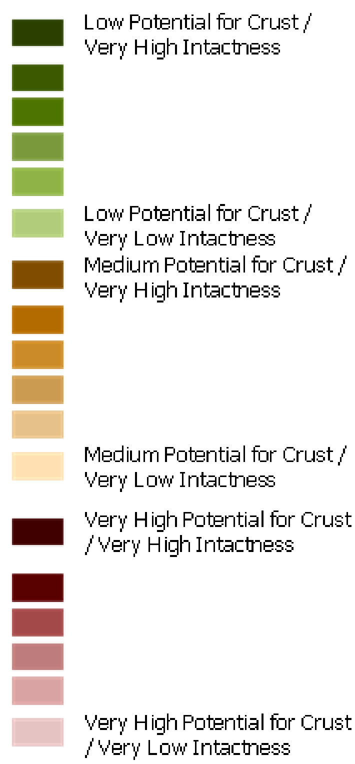
Process Model or Description

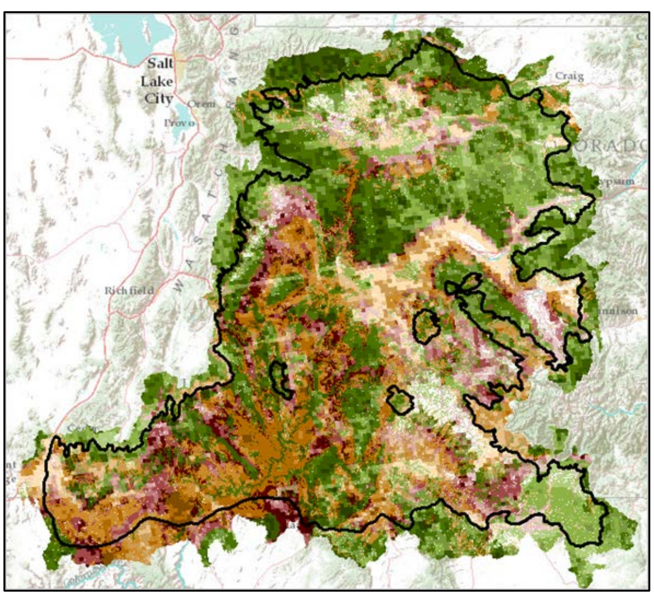
For each type of crust (early and late successional), we combined 3 natural breaks classes of soil crust (MQA4) with combined results of current and near-term terrestrial intactness and long-term potential for climate change and energy development. For potential for future change, we selected the highest category of potential crust based on natural breaks of the original data by Bowker and analyzed it against near-term intactness, potential energy, and climate change.

Results



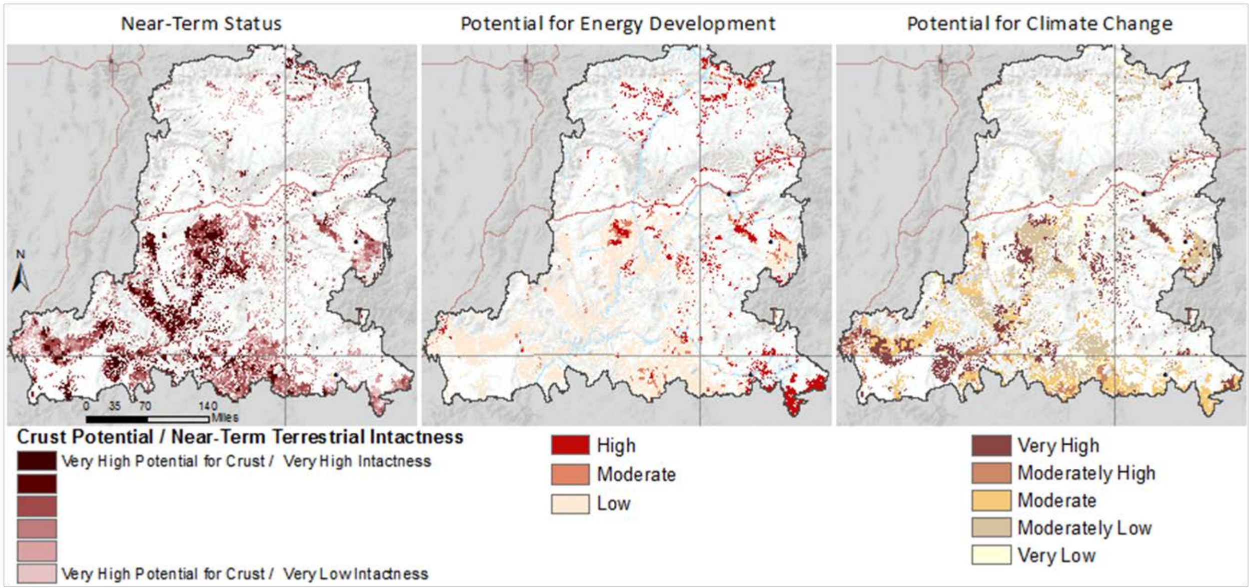
Early successional crust

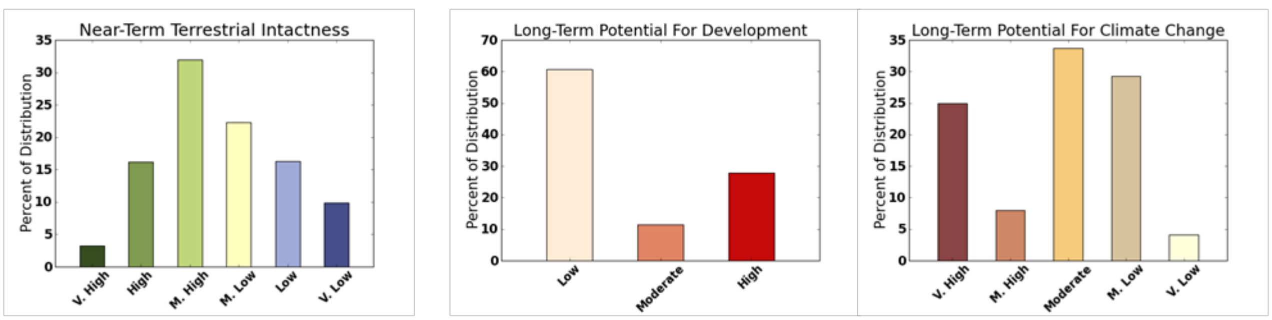




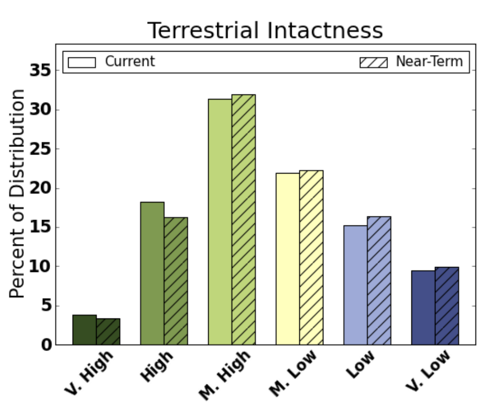
Late Successional Crust

Early Successional Crust



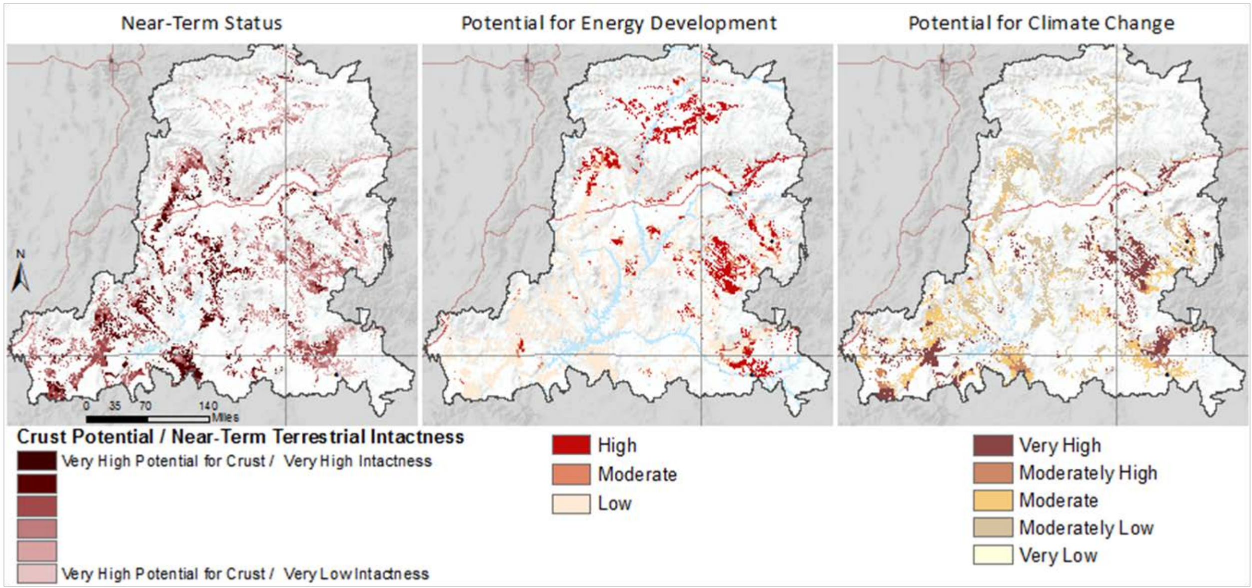


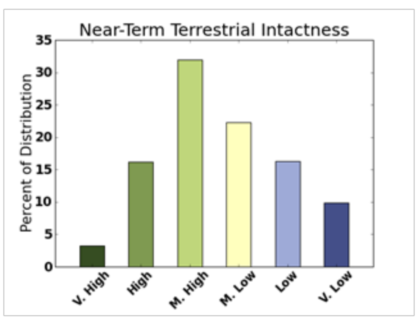
Current & Near-term Intactness

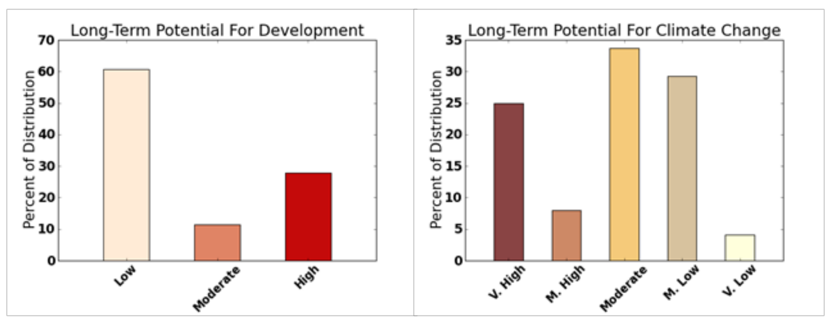


Current (solid color) and Near-term (cross-hatched) Intactness

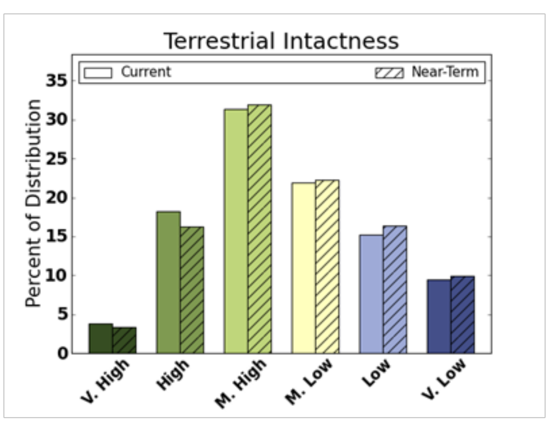
Late Successional Crust







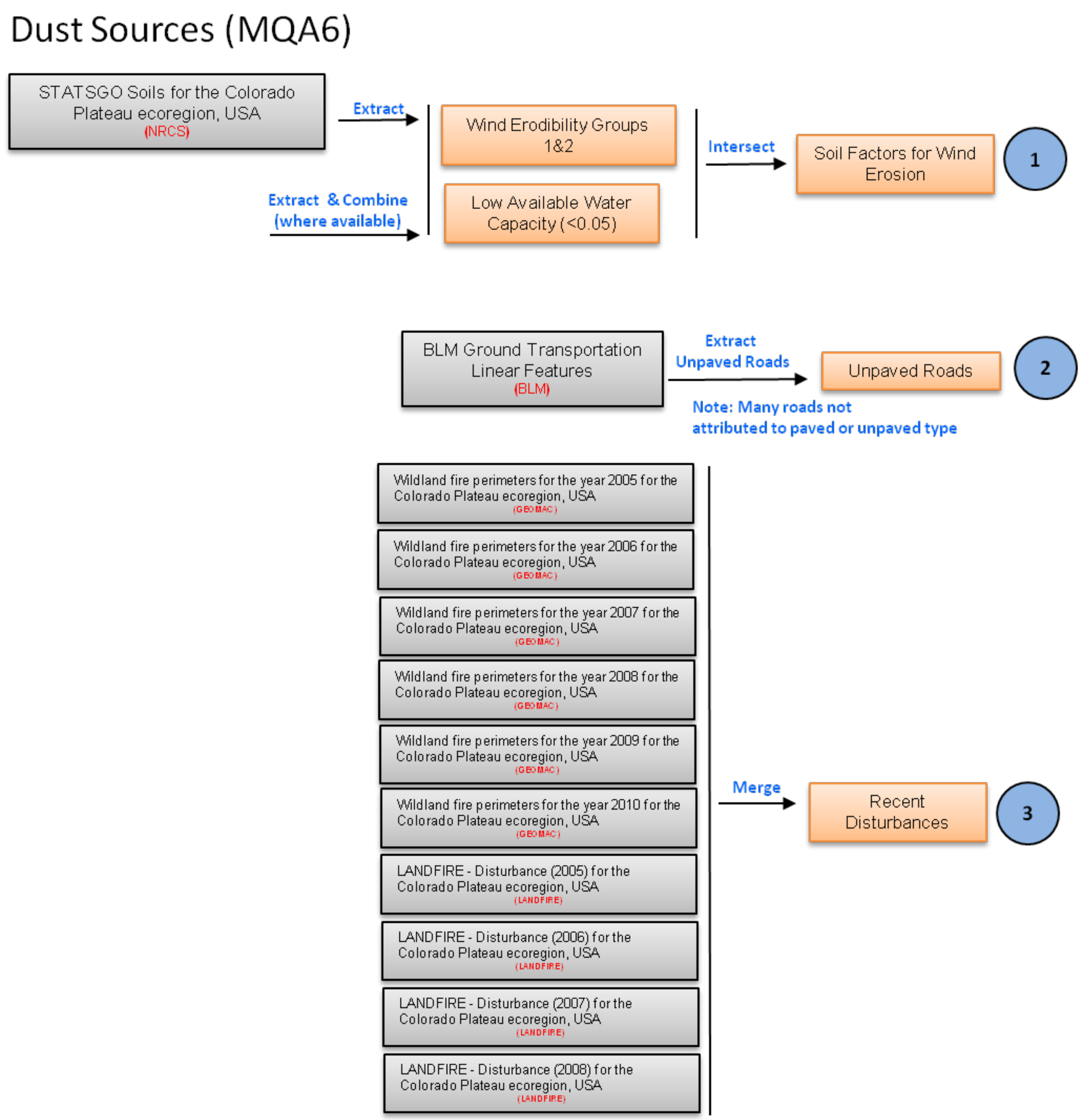
Current & Near-term Intactness

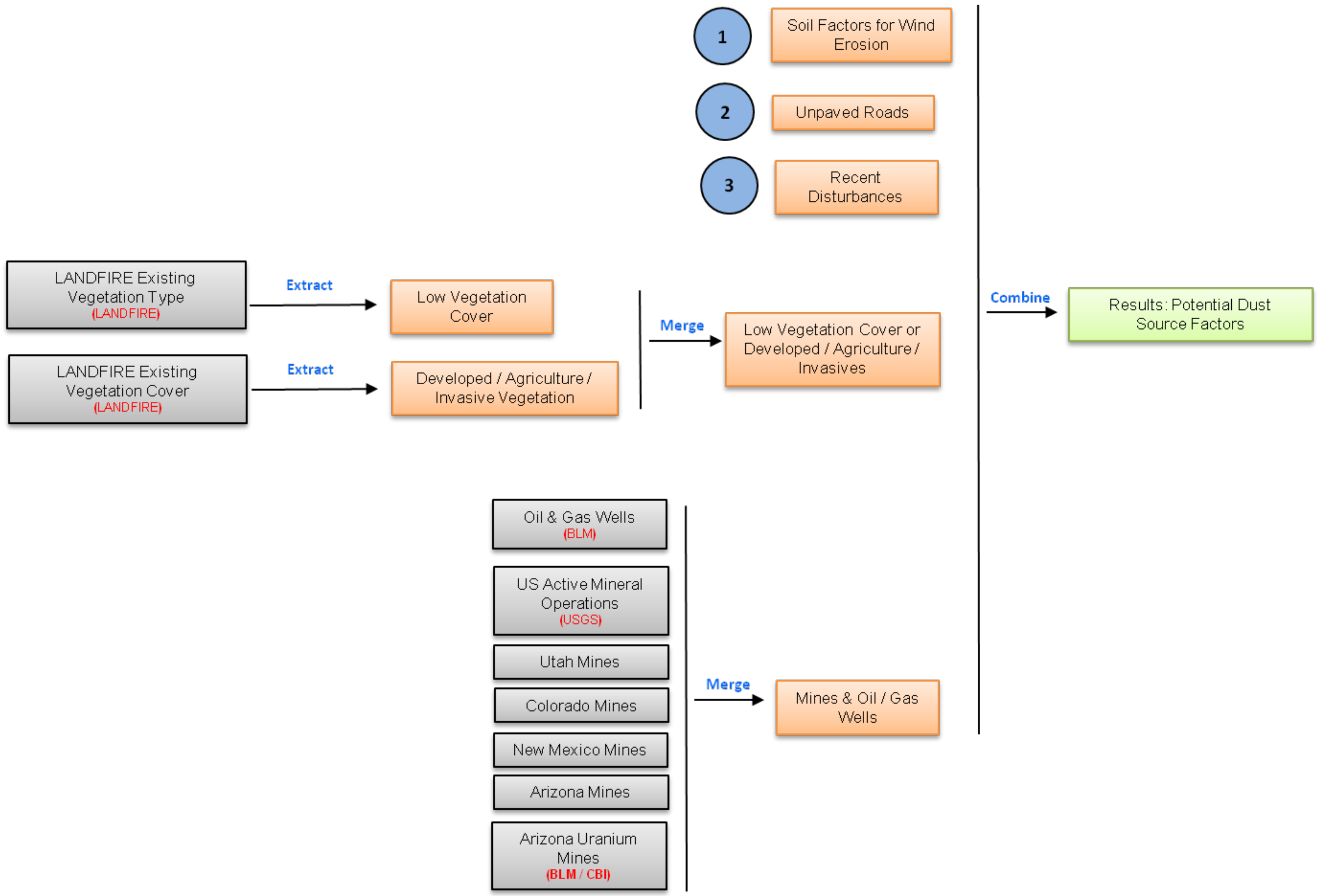


Current (solid color) and Near-term (cross-hatched) Intactness

A. Soils, Biological Crust, and Forage
MQ A6. Where are hotspots producing fugitive dust that may contribute to accelerated snow melt in the Colorado Plateau?

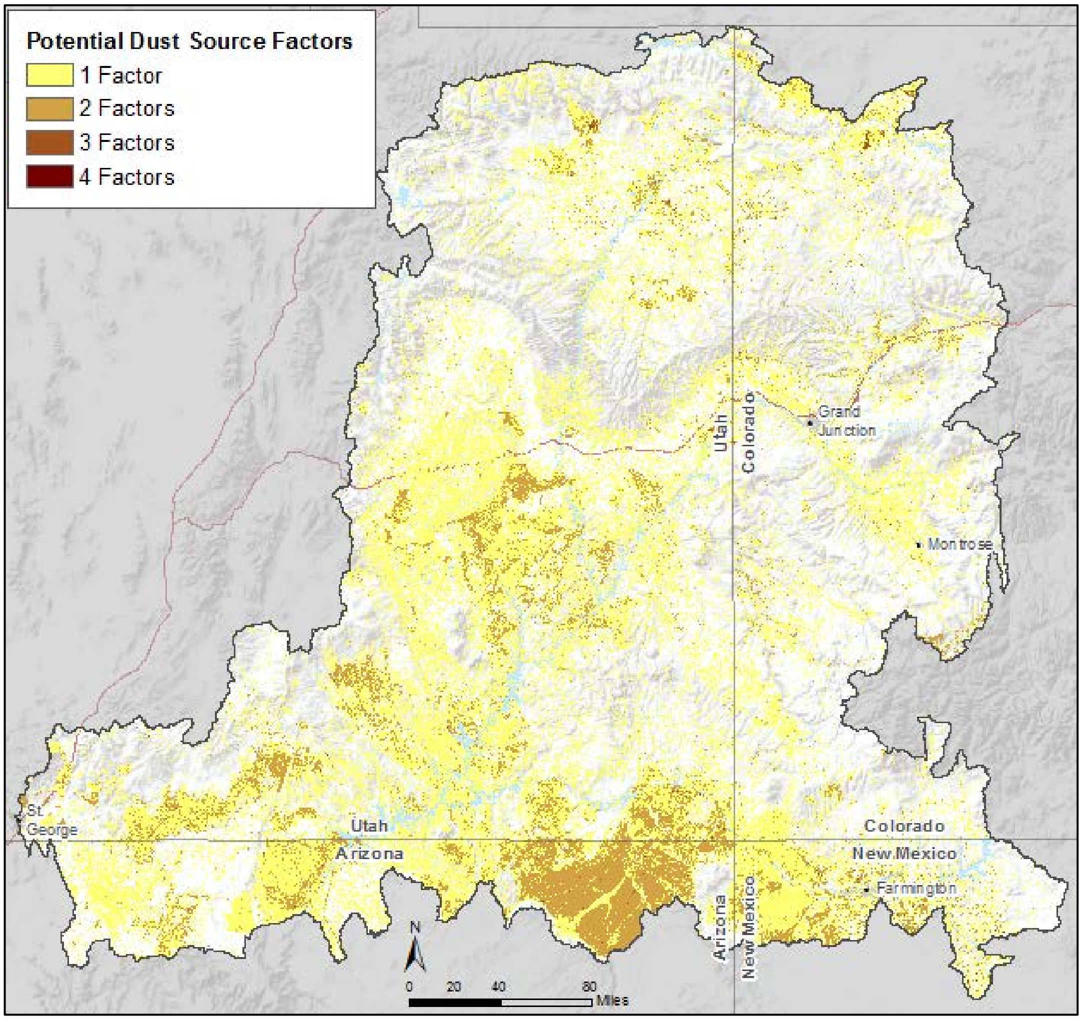
Process Model or Description




1
Soil Factors for Wind Erosion
2
Unpaved Roads
3
Recent Disturbances
LANDFIRE Existing Vegetation Type (LANDFIRE)
Extract
Low Vegetation Cover
LANDFIRE Existing Vegetation Cover (LANDFIRE)
Extract
Developed / Agriculture / Invasive Vegetation
Merge
Low Vegetation Cover or Developed / Agriculture / Invasives
Combine
Results: Potential Dust Source Factors
Oil & Gas Wells (BLM)
US Active Mineral Operations (USGS)
Utah Mines
Colorado Mines
New Mexico Mines
Arizona Mines
Arizona Uranium Mines (BLM / CBI)
Merge
Mines & Oil / Gas Wells

Results

MQ A6. Where are hotspots producing fugitive dust that may contribute to accelerated snow melt in the Colorado Plateau?



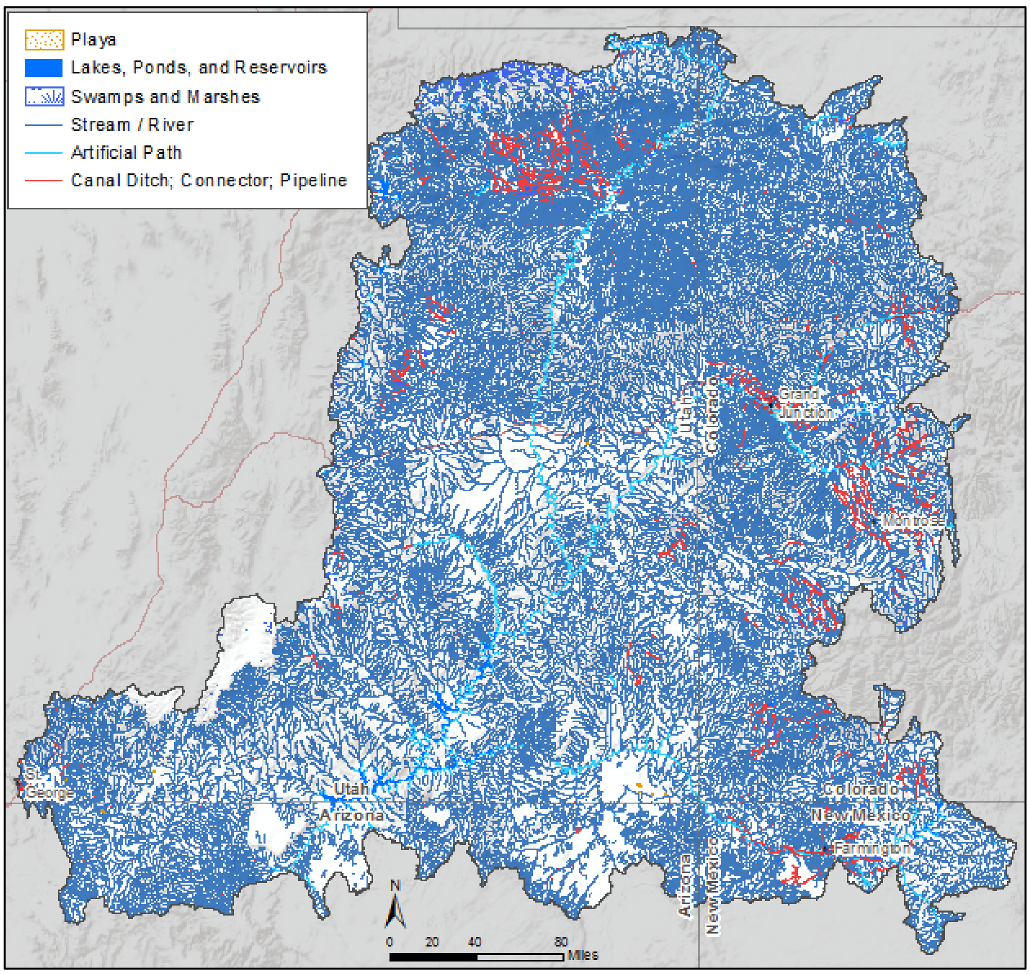
This dataset shows a number of factors that may contribute to dust production at a location. These factors include areas around mines and oil/gas wells, low vegetation cover or invasive annual vegetation, recent disturbances (since 2005), unpaved roads, and soils with high potential for wind erosion. Note that the roads factor should be treated with the least certainty because the dataset used for this analysis does not fully distinguish paved from unpaved roads. The combination of factors at a location may produce a non-linear response with respect to dust production: each factor alone may have varying magnitude depending on location, local wind and topography, and degree of disturbance. Factors may combine such that the net effect is greater than the sum of the factors taken independently

B. Surface and Groundwater
MQ B1. Where are lotic and lentic surface waterbodies and livestock and wildlife watering tanks and artificial water bodies?

Process Model or Description

Features from National Hydrography Dataset (USGS) Flowlines and Water Bodies datasets extracted. **Flowlines represent ephemeral, intermittent, and perennial stream channels.**

Results

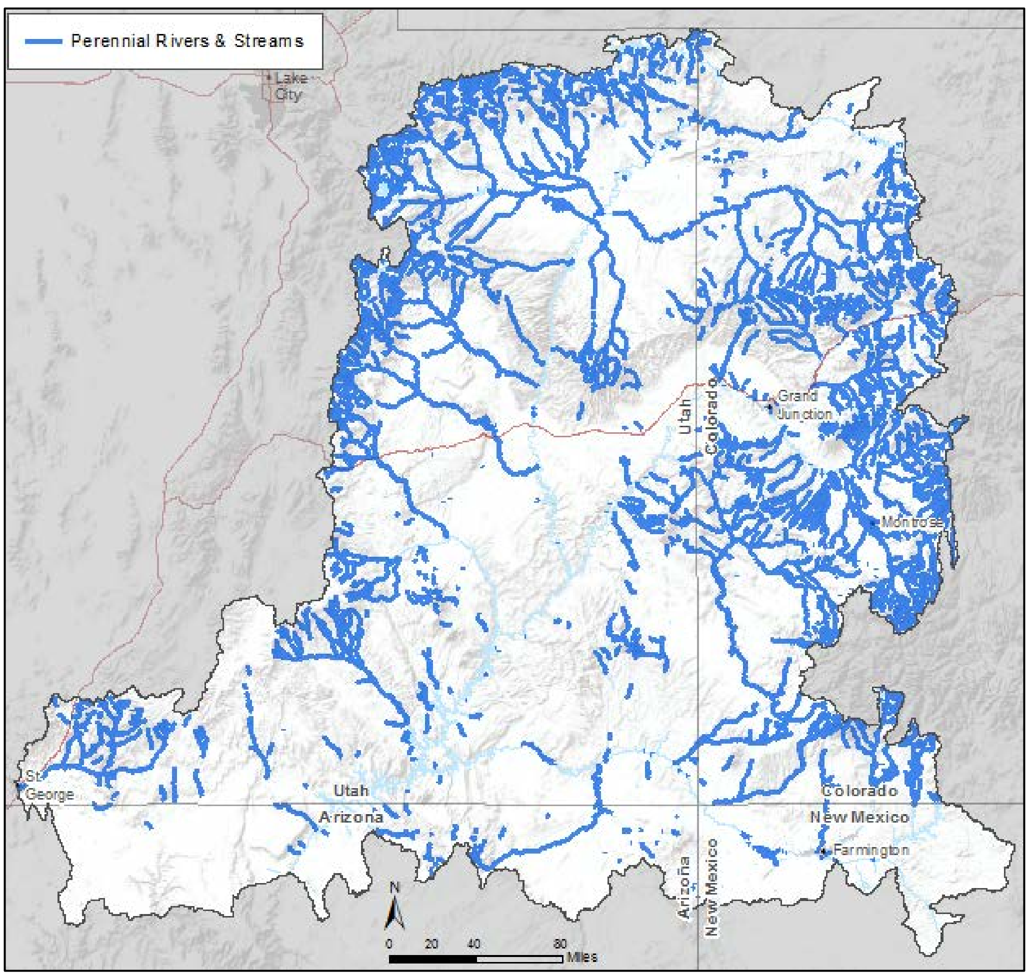


B. Surface and Groundwater
MQ B2. Where are perennial streams and stream reaches?

Process Model or Description

Features marked as perennial streams from National Hydrography Dataset (USGS) Flowlines (note: many features that may in fact be perennial were not marked as such, due to use of other labels, e.g., Artificial Path)

Results



B. Surface and Groundwater
MQ B3. What are seasonal discharge maxima and minima for the Colorado River and major tributaries at gaging stations?

Process Description

For each gaging station, daily summary statistics were obtained from USGS for the period of record of the station up to 9/30/2010. Daily statistics were partitioned into seasons and minimums and maximums calculated for each season.

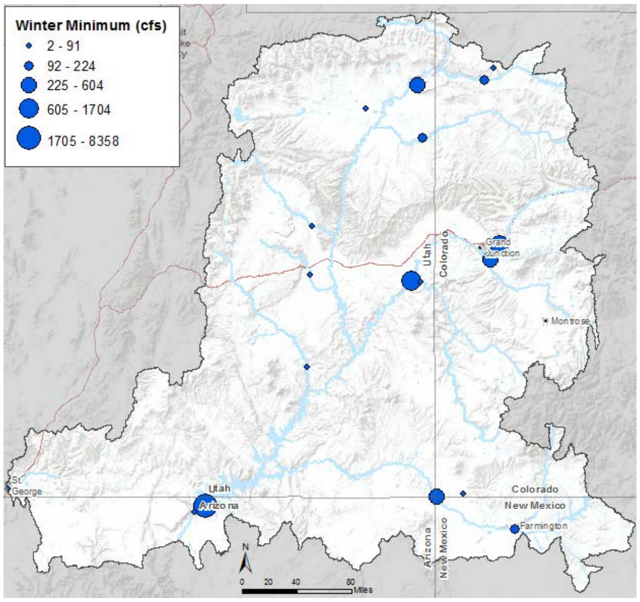
Table 4.2. Average seasonal maxima and minima for gaging stations on the Colorado River and major tributaries recording 7–102 years of records from various stations through 9-30-2010 (Source weblink: http://waterdata.usgs.gov/nwis. Figures in cubic feet/second (cfs) rounded to the nearest cfs.

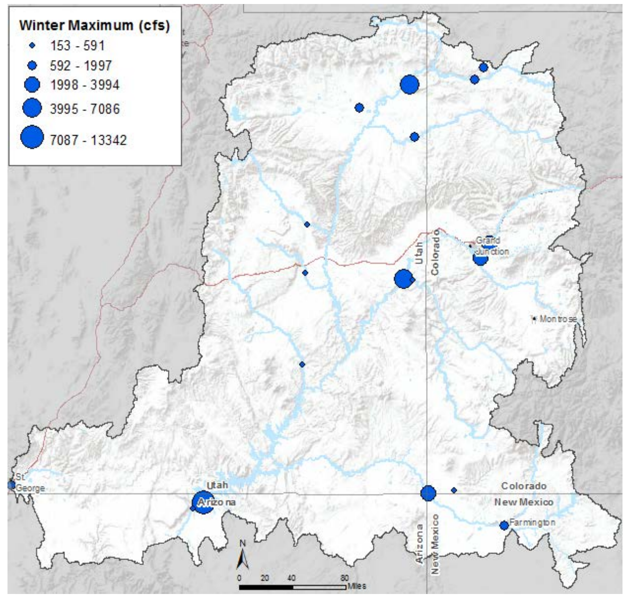
Gaging Station Location	SPMN	SPMX	SUMN	SUMX	FMN	FMX	WMN	WMX
GREEN RIVER NEAR JENSEN, UT	2481	23991	559	11378	430	5089	604	6220
YAMPA RIVER AT DEERLODGE PARK, CO.	1670	15381	56	4485	161	1392	224	1643
DUCHESNE RIVER NEAR RANDLETT, UT	19	4570	7	2930	31	1560	47	1264
WHITE RIVER NEAR WATSON, UTAH	301	3581	79	2886	207	1135	190	1280
PRICE RIVER AT WOODSIDE, UT	8	1646	1	1299	11	731	13	271
COLO RIVER NR PALISADE CO	945	13246	161	9551	839	2621	1130	2500
SAN RAFAEL RIVER NEAR GREEN RIVER, UT	4	1768	0	1391	3	885	11	449
GUNNISON RIVER GRAND JUNCTION, CO.	541	18088	174	9474	361	3671	498	3859
COLORADO RIVER NEAR CISCO, UT	2041	43002	991	25958	1565	9093	1704	7086
DOLORES RIVER NEAR CISCO, UT	110	6132	16	1617	94	895	91	591
DIRTY DEVIL R NR HANKSVILLE, UT	9	562	0	1218	21	1434	36	342
VIRGIN RIVER NEAR BLOOMINGTON, UT	25	1938	10	644	42	722	56	1997
PARIA RIVER AT LEES FERRY, AZ	3	165	2	939	5	502	6	354
SAN JUAN RIVER AT FOUR CORNERS, CO	536	9613	283	6978	518	3853	537	3994
MANCOS RIVER NEAR TOWAOC, CO.	0	700	0	465	0	264	2	153
ANIMAS RIVER AT FARMINGTON, NM	124	5806	8	4292	108	2042	142	861

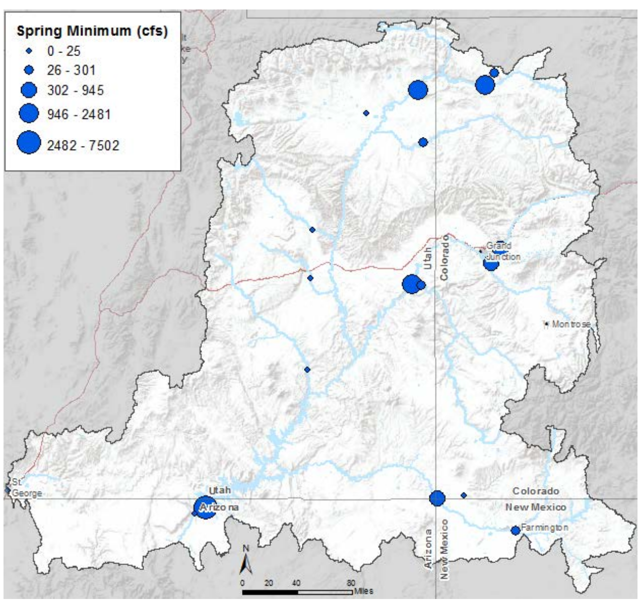
SPMN=spring minimum; SPMX=spring maximum; SUMN=summer minimum; SUMX=summer maximum; FMN=fall minimum; FMX=fall maximum; WMN=winter minimum; WMX=winter maximum.

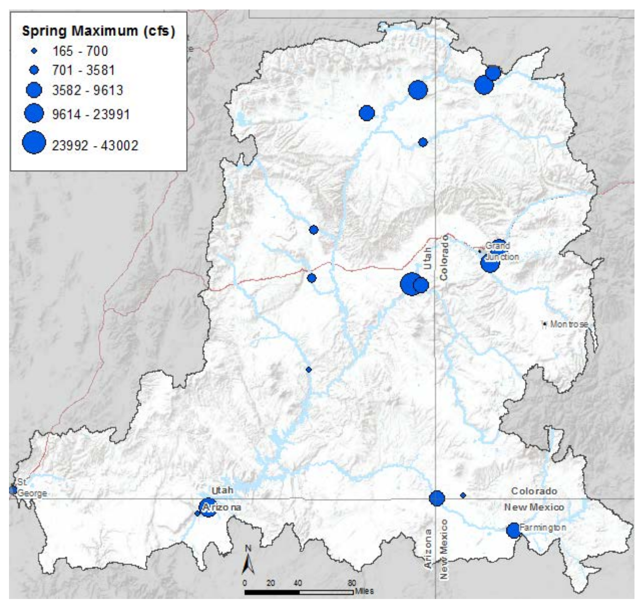
MQ B3. What are seasonal discharge maxima and minima for the Colorado River and major tributaries at gaging stations?

Results for Seasonal Max/Min at Various Gaging Stations: Winter/Spring



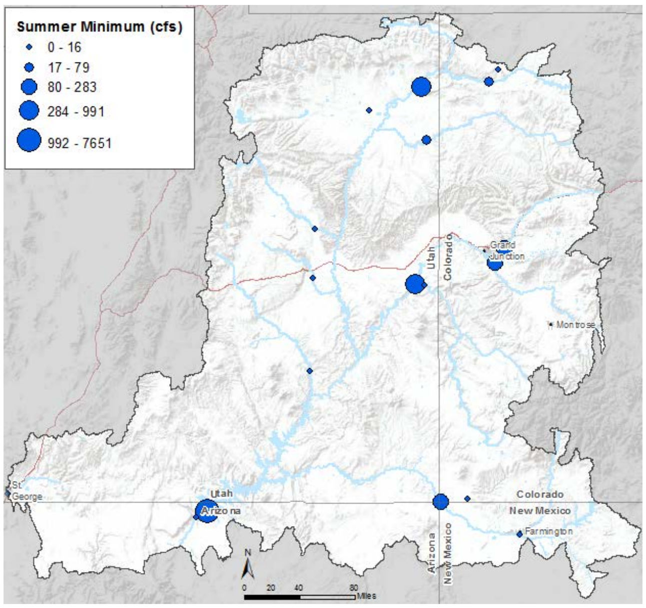


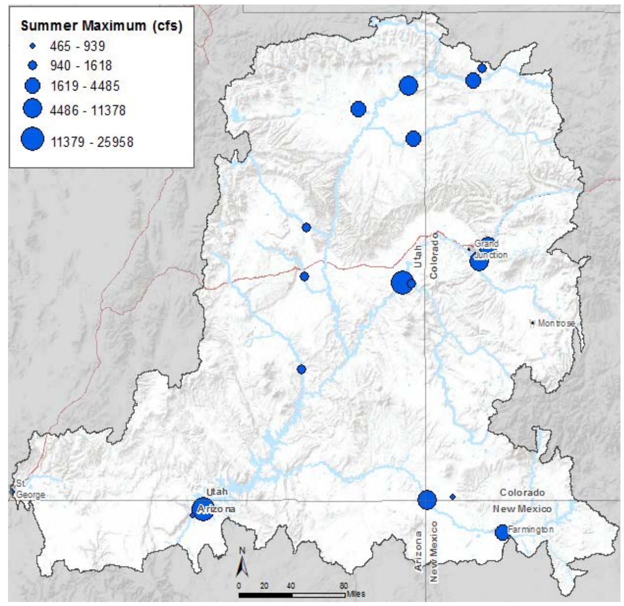


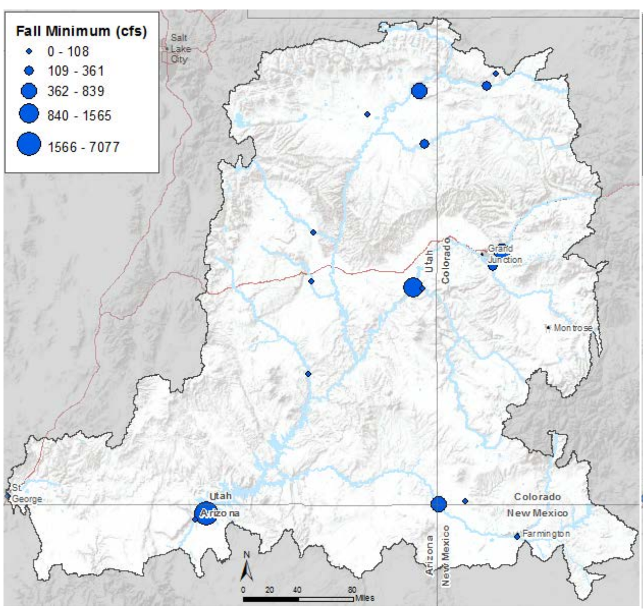


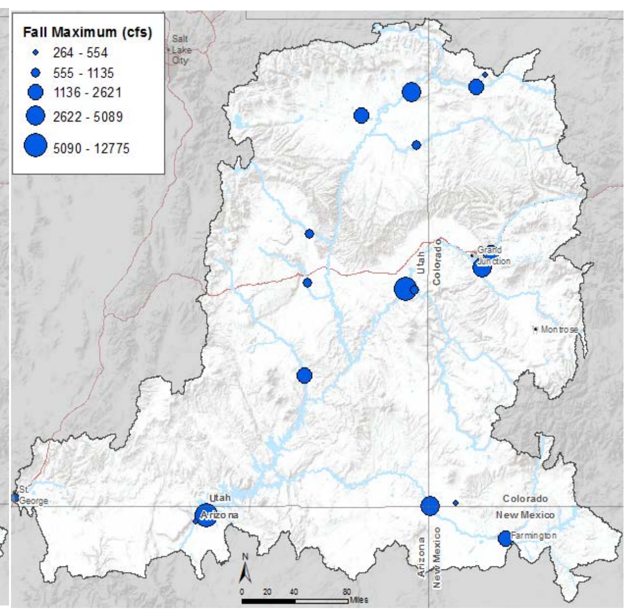
MQ B3. What are seasonal discharge maxima and minima for the Colorado River and major tributaries at gaging stations?

Results for Seasonal Max/Min at Various Gaging Stations: Summer/Fall







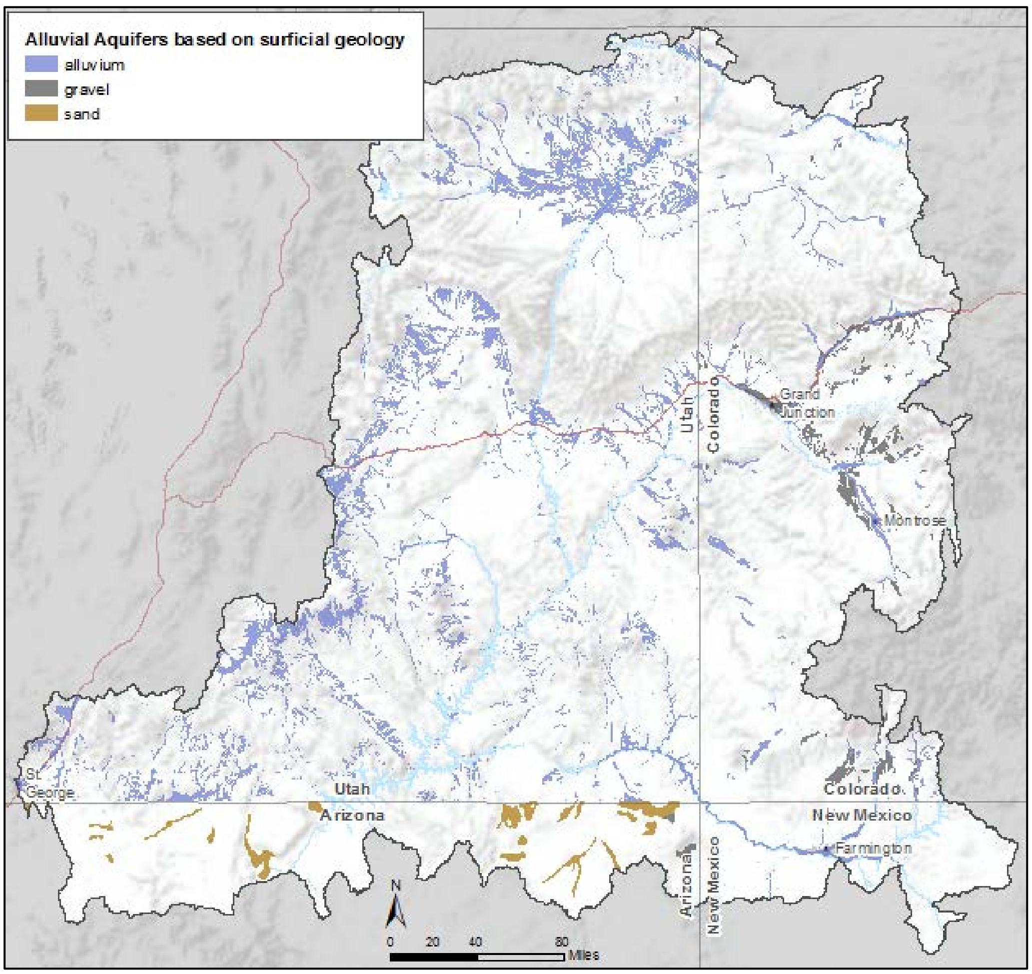


B. Surface and Groundwater
MQ B4. Where are the alluvial aquifers and their recharge areas (if known)?

Process Model or Description

Alluvium, sand, and gravel types were selected from composite state geology dataset.

Results for Alluvial Aquifers

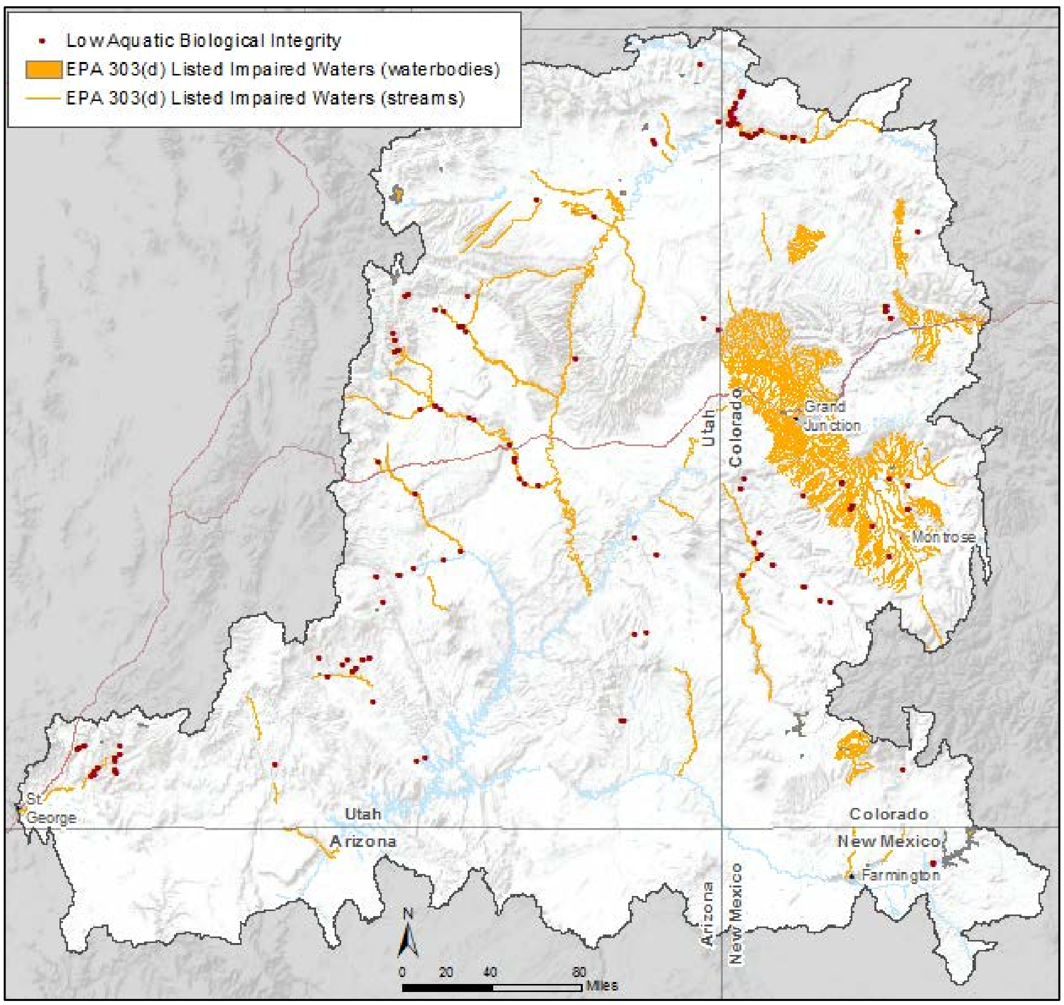


B. Surface and Groundwater
MQ B6. Where are the aquatic systems listed in 303(d) with degraded water quality or low macroinvertebrate diversity?

Process Model or Description

Features were identified in Environmental Protection Agency (EPA) 303(d) datasets. Explanation of 303(d) below from EPA website http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/overview.cfm:
The term "303(d) list" refers to the list of impaired and threatened waters (stream and river segments, lakes) that the Clean Water Act requires all states to submit for EPA approval every two years on even-numbered years. The states identify all waters where required pollution controls are not sufficient to attain or maintain applicable water quality standards, and establish priorities for development of Total Maximum Daily Loads (TMDLs) based on the severity of the pollution and the sensitivity of the uses to be made of the waters, among other factors. States then provide a long-term plan for completing TMDLs within 8 to 13 years from first listing.

Results for 303(d) waters and Sites with Low Macroinvertebrate Scores



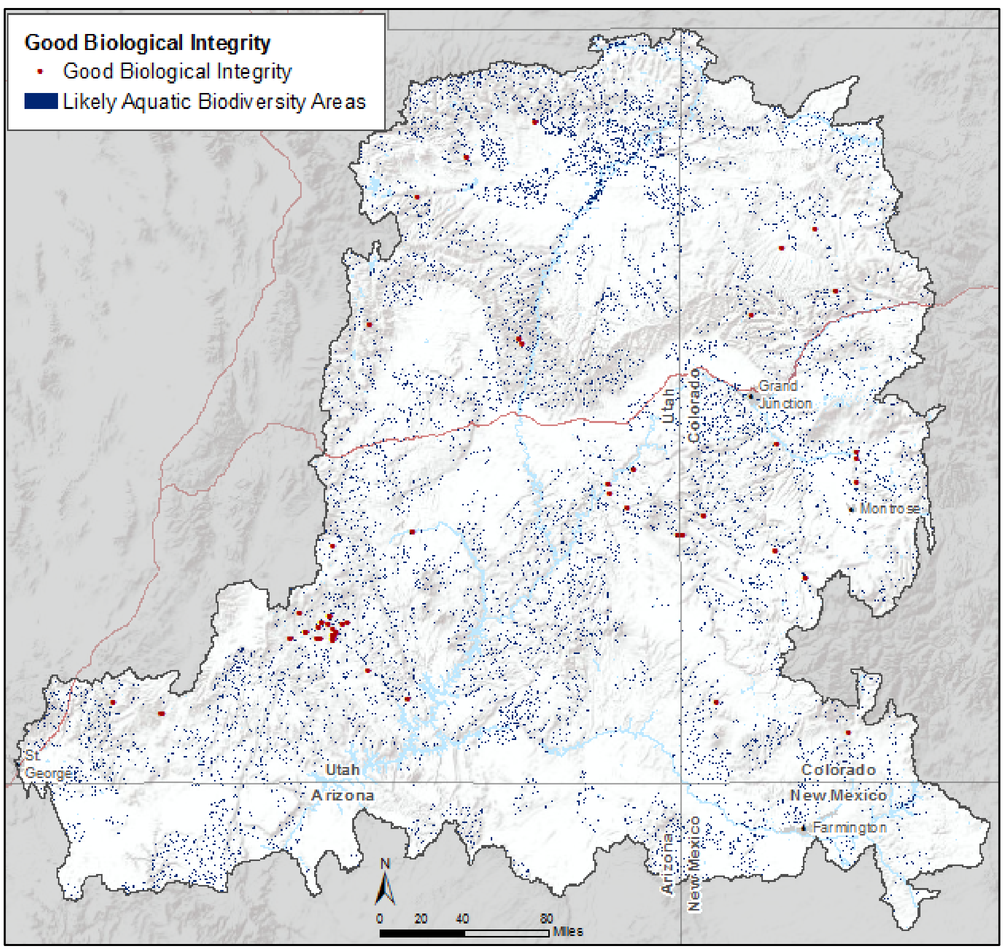
B. Surface and Groundwater
MQ B7. What is the location/distribution of these aquatic biodiversity sites?

Process Model or Description

40 meter buffers were selected around NHD flowlines, wetlands, and deep water habitats (USFWS) that fell within Nature Conservancy (TNC) Conservation Portfolio areas or Special Designations.

Biological integrity was assessed using an observed/expected (O/E) index. O/E models compare the macroinvertebrate taxa observed at sites of unknown biological condition (i.e., 'test sites') to the assemblages expected to be found in the absence of anthropogenic stressors. Test sites scoring less than one SD below the mean of reference sites (mean OE =1.01, standard deviation = 0.17) are considered in "Good" biological condition. Sites scoring more than two SD below the mean of reference sites are considered in "Poor" biological condition (see previous map for MQ B6).

Results for Aquatic Biodiversity Areas and Sites with High Macroinvertebrate Scores



C. Ecological Systems Conservation Elements
Colorado Plateau Pinyon-Juniper Woodland – go to Appendix B
MQ C1. Where is existing Colorado Plateau Pinyon-Juniper Woodland and what is its status?
MQ C2. Where are vegetative communities vulnerable to change agents in the future?
MQ C3. What change agents have affected existing vegetative communities?
Colorado Plateau Pinyon-Juniper Shrubland - go to Appendix B
MQ C1. Where is existing Colorado Plateau Pinyon-Juniper Shrubland and what is its status?
MQ C2. Where are vegetative communities vulnerable to change agents in the future?
MQ C3. What change agents have affected existing vegetative communities?
Inter-Mountain Basins Big Sagebrush Shrubland - go to Appendix B
MQ C1. Where is existing Inter-mountain Basins Big Sagebrush Shrubland and what is its status?
MQ C2. Where are vegetative communities vulnerable to change agents in the future?
MQ C3. What change agents have affected existing vegetative communities?
Inter-Mountain Basins Montane Sagebrush Steppe - go to Appendix B
MQ C1. Where is existing Inter-Mountain Basins Montane Sagebrush Steppe and what is its status?
MQ C2. Where are vegetative communities vulnerable to change agents in the future?
MQ C3. What change agents have affected existing vegetative communities?
Rocky Mountain Gambel Oak-Mixed Montane Shrubland - go to Appendix B
MQ C1. Where is existing Rocky Mt. Gambel Oak-Mixed Montane Shrubland and what is its status?
MQ C2. Where are vegetative communities vulnerable to change agents in the future?
MQ C3. What change agents have affected existing vegetative communities?
Colorado Plateau Blackbrush-Mormon Tea Shrubland - go to Appendix B
MQ C1. Where is existing Colorado Plateau Blackbrush-Mormon Tea Shrubland and what's its status?
MQ C2. Where are vegetative communities vulnerable to change agents in the future?
MQ C3. What change agents have affected existing vegetative communities?
Inter-Mountain Basins Mixed Salt Desert Scrub - go to Appendix B
MQ C1. Where is existing Inter-mountain Basins Mixed Salt Desert Scrub and what is its status?
MQ C2. Where are vegetative communities vulnerable to change agents in the future?
MQ C3. What change agents have affected existing vegetative communities?
Colorado Plateau Mixed Bedrock Canyon and Tablelands - go to Appendix B
MQ C1. Where is Colorado Plateau Mixed Bedrock Canyon and Tablelands and what is its status?
MQ C2. Where are vegetative communities vulnerable to change agents in the future?
MQ C3. What change agents have affected existing vegetative communities?
Riparian Vegetation - go to Appendix B
MQ C1. Where is existing Riparian Vegetation and what is its status?
MQ C2. Where are vegetative communities vulnerable to change agents in the future?
MQ C3. What change agents have affected existing vegetative communities?

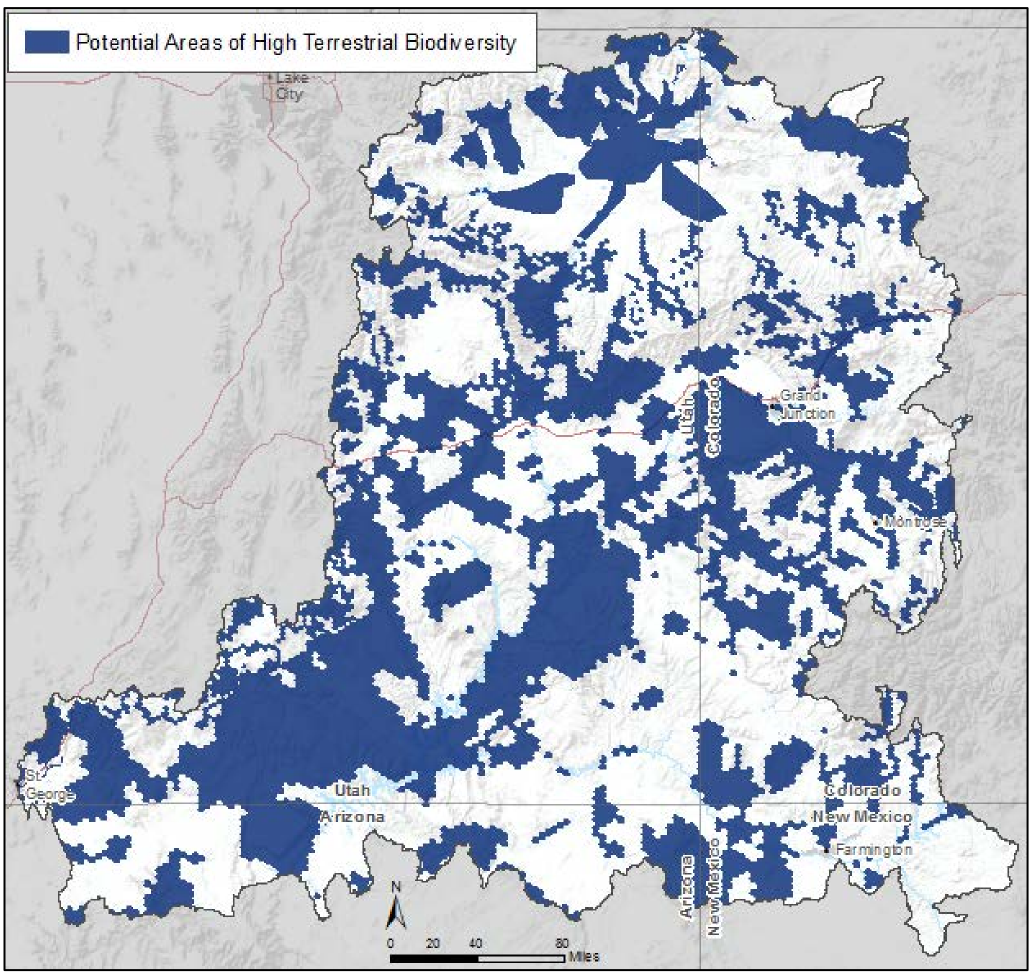
D. Species Conservation Elements
MQ D5. What is the location/distribution of terrestrial biodiversity sites and designated sites?

Process Model or Description

Terrestrial Biodiversity Sites are defined by TNC Terrestrial Conservation Portfolio areas plus Special Designations: combined CBI Protected Areas Database GAP 1 & 2, roadless areas (USFS), and conservation easements (NCED) with recent versions of wilderness areas and areas of critical environmental concern (BLM). Map also shows national historic and scenic trails, and wild and scenic rivers.

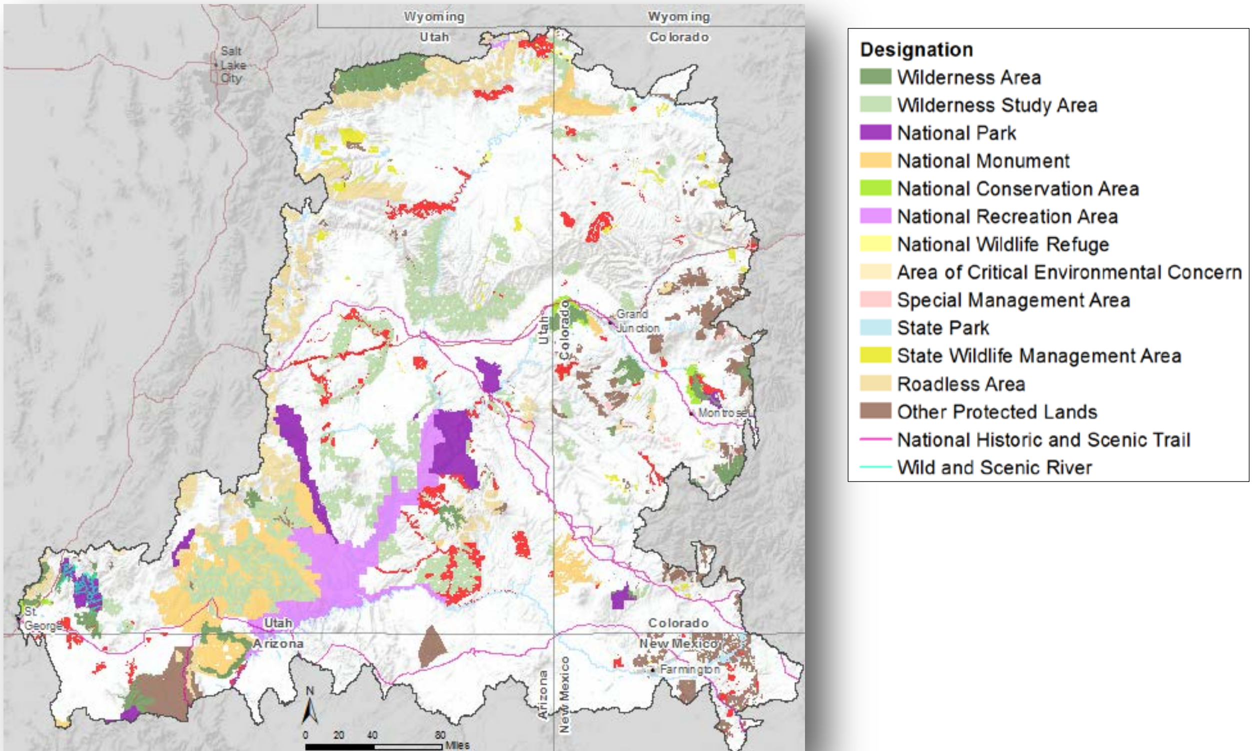
Results

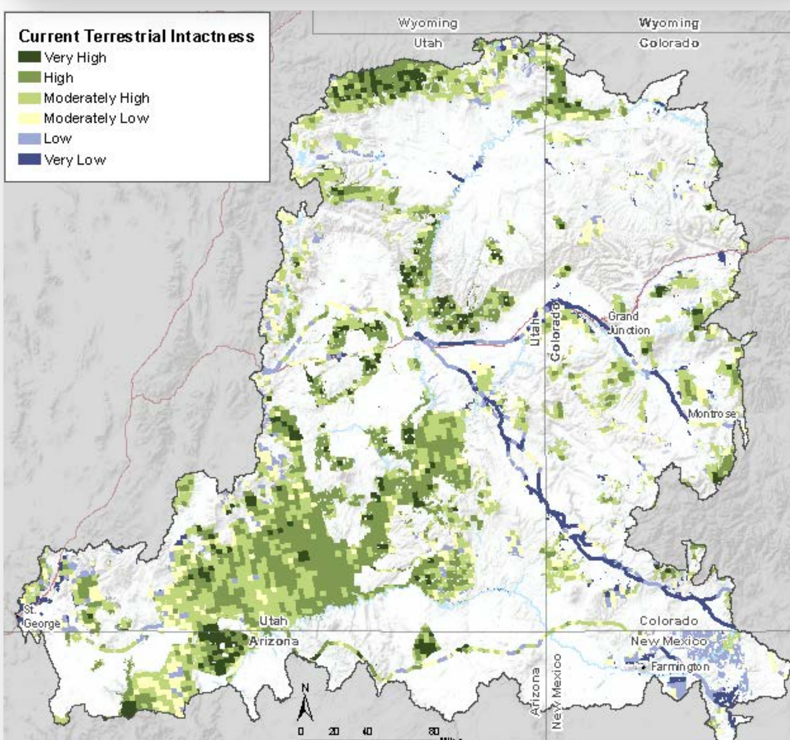
MQ D5. What is the location/distribution of terrestrial biodiversity sites?

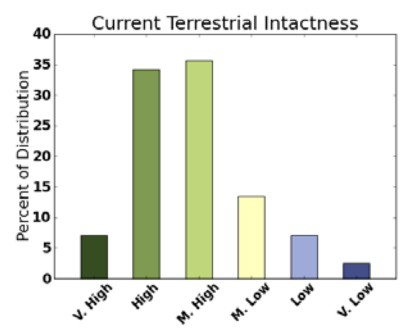


MQ D5. What is the location/distribution of designated sites?

Map of Designated Sites Distribution (Top) and Status of Designated Sites (Bottom)





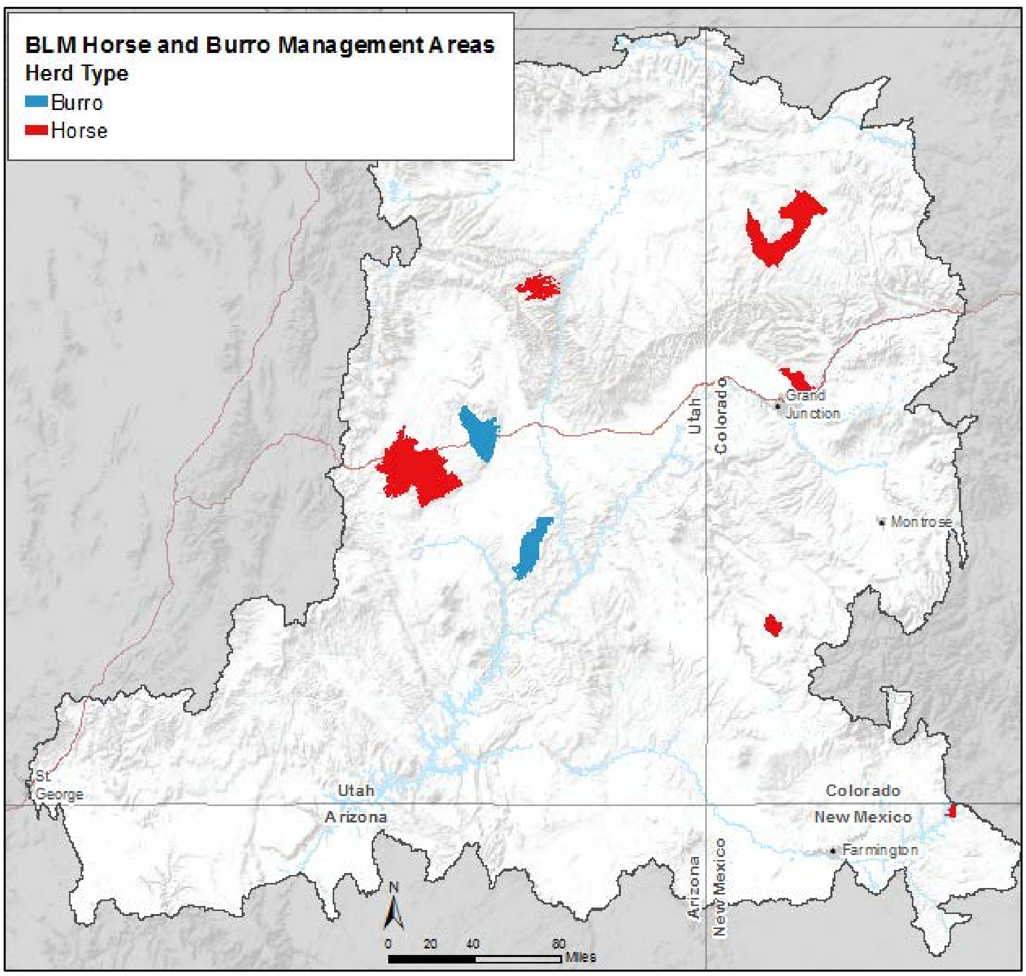


D. Species Conservation Elements
MQ D7. Where are HMAs located?

Process Model or Description

Data on BLM Wild Horse and Burro Herd Management Areas (HMAs) obtained from BLM.

Results for Wild Horse and Burro Herd Management Areas

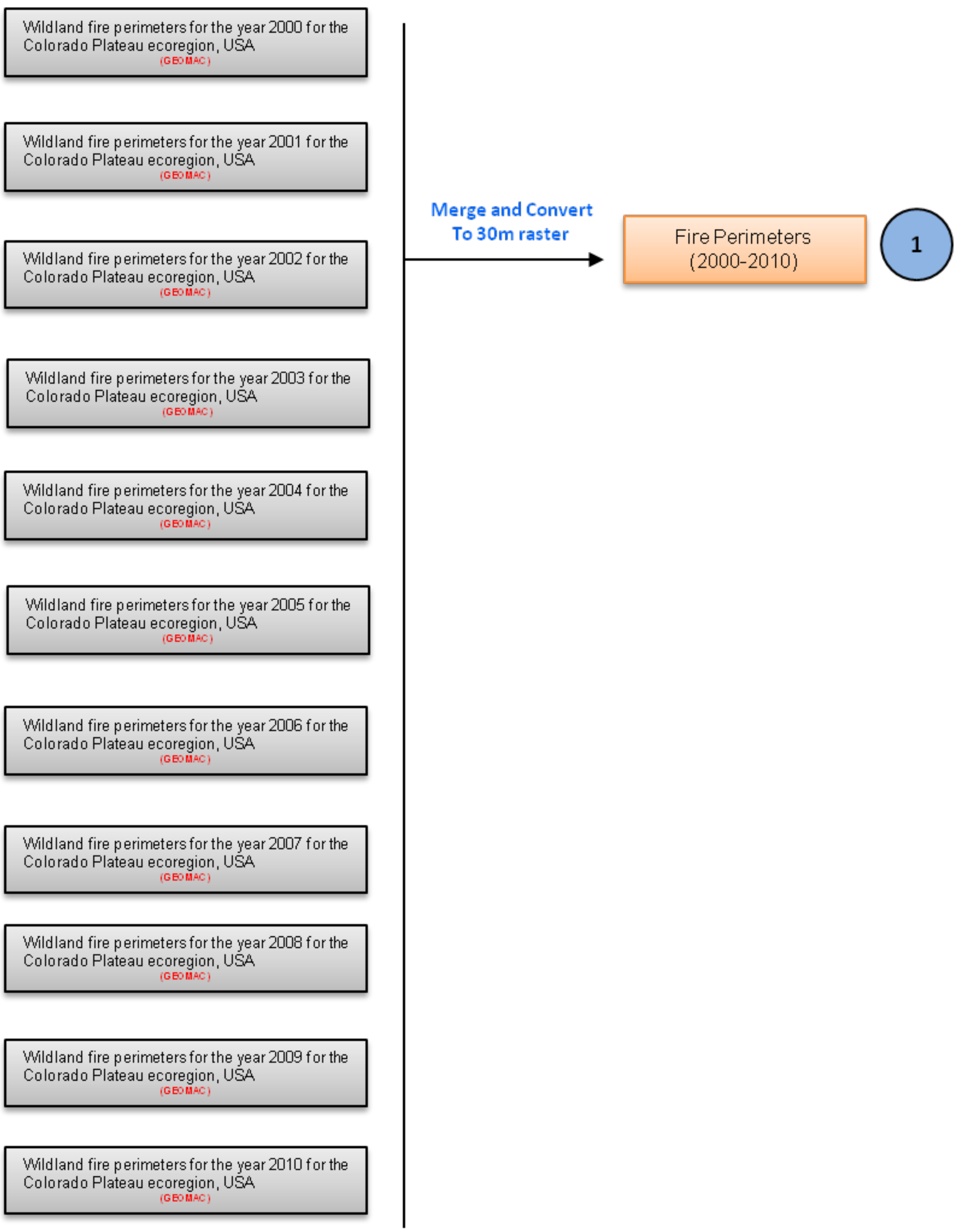


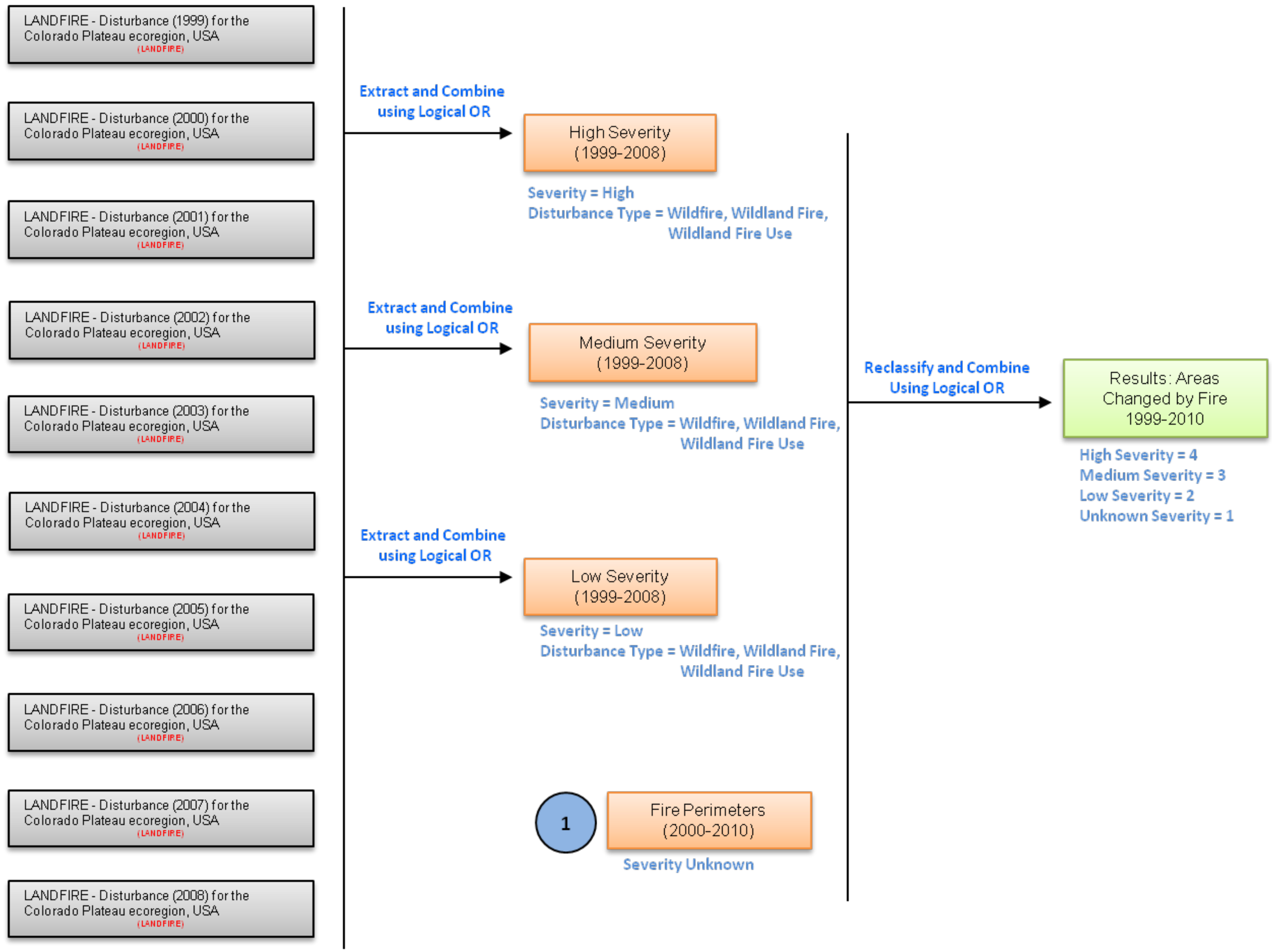
D. Species Conservation Elements – Management Questions
MQ D1. What is the most current distribution and status of available occupied habitat (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?
D. Wildlife Species Conservation Elements – Mammals: Go to Appendix C
Black-footed Ferret
Desert Bighorn Sheep
Gunnison's Prairie Dog
Mountain Lion
Mule Deer
Pronghorn Antelope
White-tailed Prairie Dog
D. Wildlife Species Conservation Elements – Birds: Go to Appendix C
American Peregrine Falcon
Burrowing Owl
Ferruginous Hawk
Golden Eagle
Greater Sage Grouse
Gunnison Sage Grouse
Mexican Spotted Owl
Yellow-breasted Chat
D. Wildlife Species Conservation Elements – Fishes: Go to Appendix C
Colorado Cutthroat Trout
Flannelmouth Sucker
Razorback Sucker

E. Wildfire
MQ E1. Where are areas that have been changed by wildfire between 1999 and 2009?

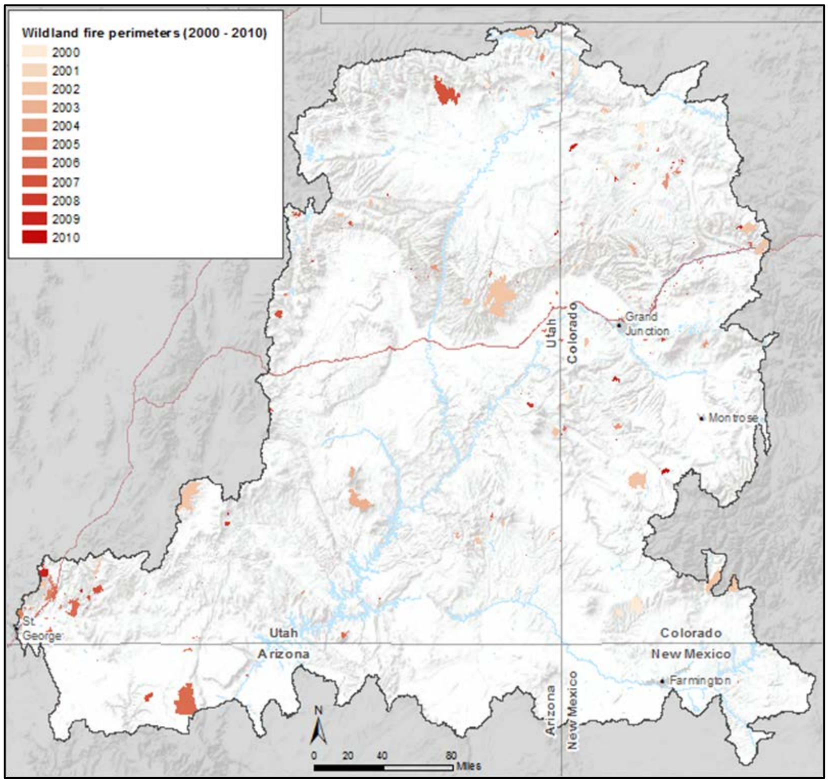
Process Model or Description

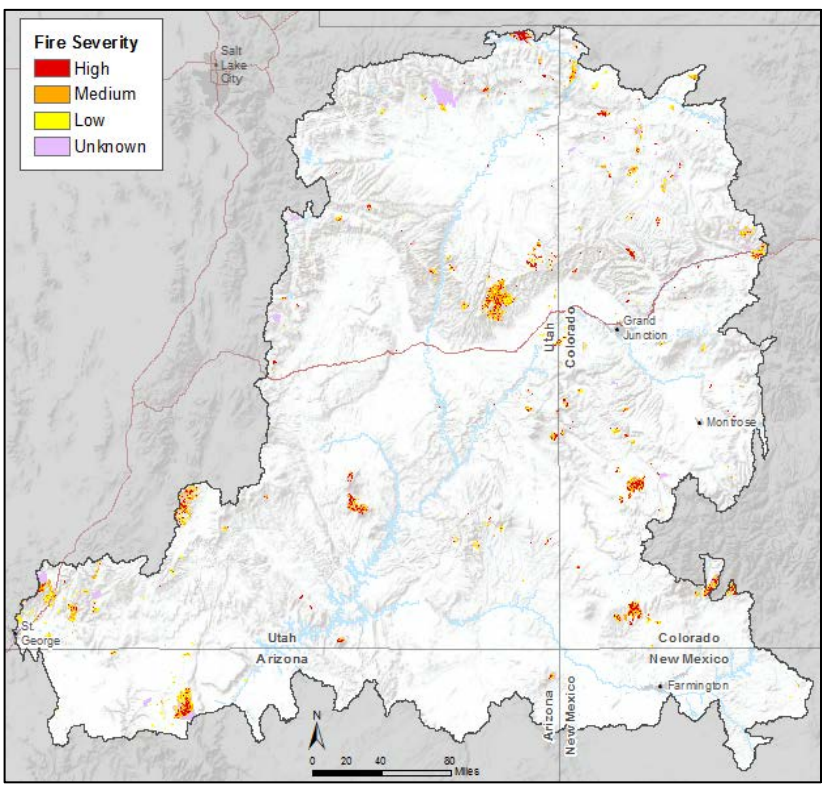
Merged fire perimeters from USGS for 2000-2010 with fire severity data obtained from LANDFIRE Disturbance datasets (1999-2008).




LANDFIRE - Disturbance (1999) for the Colorado Plateau ecoregion, USA
(LANDFIRE)
LANDFIRE - Disturbance (2000) for the Colorado Plateau ecoregion, USA
(LANDFIRE)
LANDFIRE - Disturbance (2001) for the Colorado Plateau ecoregion, USA
(LANDFIRE)
LANDFIRE - Disturbance (2002) for the Colorado Plateau ecoregion, USA
(LANDFIRE)
LANDFIRE - Disturbance (2003) for the Colorado Plateau ecoregion, USA
(LANDFIRE)
LANDFIRE - Disturbance (2004) for the Colorado Plateau ecoregion, USA
(LANDFIRE)
LANDFIRE - Disturbance (2005) for the Colorado Plateau ecoregion, USA
(LANDFIRE)
LANDFIRE - Disturbance (2006) for the Colorado Plateau ecoregion, USA
(LANDFIRE)
LANDFIRE - Disturbance (2007) for the Colorado Plateau ecoregion, USA
(LANDFIRE)
LANDFIRE - Disturbance (2008) for the Colorado Plateau ecoregion, USA
(LANDFIRE)
Extract and Combine using Logical OR
High Severity (1999-2008)
Severity = High
Disturbance Type = Wildfire, Wildland Fire, Wildland Fire Use
Extract and Combine using Logical OR
Medium Severity (1999-2008)
Severity = Medium
Disturbance Type = Wildfire, Wildland Fire, Wildland Fire Use
Extract and Combine using Logical OR
Low Severity (1999-2008)
Severity = Low
Disturbance Type = Wildfire, Wildland Fire, Wildland Fire Use
1
Fire Perimeters (2000-2010)
Severity Unknown
Reclassify and Combine Using Logical OR
Results: Areas Changed by Fire 1999-2010
High Severity = 4
Medium Severity = 3
Low Severity = 2
Unknown Severity = 1

Results for Wildfires 1999–2009



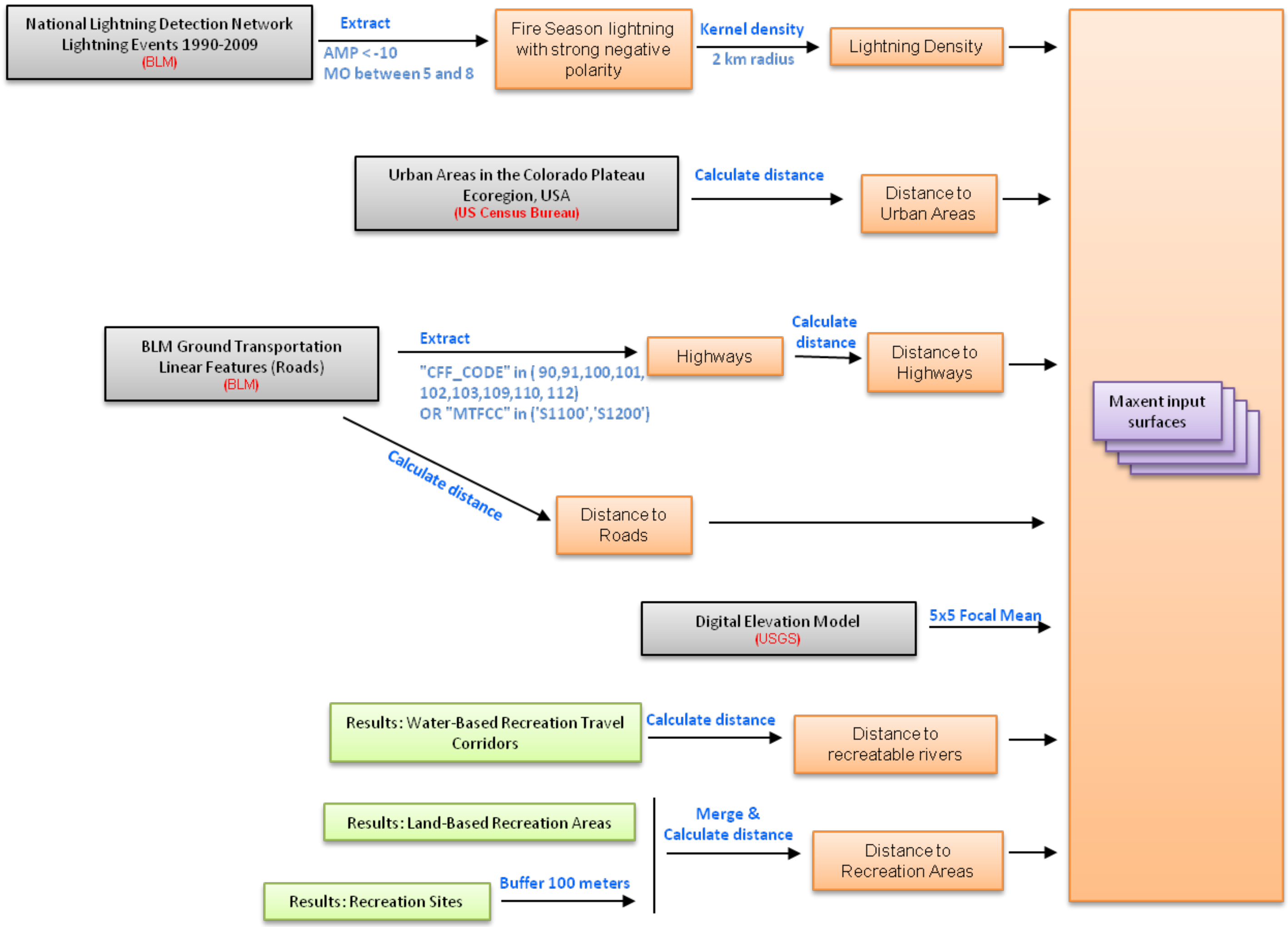


E. Wildfire
MQ E2. Where are areas with potential to change from wildfire?

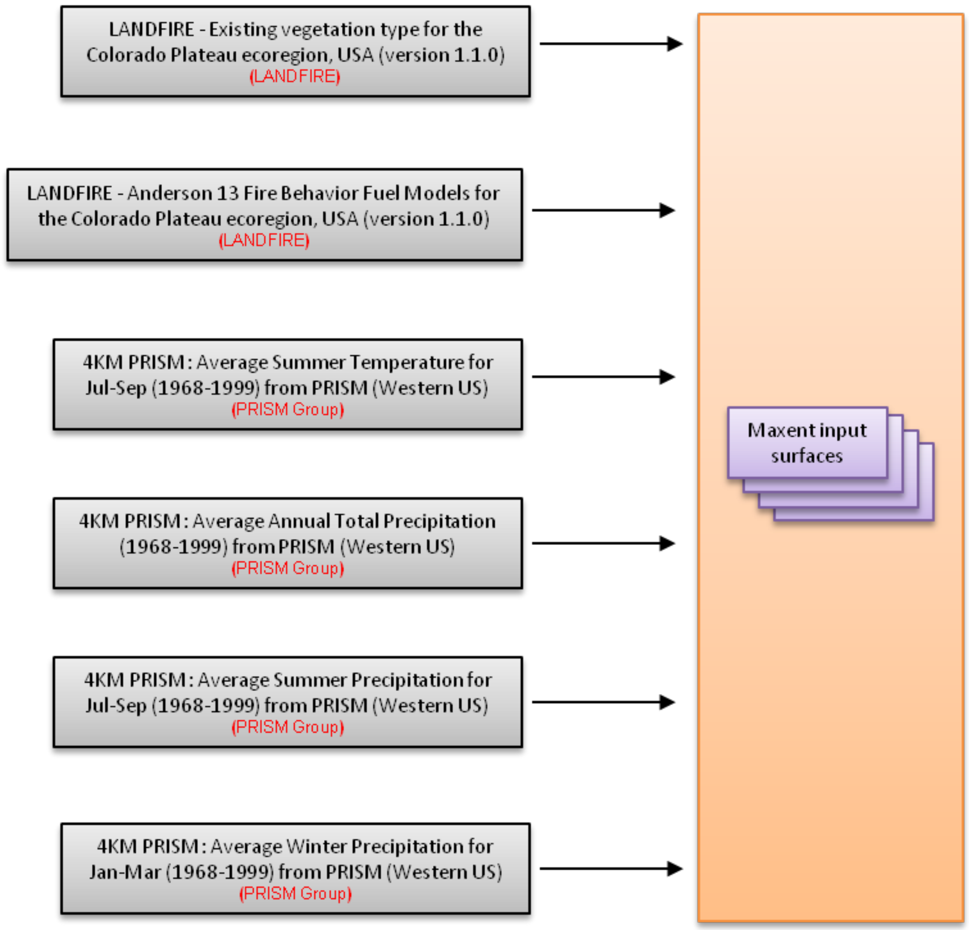
Process Model or Description

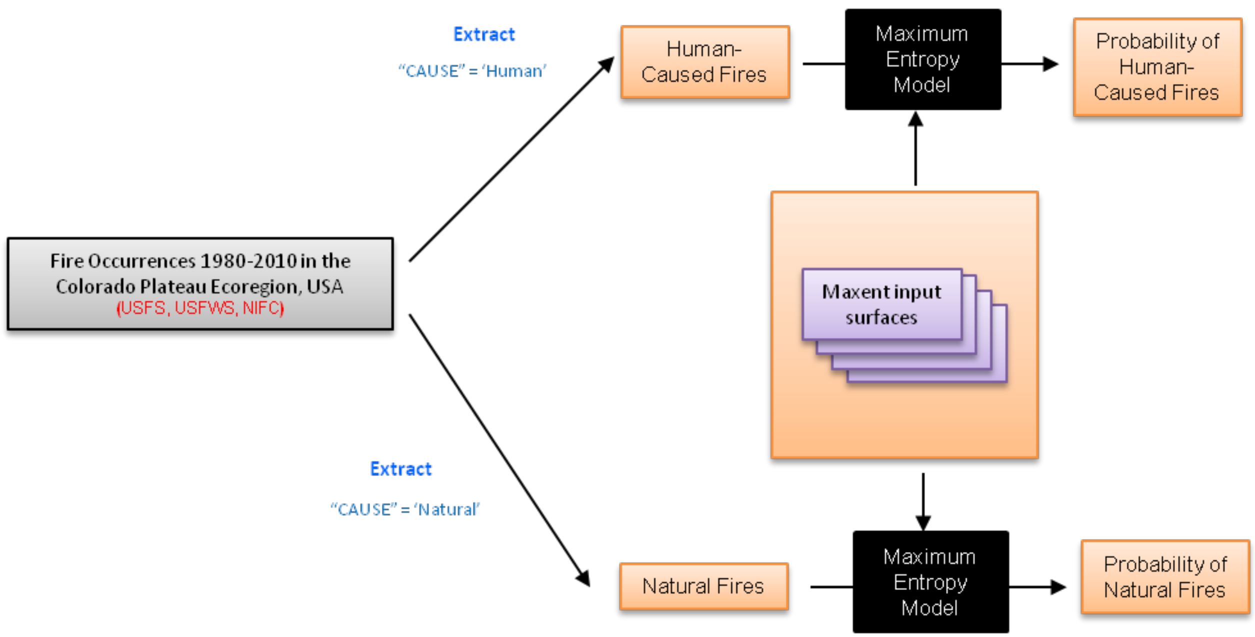
See process model for development of MaxEnt model based on current climate (PRISM) and landscape factors. Projected near-term (2015–2030) and long-term (2045–2060) results using this same model with near-term and long-term climate parameters obtained from RegCM3 regional climate model based on ECHAM5 boundary conditions. Other landscape factors were not changed for future projections. Calculated difference between near-term and long-term areas of high potential for fire occurrence compared to current areas of high potential.

Input Surface Creation

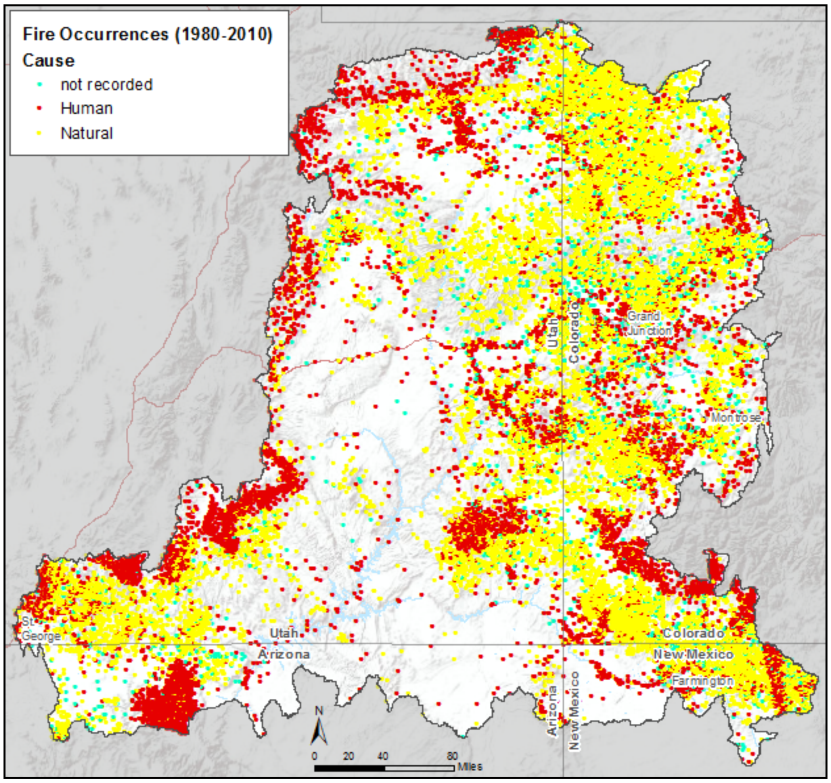


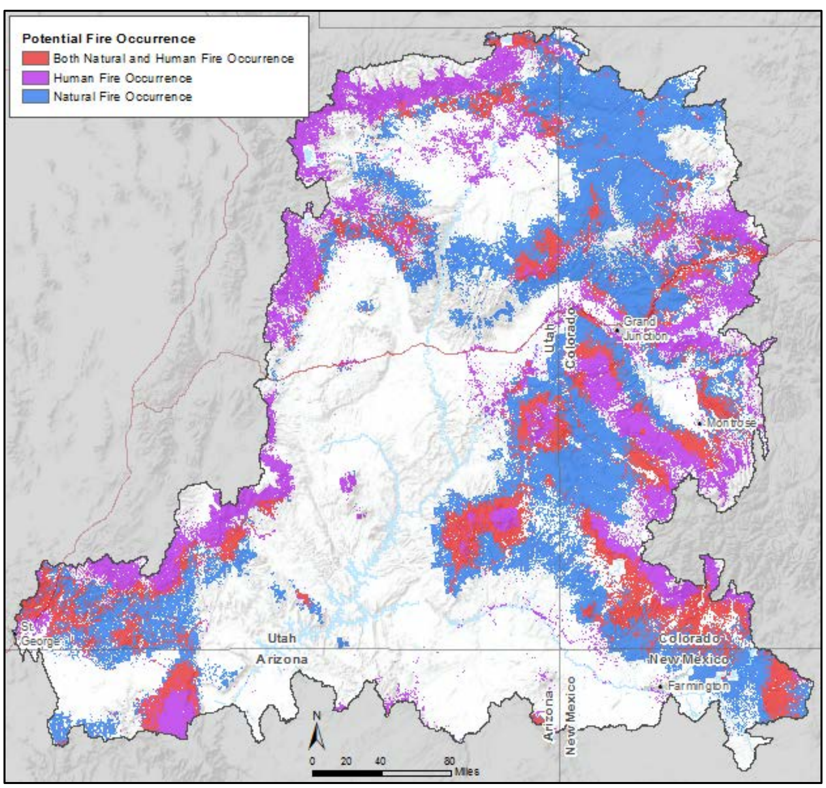
Input Surface Creation (continued)

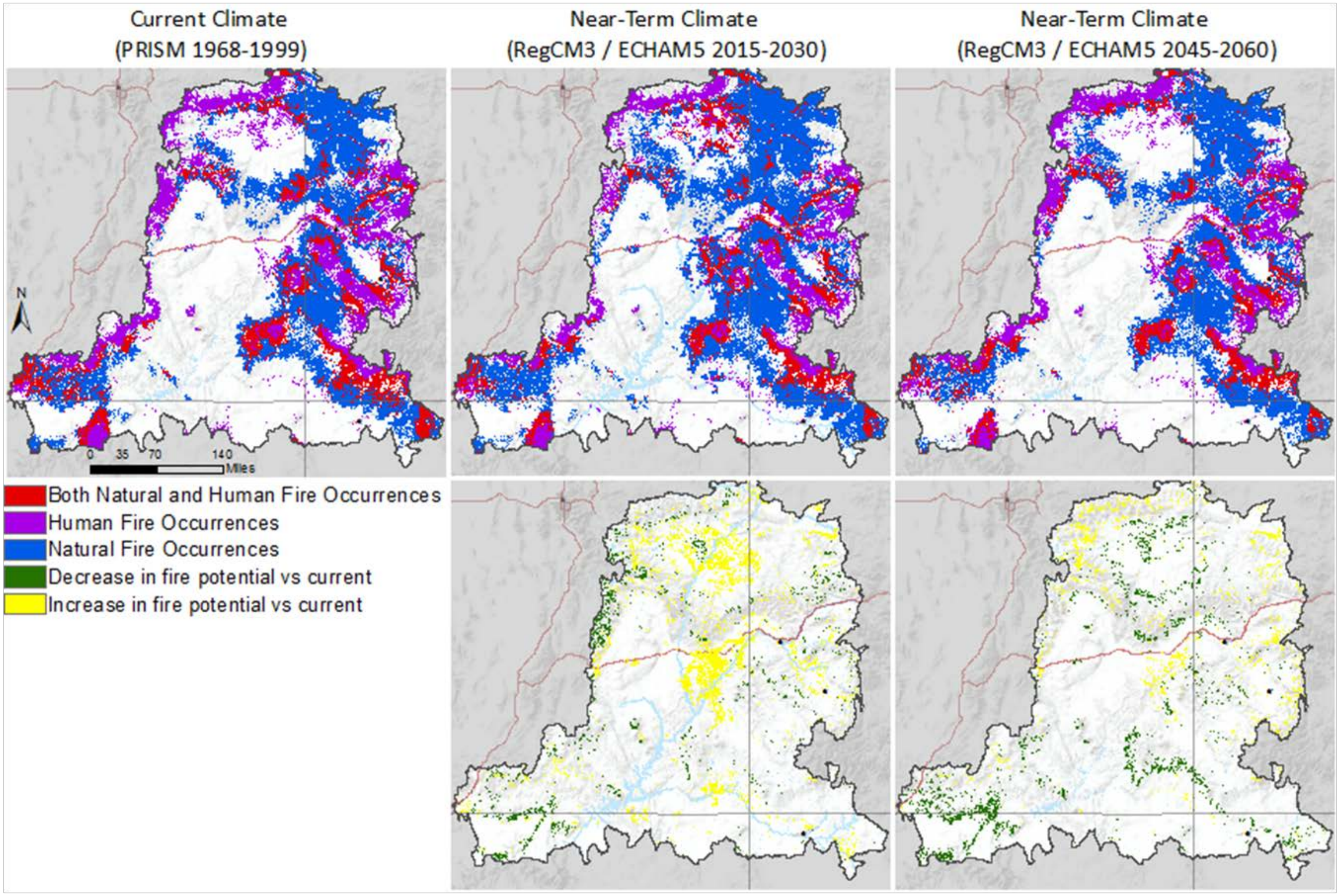



Extract
"CAUSE" = 'Human'
Human-Caused Fires
Maximum Entropy Model
Probability of Human-Caused Fires
Fire Occurrences 1980-2010 in the Colorado Plateau Ecoregion, USA
(USFS, USFWS, NIFC)
Maxent input surfaces
Extract
"CAUSE" = 'Natural'
Natural Fires
Maximum Entropy Model
Probability of Natural Fires

Results for Areas with Potential to Change from Wildfire

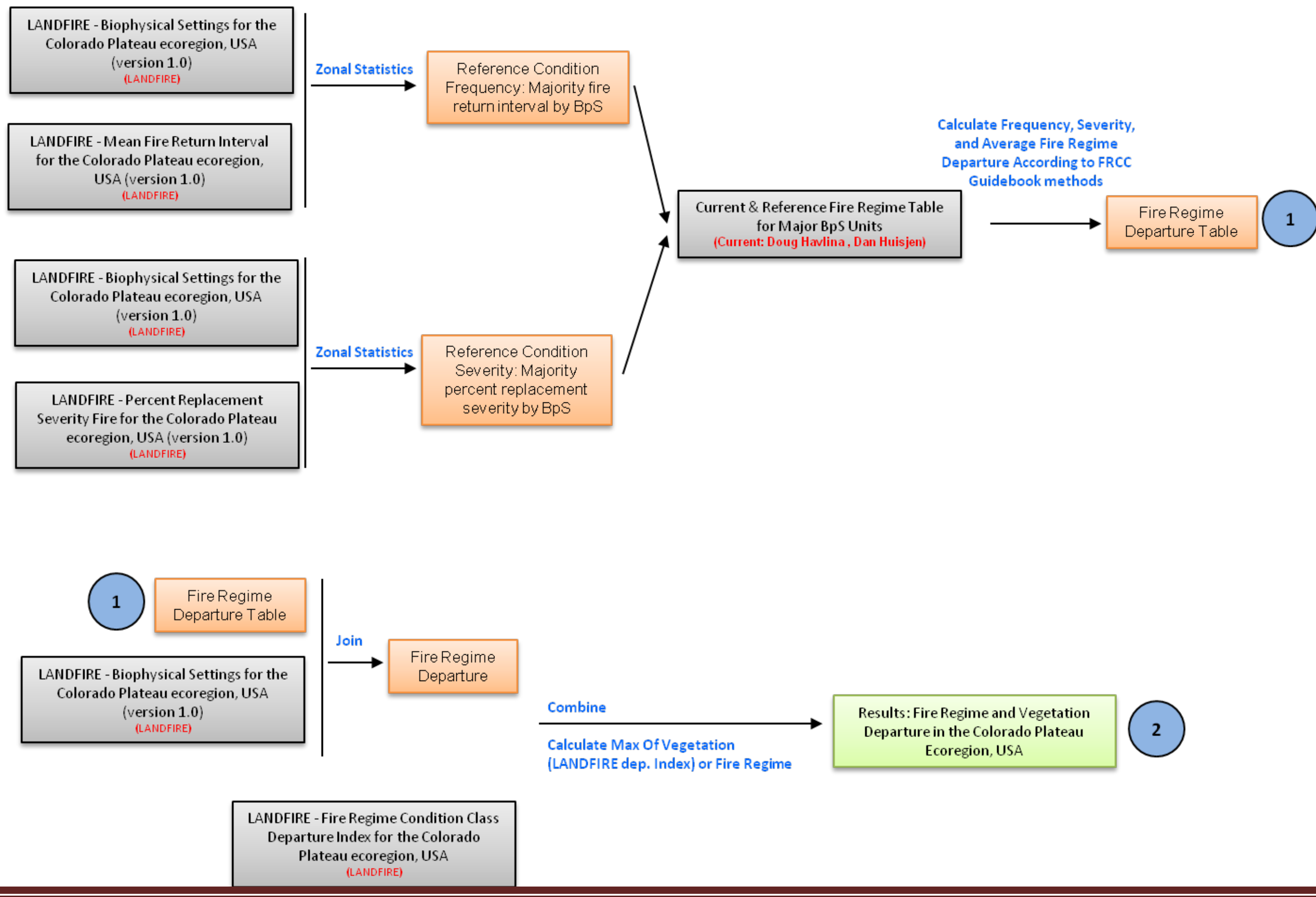





Current Climate
(PRISM 1968-1999)
Near-Term Climate
(RegCM3 / ECHAM5 2015-2030)
Near-Term Climate
(RegCM3 / ECHAM5 2045-2060)
N
0 35 70 140 Miles
Both Natural and Human Fire Occurrences
Human Fire Occurrences
Natural Fire Occurrences
Decrease in fire potential vs current
Increase in fire potential vs current

E. Wildfire
MQ E3. Where are the Fire Regime Condition Classifications?

Process Model or Description

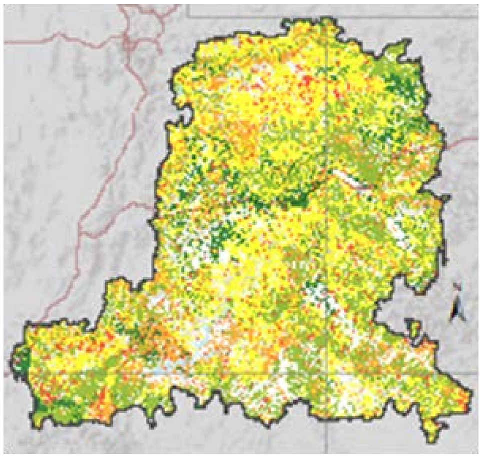


Biophysical Setting	Acres (1000s)	LANDFIRE Reference Condition Fire Return Interval	Current Fire Return Interval	LANDFIRE Reference Condition Replacement Fire Severity	Current Fire Severity	Mean Fire Frequency / Severity Departure
Inter-Mountain Basins Big Sagebrush Shrubland	8,389	151–200 Yrs	300 Yrs	76–80%	85–90%	27
Colorado Plateau Pinyon-Juniper Woodland	7,650	151–200 Yrs	250–300 Yrs	26–30%	76–80%	50
Inter-Mountain Basins Mixed Salt Desert Scrub	3,179	201–300 Yrs	201–300 Yrs	96–100%	96–100%	0
Colorado Plateau Blackbrush-Mormon-tea Shrubland	3,139	101–125 Yrs	101–125 Yrs	51–55%	80–85	18
Rocky Mountain Montane Riparian Systems	1,936	151–200 Yrs	151–200 Yrs	46–50%	46–50%	0
Rocky Mountain Gambel Oak-Mixed Montane Shrubland	1,783	51–60 Yrs	70–80 Yrs	66–70%	80–85%	22
Southern Rocky Mountain Ponderosa Pine Woodland	1,533	26–30 Yrs	75–100 Yrs	11–15%	46–50%	70
Southern Colorado Plateau Sand Shrubland	1,483	151–200 Yrs	151–200 Yrs	66–70%	66–70%	0
Rocky Mountain Aspen Forest and Woodland	1,323	51–60 Yrs	100–120 Yrs	41–45%	61–65%	41
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	1,176	151–200 Yrs	200–250 Yrs	96–100%	96–100%	10
Inter-Mountain Basins Greasewood Flat	1,173	201–300 Yrs	201–300 Yrs	96–100%	96–100%	0
Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	891	36–45 Yrs	75–100 Yrs	11–15%	46–50%	70
Inter-Mountain Basins Montane Sagebrush Steppe - Mountain Big Sagebrush	852	51–60 Yrs	150 Yrs	96–100%	96–100%	32
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland - High Elevation	674	51–60 Yrs	100–125 Yrs	46–50%	75–80%	44
Inter-Mountain Basins Semi-Desert Grassland	663	101–125 Yrs	101–125 Yrs	31–35%	31–35%	0
Inter-Mountain Basins Semi-Desert Shrub-Steppe	448	151–200 Yrs	151–200 Yrs	56–60%	56–60%	0
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	444	51–60 Yrs	100–125 Yrs	41–45%	75–80%	48
Rocky Mountain Lower Montane-Foothill Shrubland	432	51–60 Yrs	75–100 Yrs	21–25%	46–50%	44
Colorado Plateau Mixed Low Sagebrush Shrubland	373	126–150 Yrs	150–200 Yrs	36–40%	36–40%	10

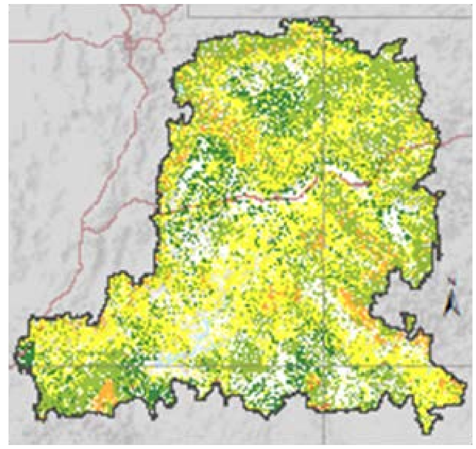
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland - Low Elevation	324	26–30 Yrs	90–100 Yrs	21–25%	70–75%	70
Rocky Mountain Gambel Oak-Mixed Montane Shrubland - Continuous	265	61–70 Yrs	75–100 Yrs	71–75%	86–90%	20
Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland	235	40–55 Yrs	75–100 Yrs	16–20%	46–50%	65
Mojave Mid-Elevation Mixed Desert Scrub	162	301–500 Yrs	301–500 Yrs	96–100%	96–100%	0
Inter-Mountain Basins Curl-leaf Mountain Mahogany Woodland and Shrubland	155	51–60 Yrs	80–85 Yrs	21–25%	60–65%	48
Inter-Mountain Basins Montane Sagebrush Steppe - Low Sagebrush	153	51–60 Yrs	90–100 Yrs	96–100%	96–100%	21
Southern Rocky Mountain Ponderosa Pine Savanna	143	16–20 Yrs	80–100 Yrs	0–5%	41–45%	87
Inter-Mountain Basins Big Sagebrush Shrubland - Wyoming Big Sagebrush	126	151–200 Yrs	151–200 Yrs	96–100%	96–100%	0
Rocky Mountain Subalpine/Upper Montane Riparian Systems	105	151–200 Yrs	151–200 Yrs	26–30%	26–30%	0
Sonora-Mojave Creosotebush-White Bursage Desert Scrub	96	301–500 Yrs	301–500 Yrs	56–60%	56–60%	0
Colorado Plateau Pinyon-Juniper Shrubland	95	101–125 Yrs	150–175 Yrs	16–20%	71–75%	53
Rocky Mountain Subalpine-Montane Mesic Meadow	89	51–60 Yrs	90–100 Yrs	71–75%	71–75%	21
Rocky Mountain Alpine Turf	87	201–300 Yrs	201–300 Yrs	96–100%	96–100%	0
Rocky Mountain Lodgepole Pine Forest	82	151–200 Yrs	200–250 Yrs	91–95%	91–95%	10
Inter-Mountain Basins Montane Sagebrush Steppe	82	101–125 Yrs	200 Yrs	96–100%	96–100%	22
Inter-Mountain Basins Juniper Savanna	74	101–125 Yrs	101–125 Yrs	16–20%	16–20%	0
Southern Rocky Mountain Montane-Subalpine Grassland	64	31–35 Yrs	75–100 Yrs	16–20%	71–75%	69
Great Basin Semi-Desert Chaparral	59	101–125 Yrs	101–125 Yrs	96–100%	96–100%	0
Rocky Mountain Gambel Oak-Mixed Montane Shrubland - Patchy	51	71–80 Yrs	90–100 Yrs	21–25%	35–40%	30
Great Basin Pinyon-Juniper Woodland	47	61–70 Yrs	130–140 Yrs	31–35%	60–65%	49
Inter-Mountain Basins Big Sagebrush Steppe	46	101–125 Yrs	200–250 Yrs	86–90%	86–90%	25

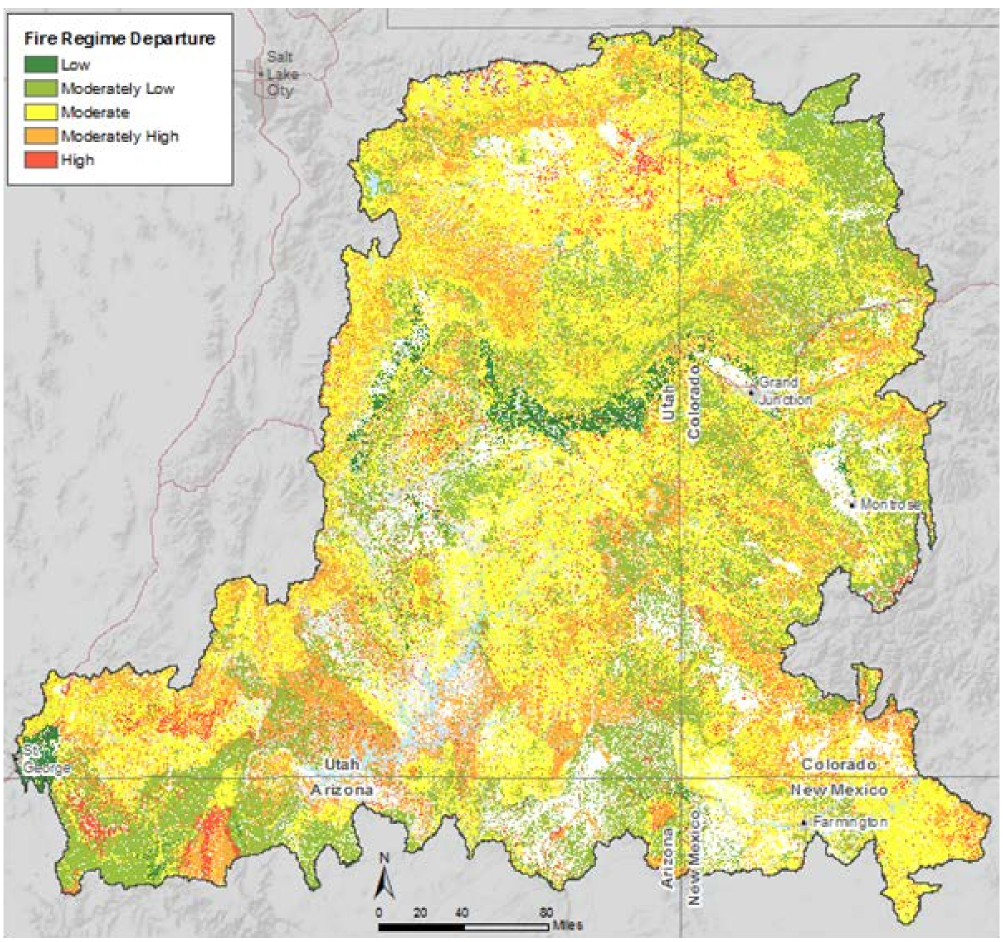
Results for Fire Regime and Vegetation Departure

Vegetation Departure



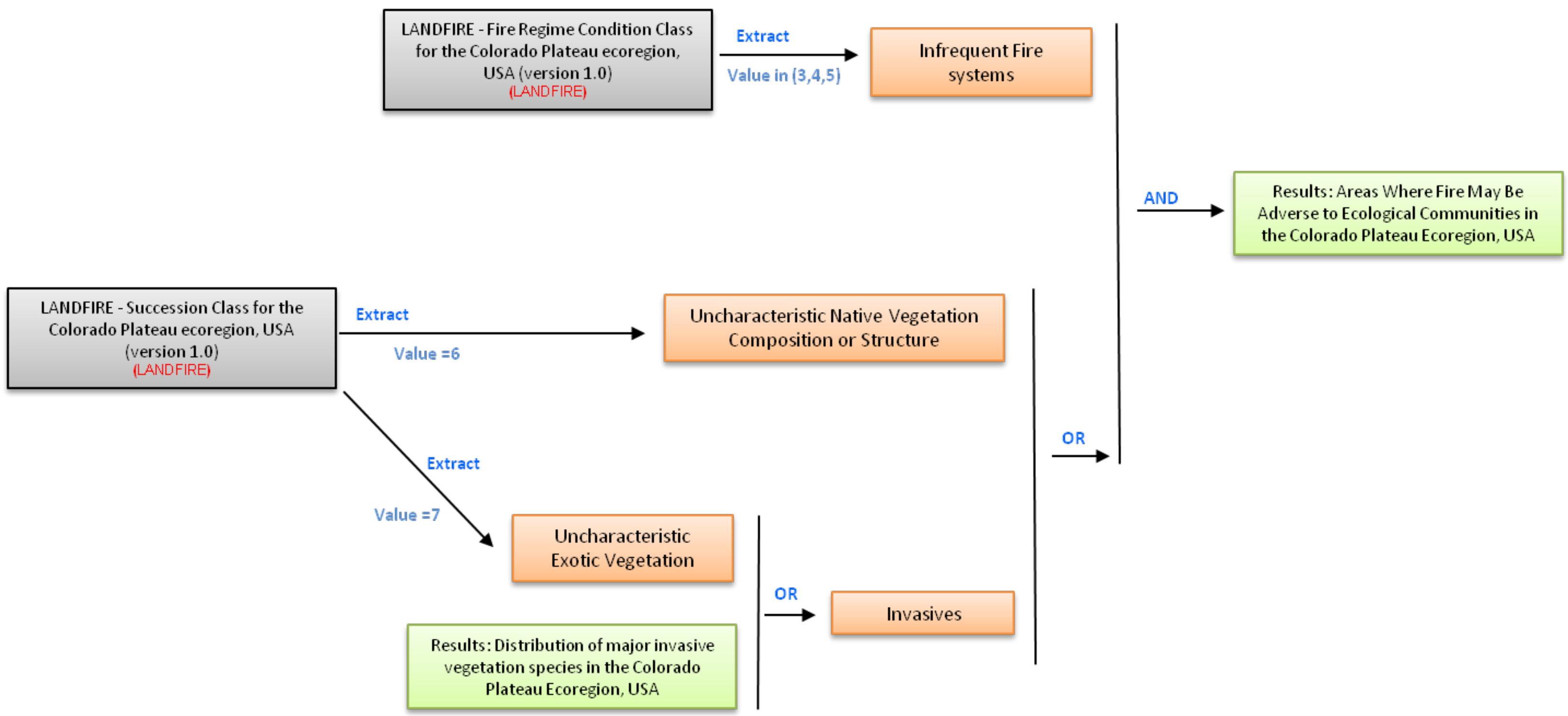
Frequency/Severity Departure



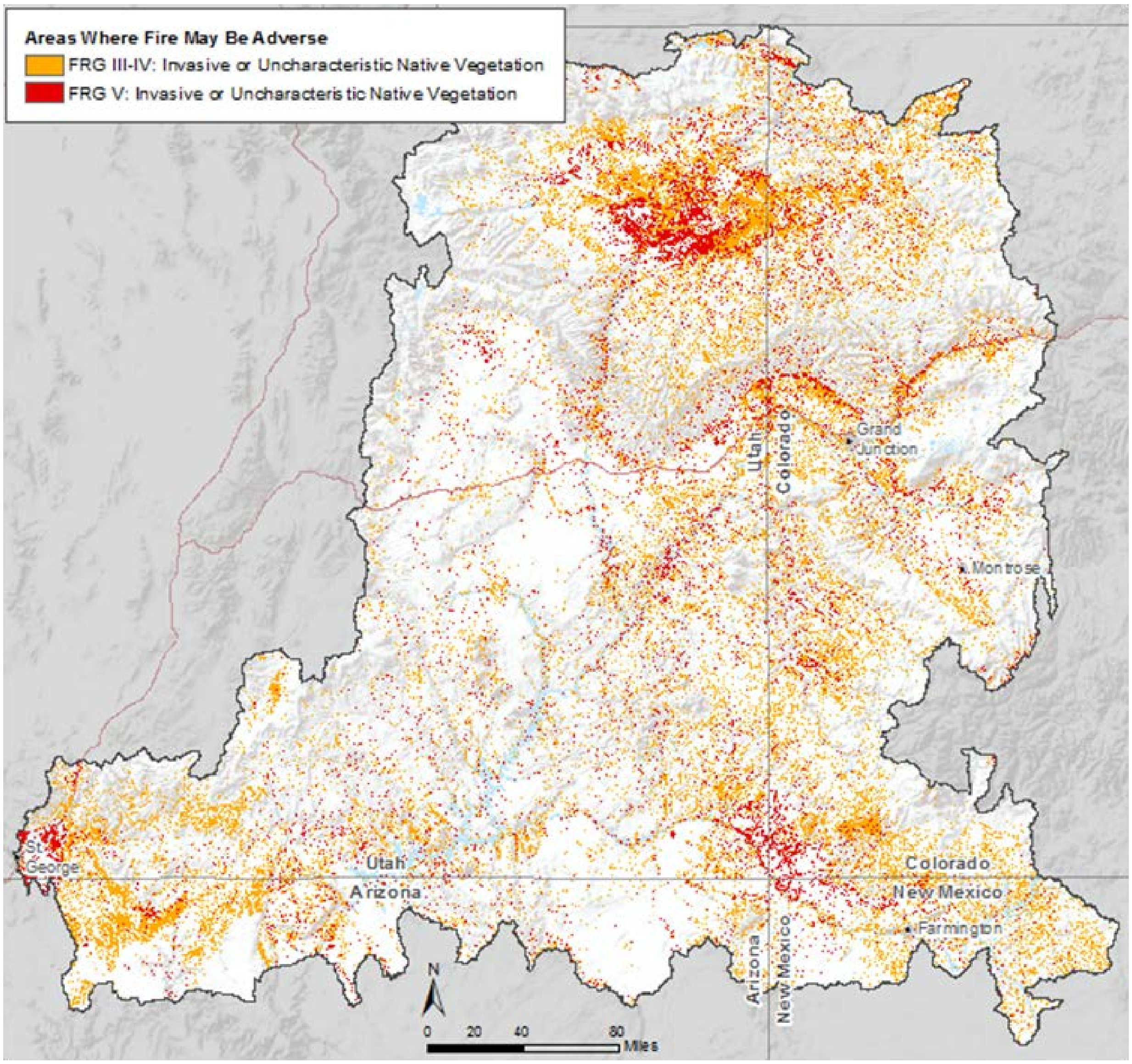


Wildfire E. Wildfire
MQ E4. Where is fire adverse to ecological communities, features, and resources of concern?

Process Model or Description



Results for Areas Where Fire is Adverse to Resources of Concern

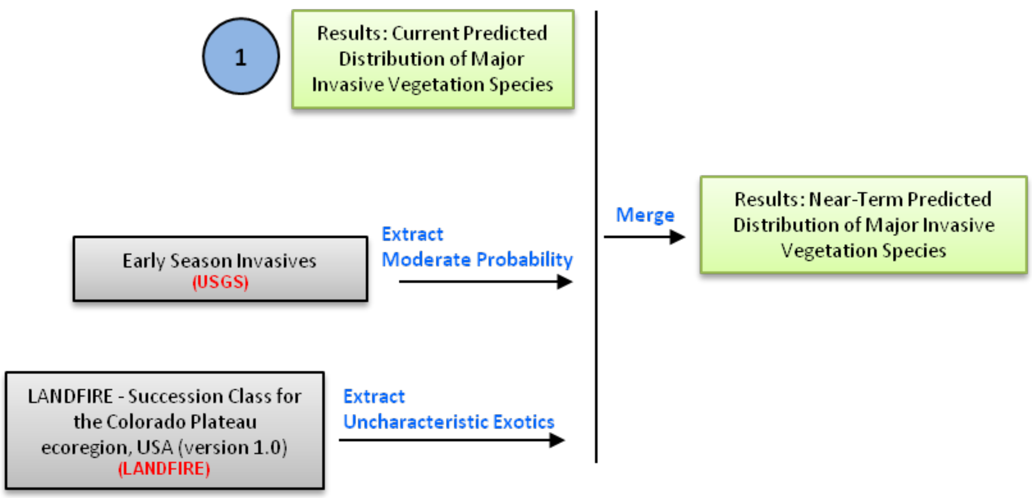


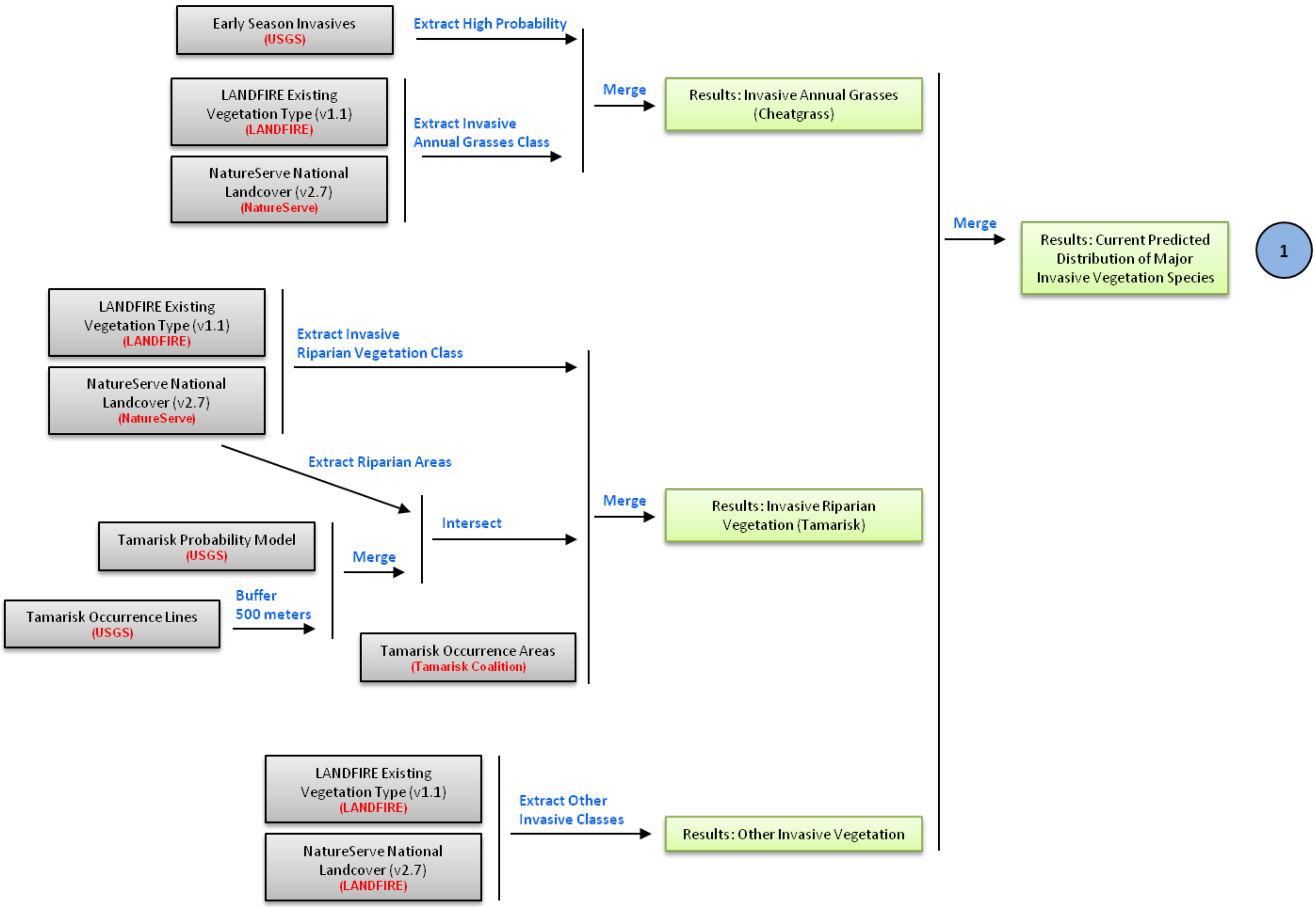
F. Invasive Species
MQ F1. Where are areas dominated by tamarisk and cheatgrass, and where are quagga, zebra mussel, and Asiatic clam present?

Process Model or Description

See process model for vegetation invasives. Aquatic invasives are simply selected from the USGS Nonindigenous Aquatic Species database (http://nas.er.usgs.gov/)

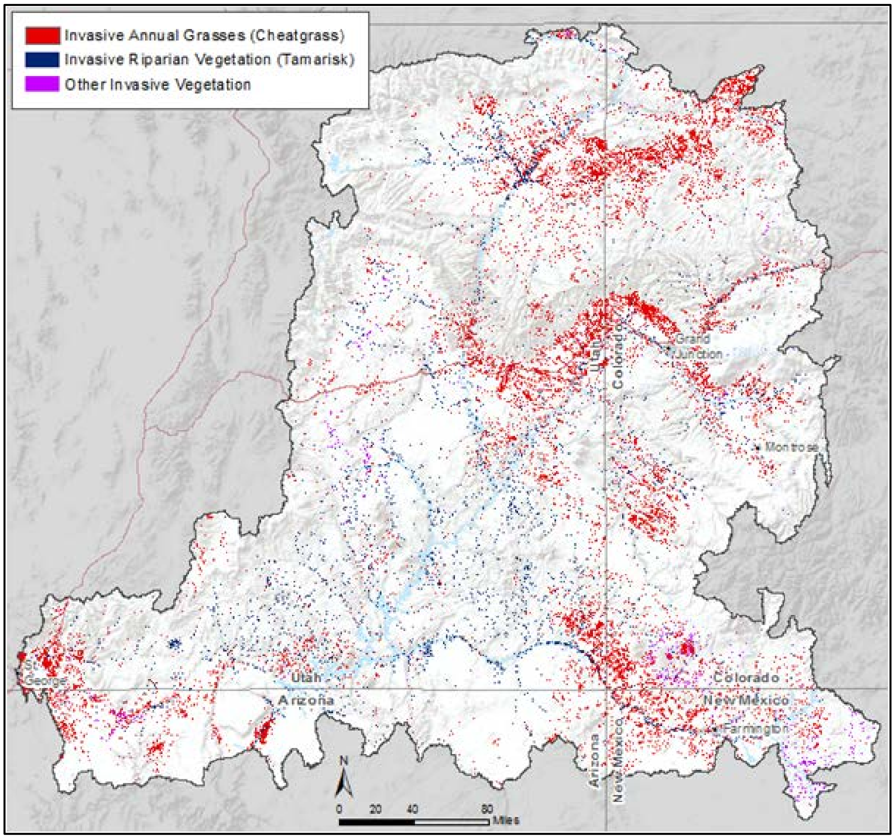
See next page for portion of process model marked with blue circled number 1 below:



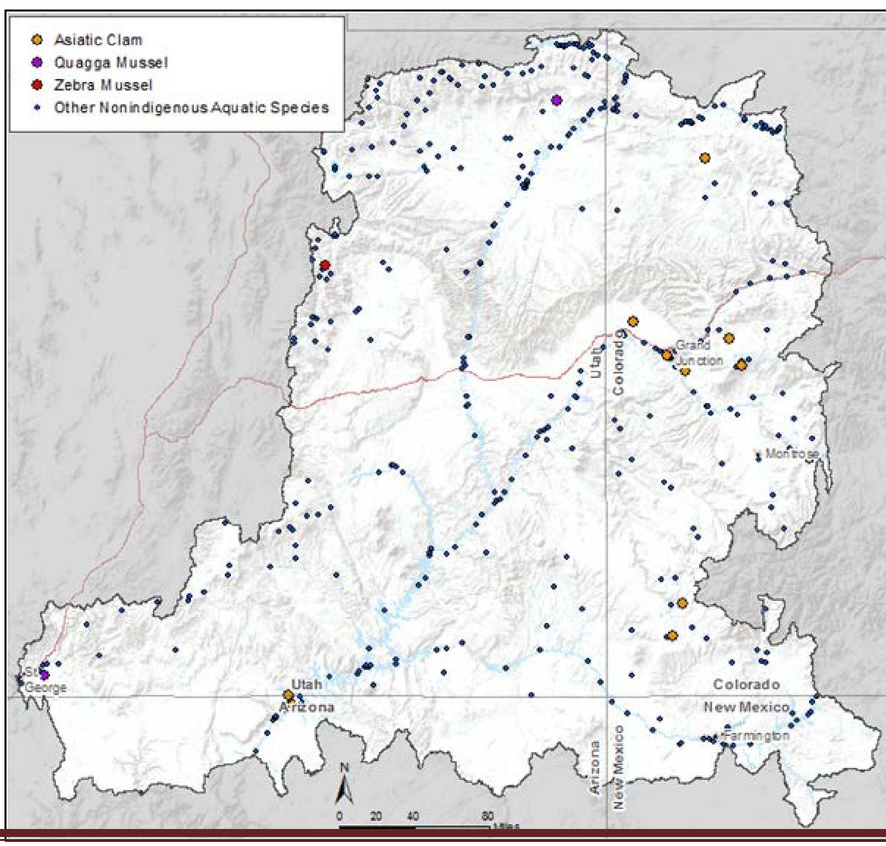


Early Season Invasives
(USGS)
Extract High Probability
LANDFIRE Existing Vegetation Type (v1.1)
(LANDFIRE)
NatureServe National Landcover (v2.7)
(NatureServe)
Extract Invasive Annual Grasses Class
Merge
Results: Invasive Annual Grasses (Cheatgrass)
Merge
Results: Current Predicted Distribution of Major Invasive Vegetation Species
1
LANDFIRE Existing Vegetation Type (v1.1)
(LANDFIRE)
NatureServe National Landcover (v2.7)
(NatureServe)
Extract Invasive Riparian Vegetation Class
Extract Riparian Areas
Intersect
Merge
Results: Invasive Riparian Vegetation (Tamarisk)
Tamarisk Probability Model
(USGS)
Merge
Tamarisk Occurrence Lines
(USGS)
Buffer 500 meters
Tamarisk Occurrence Areas
(Tamarisk Coalition)
LANDFIRE Existing Vegetation Type (v1.1)
(LANDFIRE)
NatureServe National Landcover (v2.7)
(LANDFIRE)
Extract Other Invasive Classes
Results: Other Invasive Vegetation

Results



Upland Invasive Annuals (Cheatgrass) and Invasive Riparian Vegetation (Tamarisk) with other Invasives from LANDFIRE

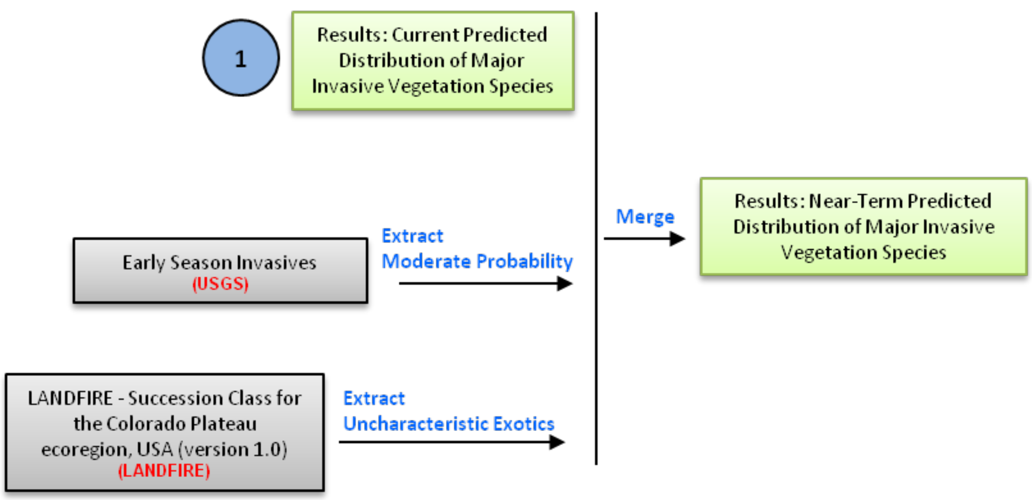


Aquatic Invasives: Asiatic clam (yellow dot), quagga mussel (red with blue outline), and zebra mussel (red dot): other non-native aquatic species (small blue dot).

F. Invasive Species
MQ F2. Where are areas of potential future encroachment from this invasive species?

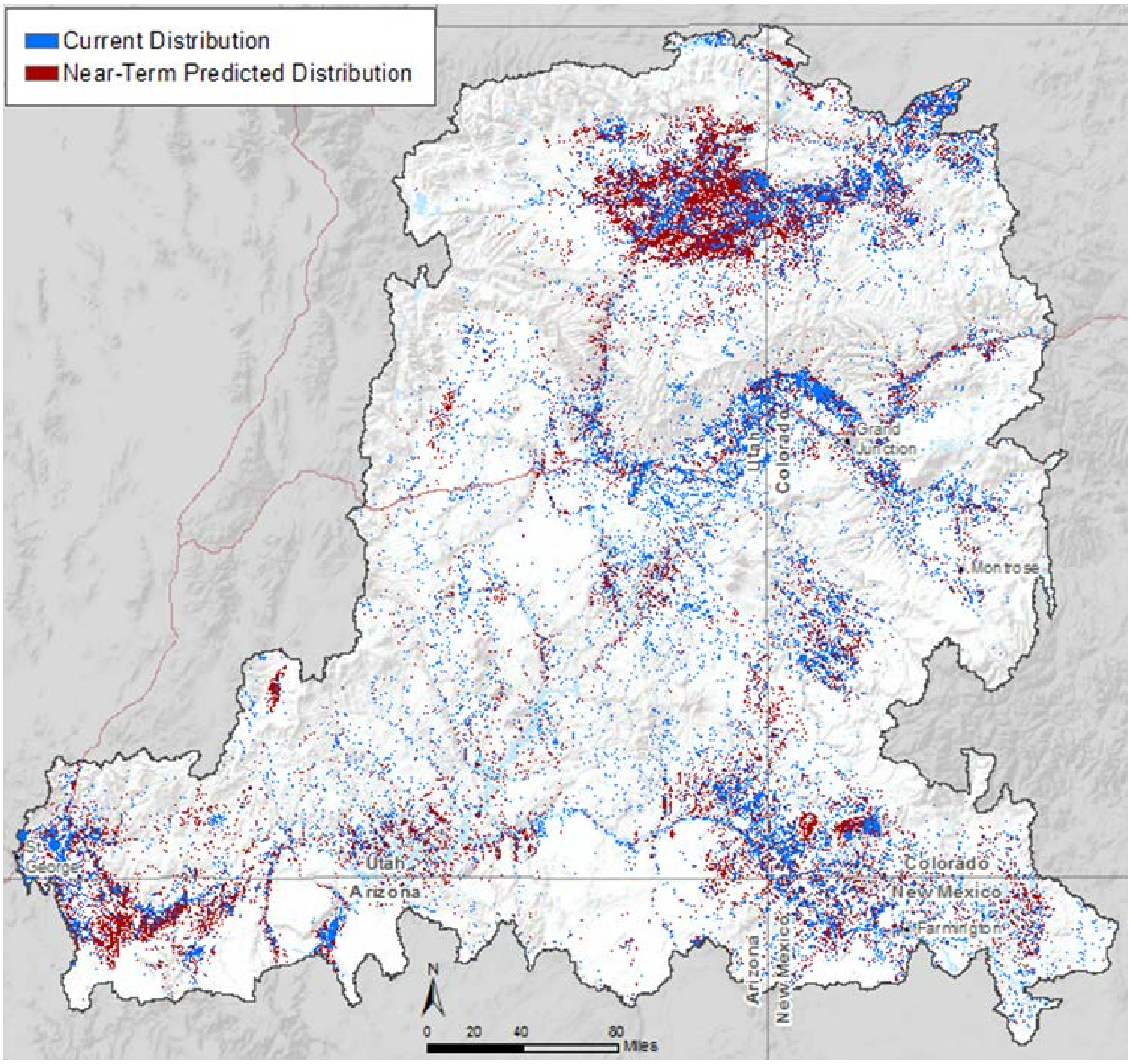
Process Model or Description

Process model for vegetation (below) is an extension of Process Model for MQ F1. MQF2 was not done for aquatic invasives due to insufficient data.



Results for Potential Future Encroachment of Invasive Species

Current Distribution and Near-term Future (2025) Predicted Distribution of Invasive Species



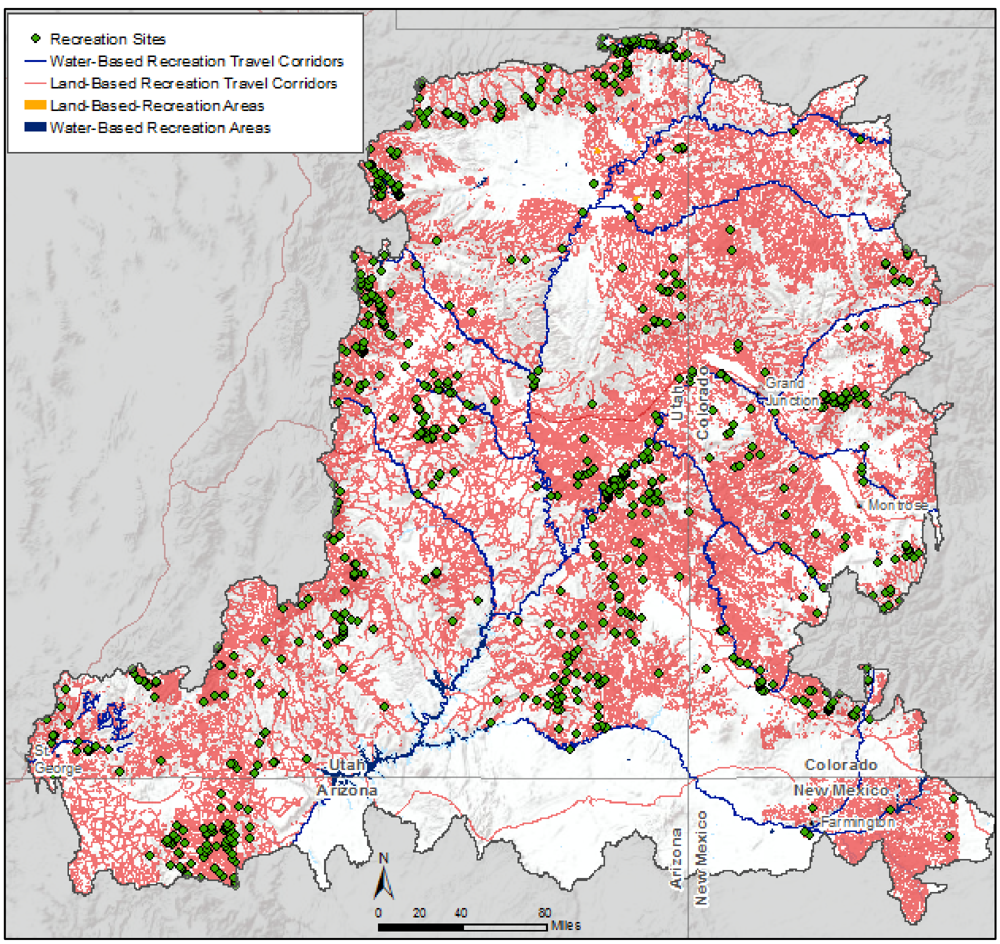
Current distribution in blue and near-term future (2025) distribution of invasive species in red.

G. Future Development
MQ G1. Where are areas of planned development? – **go to Appendix D**
MQ G2. Where are areas of potential development, including renewable energy and where are potential conflicts with conservation elements? – **go to Appendix D**
H. Resource Use
MQ H1. Where are high-use recreation sites, developments, roads, infrastructure or areas of intensive recreation use located (including boating)?

Process Model or Description

Recreation sites were compiled from USFS and BLM data. We compiled land-based recreation areas (open OHV areas) from BLM and water-based recreation areas by selecting larger water bodies from NHD (>1 square kilometer). Land-based travel corridors were extracted from BLM ground transportation linear features dataset within federal and state lands in Conservation Biology Institute protected areas database (excluding DOD lands). Water-based travel corridors were compiled by selecting rivers from NHD flowlines that were listed on BLM rivers website.

Results for High-Use Recreation

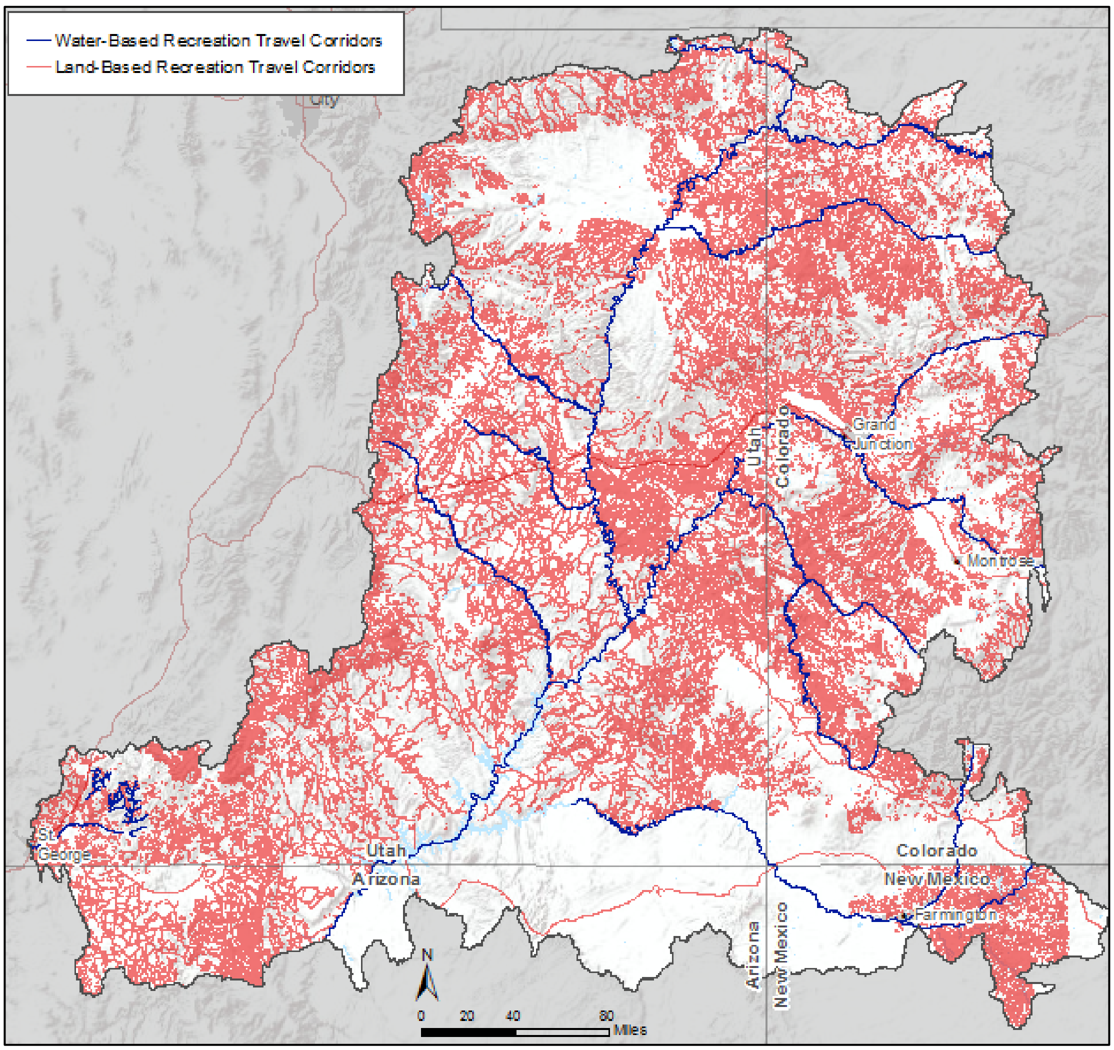


H. Resource Use
MQ H2. Where are areas of concentrated recreation travel (OHV and other travel) located?

Process Model or Description

Land-based travel corridors were compiled from BLM ground transportation linear features dataset within federal and state lands in Conservation Biology Institute protected areas database (excluding DOD lands). Water-based travel corridors were extracted by selecting rivers from NHD flowlines that were listed on BLM rivers website.

Results for Areas of Concentrated Recreation Travel

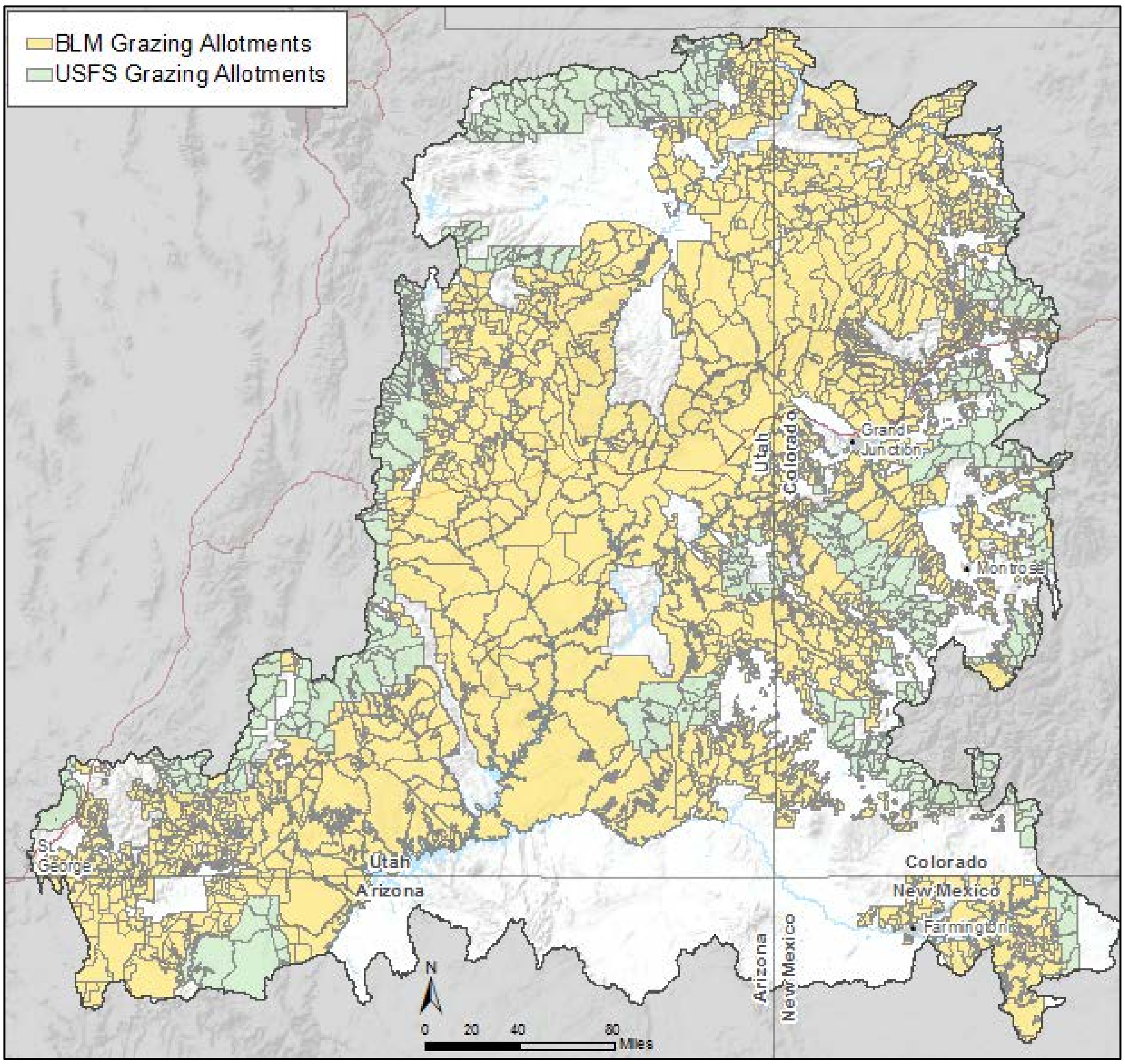


H. Resource Use
MQ H4. Where are allotments and type of allotment?

Process Model or Description

Grazing allotments were compiled from USFS and BLM datasets.

Results for Location of Grazing Allotments

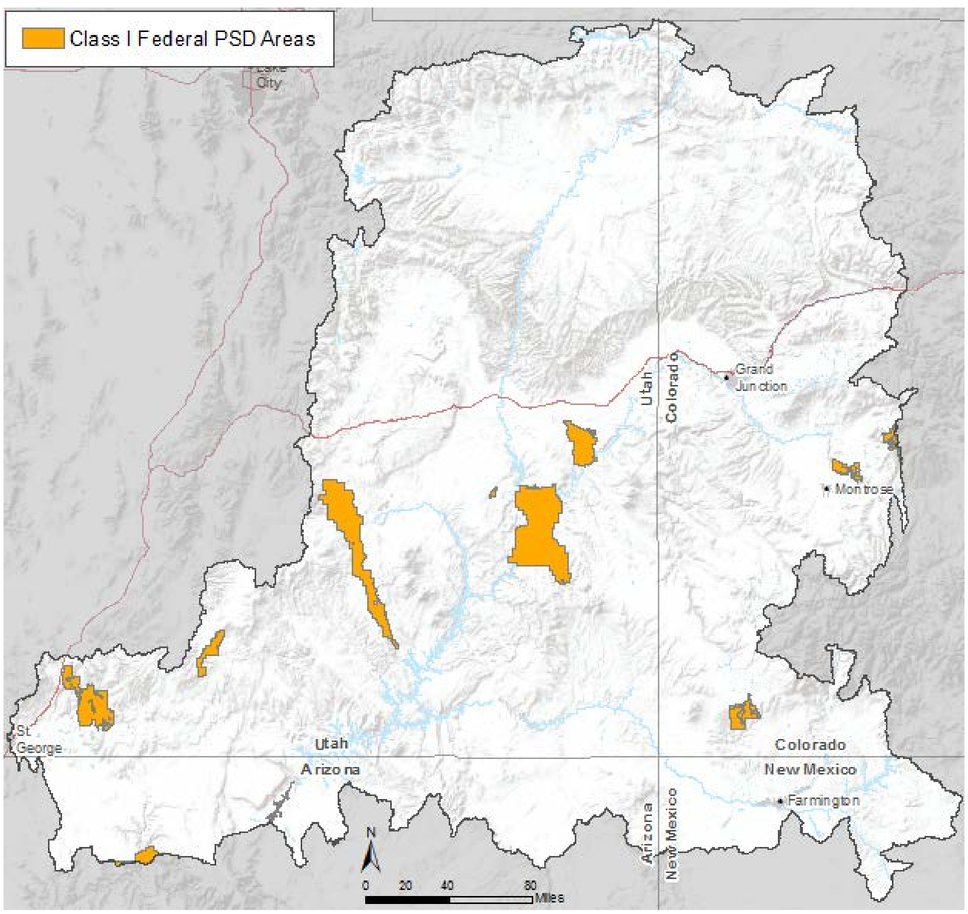


I. Air Quality
MQ I3. Where are the Class I PSD areas?

Process Model or Description

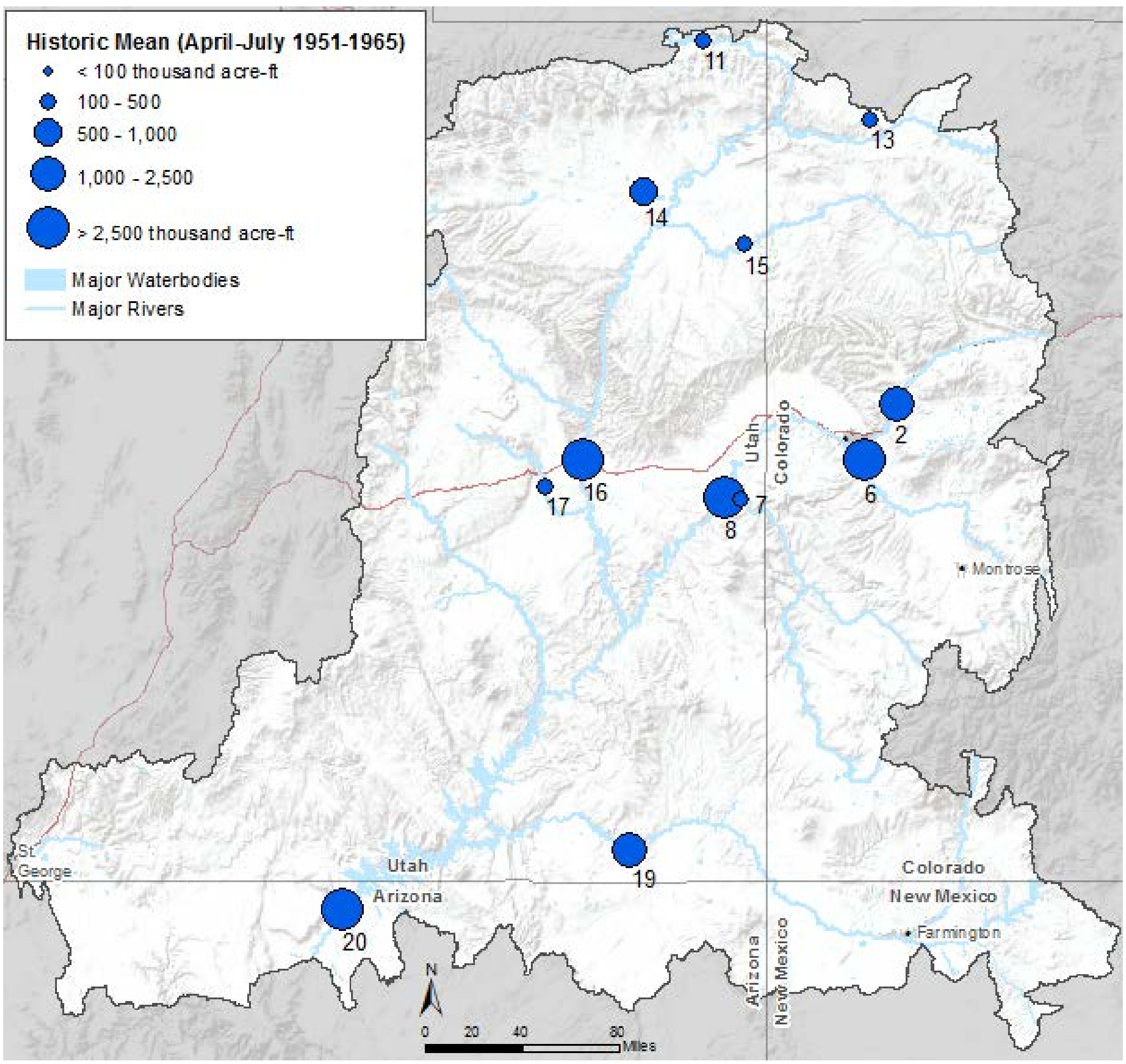
Federal Class I PSD areas selected from CBI protected areas database using authoritative list of areas (all national parks and some wilderness areas) from EPA.

Results for Class I PSD Air Quality Areas

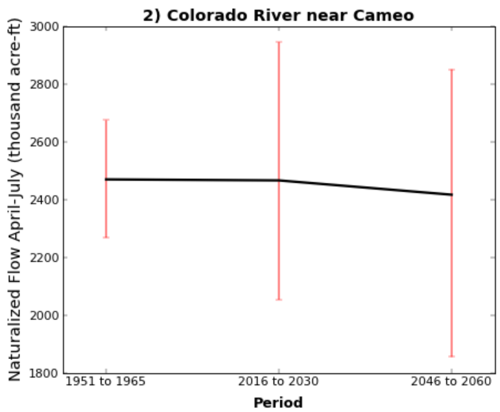


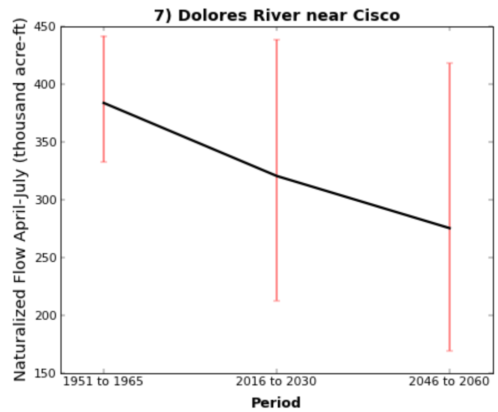
J. Climate Change
MQ J1. Where/how will the distribution of dominant native and invasive plant species be vulnerable to or have potential to change from climate change in 2060? – **see MQ C2 for each plant community**
MQ J3. Where are areas of species conservation elements distribute change between 2010 and 2060? – **see MQ D6 for each species**
MQ J4. Where are aquatic/riparian areas with potential to change from climate change? – **see MQ C2 for riparian vegetation and results below for future discharge**

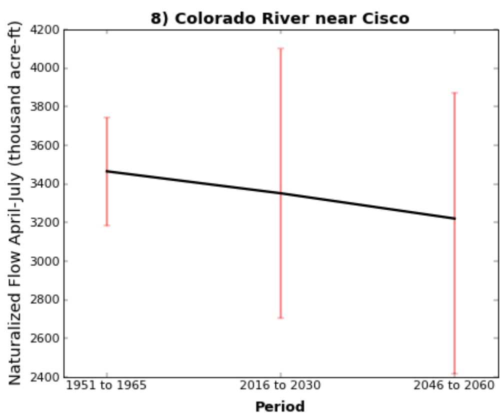
Results for Aquatic Areas with Potential to Change from Climate Change

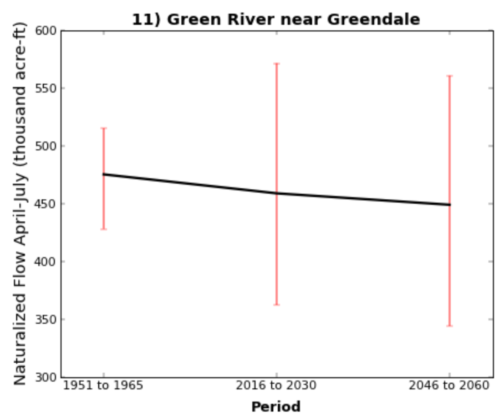


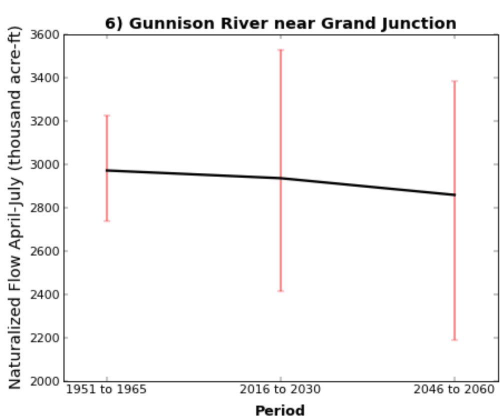
Graphs show alteration in flow at 12 gaging stations pictured above from historical period (1951) through current period and projected to mid-21st century (2060, Bureau of Reclamation data, BOR 2012). Graph numbers correspond to gaging station locations on previous map.

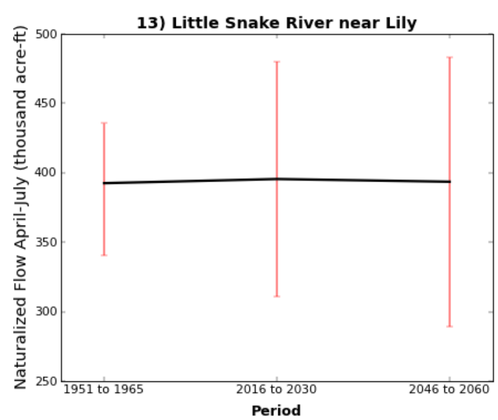


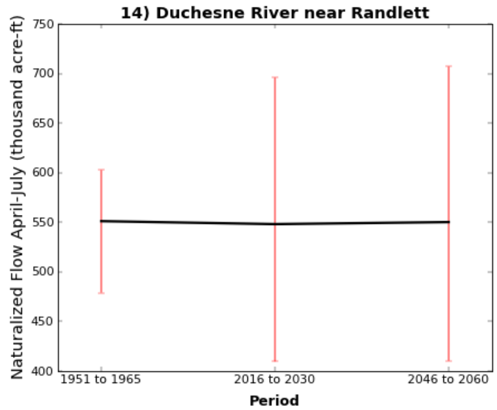


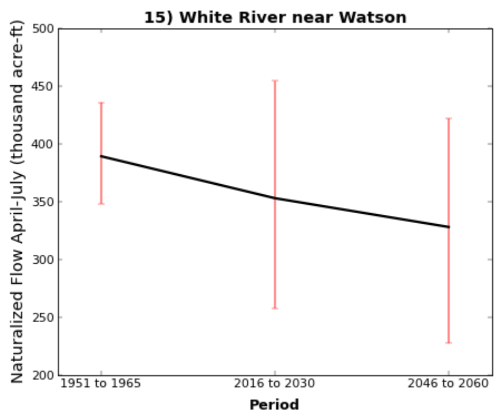


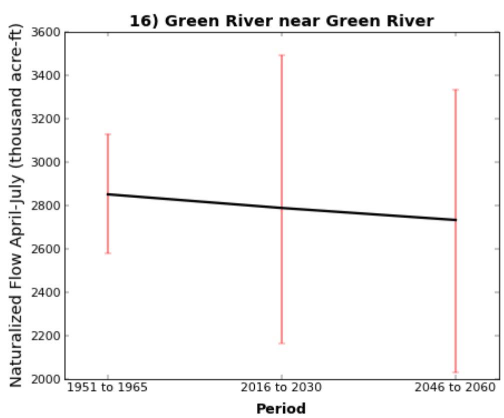


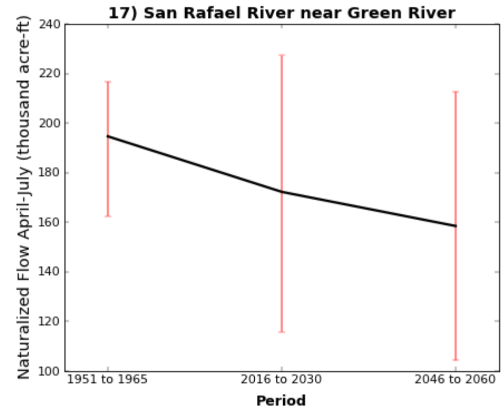


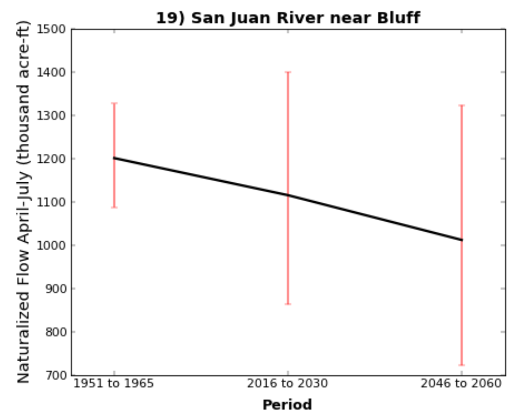


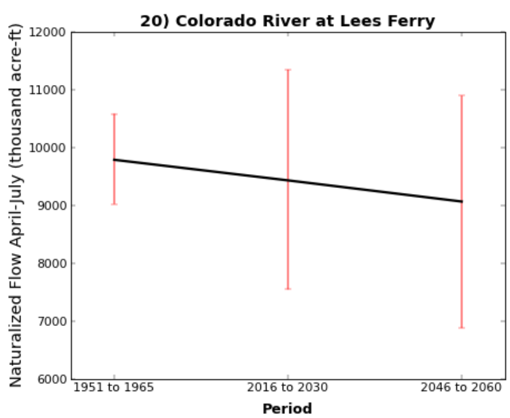












BOR (Bureau of Reclamation). 2012. Colorado River Basin water supply and demand study. Technical report B: Water Supply Assessment. Prepared by Colorado River Basin Water Supply and Demand Study Team, U.S. Bureau of Reclamation.

Appendix B – Ecological Systems Conservation Elements

Organization of Appendix B

The following sources and results are provided for each Ecological System (vegetation community) conservation element: a Conceptual Model; a description of the analytical process (including source data) and/or a Process Model for each management question, and results in the form of maps and other supporting graphics. Access to a data portal to examine the results in greater detail is available at the BLM website http://www.blm.gov/wo/st/en/prog/more/climatechange.html.

Ecological Systems Conceptual Models

Conceptual models used in the Colorado Plateau REA organize and articulate the relationship between the various change agents and natural drivers for a particular conservation element. Not all of the relationships identified lend themselves well to measurement or monitoring, but they are still important to include as it aids in our overall understanding of complex interactions.

All ecological systems (and biological crust) conceptual models include a series of change agents (depicted with yellow boxes) and natural drivers (cyan boxes). Specifics regarding some of the factors are presented in blue text. Within each ecological system, one or more dominant species are included in the model. Arrows represent relationships between the various change agents and natural drivers with the community overall and, where appropriate, with the dominant species more directly. More specific information is provided by the orange text. Thicknesses of the arrows **DO NOT** represent degree of importance. Rather, bold lines represent those factors that are tracked or modeled to varying degrees of certainty throughout the REA analysis.

Fire regime is influenced by a complex interaction of factors: fuel load and condition, grazing, invasive species, and fire frequency (both natural—a function of climate—and human-caused—a function of development). Fire suppression is another influencing factor on the fire regime. Climate change and development affects the entire complex and all of its components. Natural ecological systems are shaped by a natural fire regime and altered by a different regime. Native ecosystems can also be directly affected by invasive species and grazing.

No natural system is fixed in time or space, and it is the individual species that respond to environmental change, not the community. Evaluating natural ecological systems within the Colorado Plateau is particularly challenging for monitoring change as many of the more dominant natural communities are ecotonal and therefore demonstrate a high level of mobility on the landscape. Natural or human-caused change can drive one ecological system to another over a relatively short period of time in a given location. For example, pinyon-juniper woodlands can be driven towards a pinyon-juniper shrublands community or invasive grassland from an altered fire regime. When reviewing the different ecological systems conceptual models and resulting distribution maps, it is important to keep these dynamics in mind.

Finally, biological crust occurs as part of many of the other natural ecological systems reviewed for this REA. As part of these other systems, biological crusts inhibit invasive seed germination (Larsen 1995), help retain soil moisture (Belnap and Gardner 1993), stabilize soils (Belnap and Warren 1998), and serve as an important source of carbon and nitrogen fixation (Beymer and Klopatek 1991, Belnap 1995). Management questions (MQ A4 and MQ A5) and results maps for biological crust may be found in Appendix A.

References Cited

Belnap, J. 1995. Surface disturbances: Their role in accelerating desertification. *Environmental Monitoring and Assessment* 37: 39–57.

Belnap, J., and J.S. Gardner. 1993. Soil microstructure of the Colorado Plateau: The role of the cyanobacterium *Microcoleus vaginatus*. *Great Basin Naturalist* 53: 40–47.

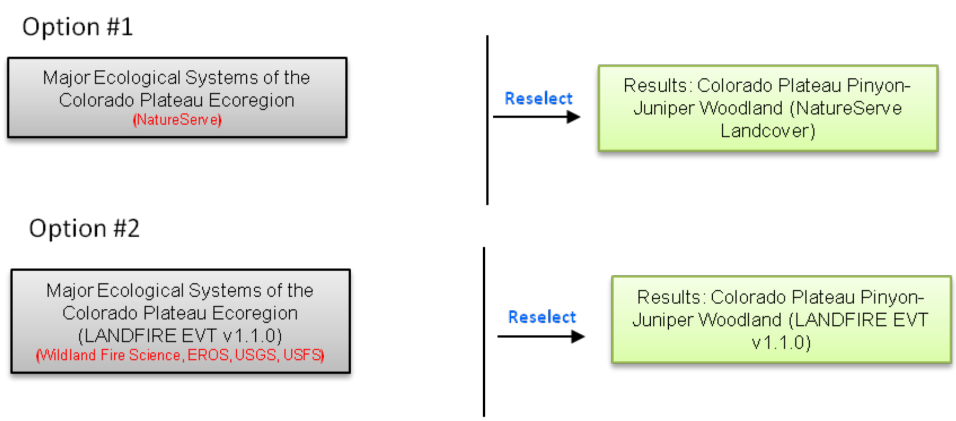
Belnap, J., and S. Warren. 1998. Measuring restoration success: A lesson from Patton's tank tracks. *Ecological Bulletin* 79: 33.

Beymer, R.J., and J.M. Klopatek. 1991. Potential contribution of carbon by microphytic crusts in pinyon-juniper woodlands. *Arid Soil Research and Rehabilitation* 5: 187–198.

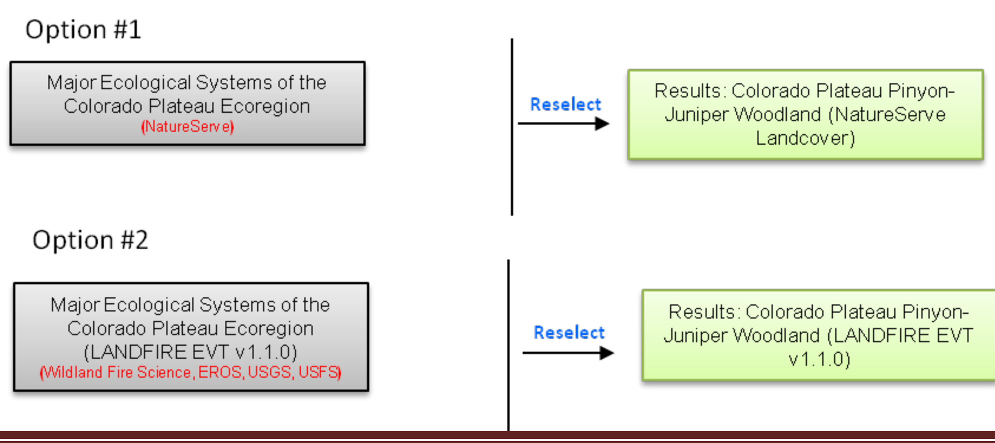
Larsen, K.D. 1995. Effects of microbiotic crusts on the germination and establishment of three range grasses. Unpublished thesis, Boise State University, Boise.

Process Models

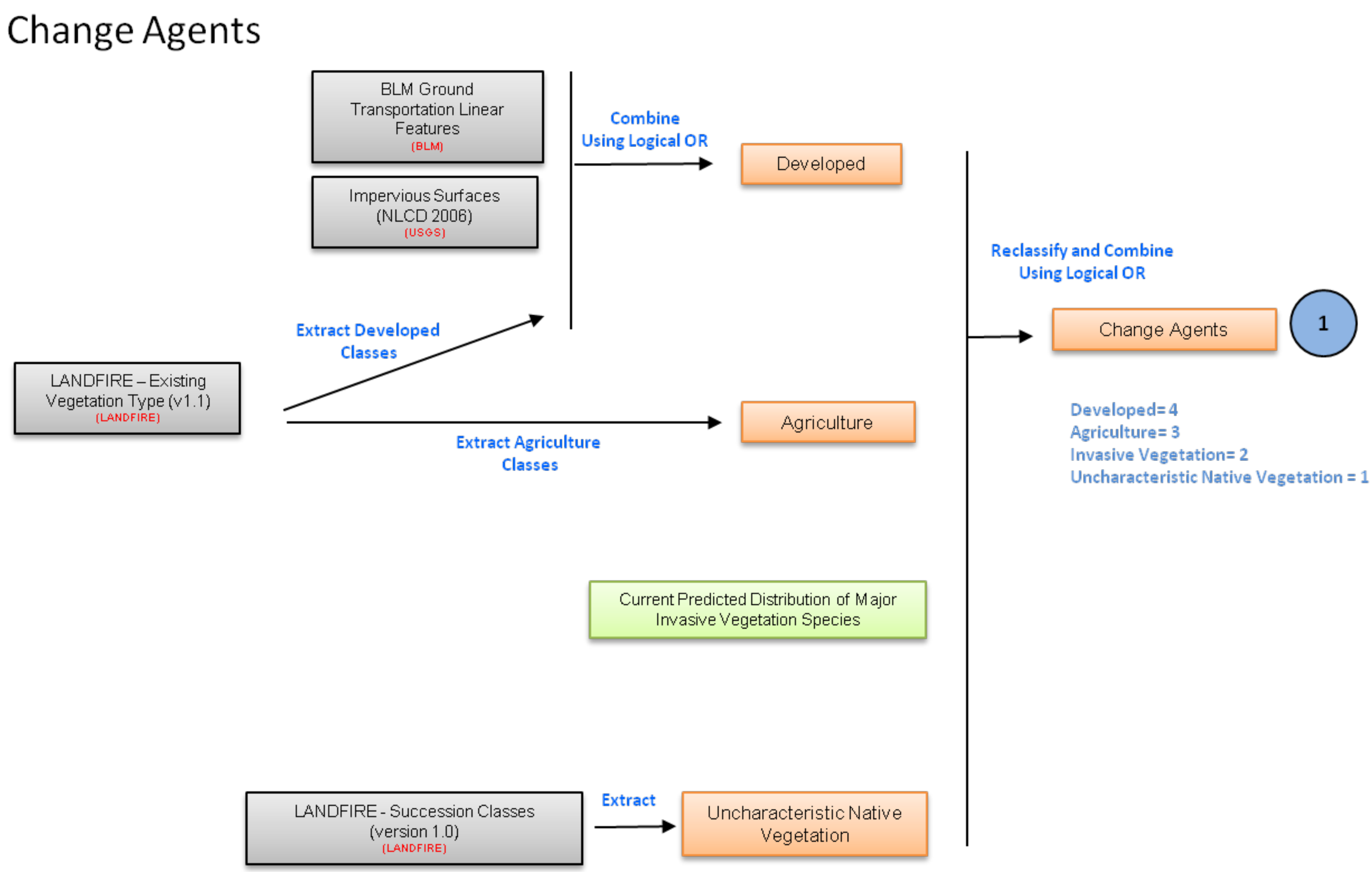
MQ C1. Where are existing vegetation communities of interest present and what is their current status?



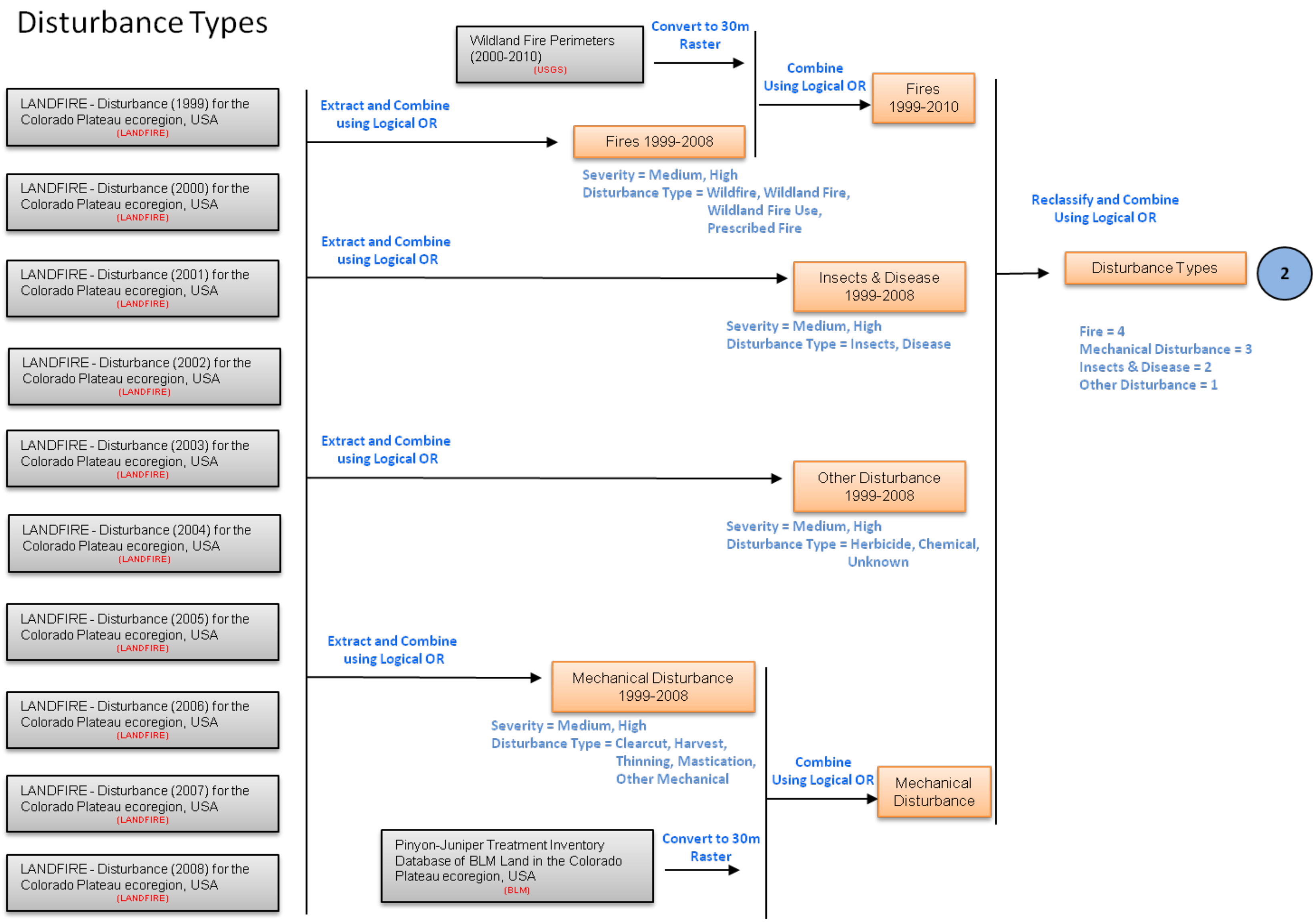
MQ C2. Where are vegetative communities vulnerable to change agents in the future?



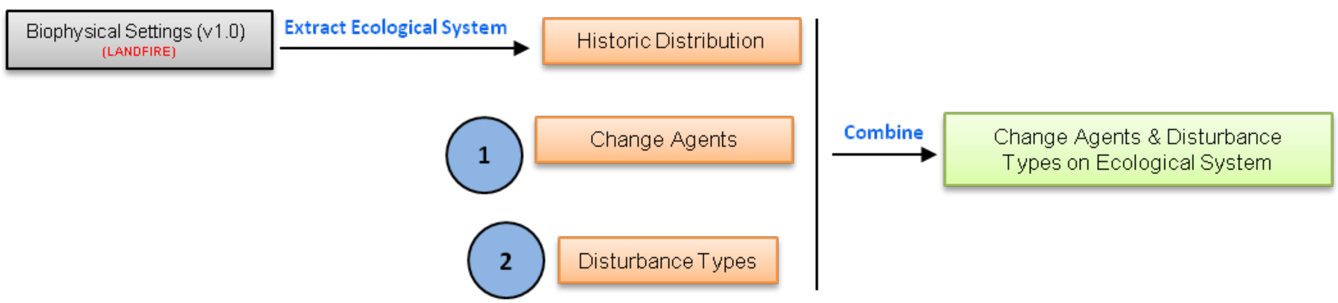
MQC3. What change agents have affected existing vegetative communities? Part 1



MQC3. What change agents have affected existing vegetative communities? Part 2



MQC3. What change agents have affected existing vegetative communities? Part 3



Colorado Plateau Pinyon-Juniper Woodland

Conceptual Model

There are six primary natural drivers (cyan boxes) for this ecological system including topography, soil characteristics, precipitation, temperature, insects and disease, and animal herbivory. Specific details on the various environmental conditions characterizing this system (blue text) are provided by NatureServe (2009). The important role jays and nutcrackers play in the life history of pinyon pine (*Pinus edulis*) is a natural driver specific for that dominant species.

Climatic events (droughts and frosts) are believed to limit the distribution of this community to a relatively narrow altitudinal band in the ecoregion. There are natural periods of range expansion of this ecological system followed by contraction due to climate stress and insect/disease vectors, especially where there are closed stands (LANDFIRE 2007). Close attention to climate change projections may be particularly important in defining where this community type can occur in the future.

The fire regime is characterized by somewhat mixed severity mosaics (mean fire return interval of 150–200 years) with infrequent replacement fires (every 200–500 years, Rondeau 2001). Scale of fire disturbance is typically small, but under certain conditions, stand replacing over 1000s of acres can occur. Mixed severity fires are on the order of 10–100s of acres in size. Lower fire frequency, which has been more common over the last decades due to fire suppression, results in an expansion of woody vegetation. Higher than normal fire frequency and severity results in a reduction of woody vegetation and a transition towards more shrubs and grasses. Livestock grazing and invasive grasses have altered the understory vegetation and, where fire has removed the tree cover, invasive grasses have become dominant eliminating woodland vegetation altogether. Where long-term grazing has occurred, there are significantly fewer grasses and cacti and more forbs and shrubs present (Harris et al. 2003).

Drought stress and subsequent insect outbreaks have been causing widespread mortality of pinyon pine throughout much of its range, especially on soil types that are more prone to moisture loss (Breshears et al. 2005, Mueller et al. 2005). Soils in regions of very high pinyon pine mortality are generally coarse, sandy, skeletal, with low fertility but rich in calcium (desert caliche layers). They have a torric moisture regime (hot and dry soils) and very little horizon development. The soils have large pores with little capillary forces that promote rapid water evaporation or drainage rather than conservation leading to tree mortality.

For many years, large areas of pinyon-juniper woodlands have been converted to rangeland through mechanical disruption known as chaining. Although not as common as it once was, conversion of this woodland type for agricultural purposes still occurs. Mechanical removal and development (urban and energy) also directly convert or degrade this system. Mechanical removal or disturbance of this community can promote invasive grasses altering the system in significant ways. Direct harvest of the tree dominants in this community are also important change agents but more difficult to track with the data available.

Change agents affecting this ecological system accounted for in the REA process include Development (based on current and projected future extent of urban land cover) and recent disturbance (1999–2008) from Mechanical Removal, Fires, and Insects and Disease. Overall landscape intactness, which includes development from all sources (urban, agriculture, energy, and roads), invasive species, and habitat fragmentation, is used to describe the regional environment that contains this ecosystem type. Climate change projections (including precipitation and temperature changes as well as MAPSS modeling outputs) are also used to predict where existing pinyon-juniper woodlands may be under significant climate stress.

References Cited

Breshears, D.D., N.S. Cobb, P.M. Price, C.D. Allen, R.G. Balice, W.H. Romme, J.H. Kastens, M.L. Floyd, J. Belnap, J.J. Anderson, O.B. Myers, and C.W. Meyer. 2005. Regional vegetation die-off in response to global change-type-drought. *Proceedings of the National Academy of Sciences* 102: 15144–15148.

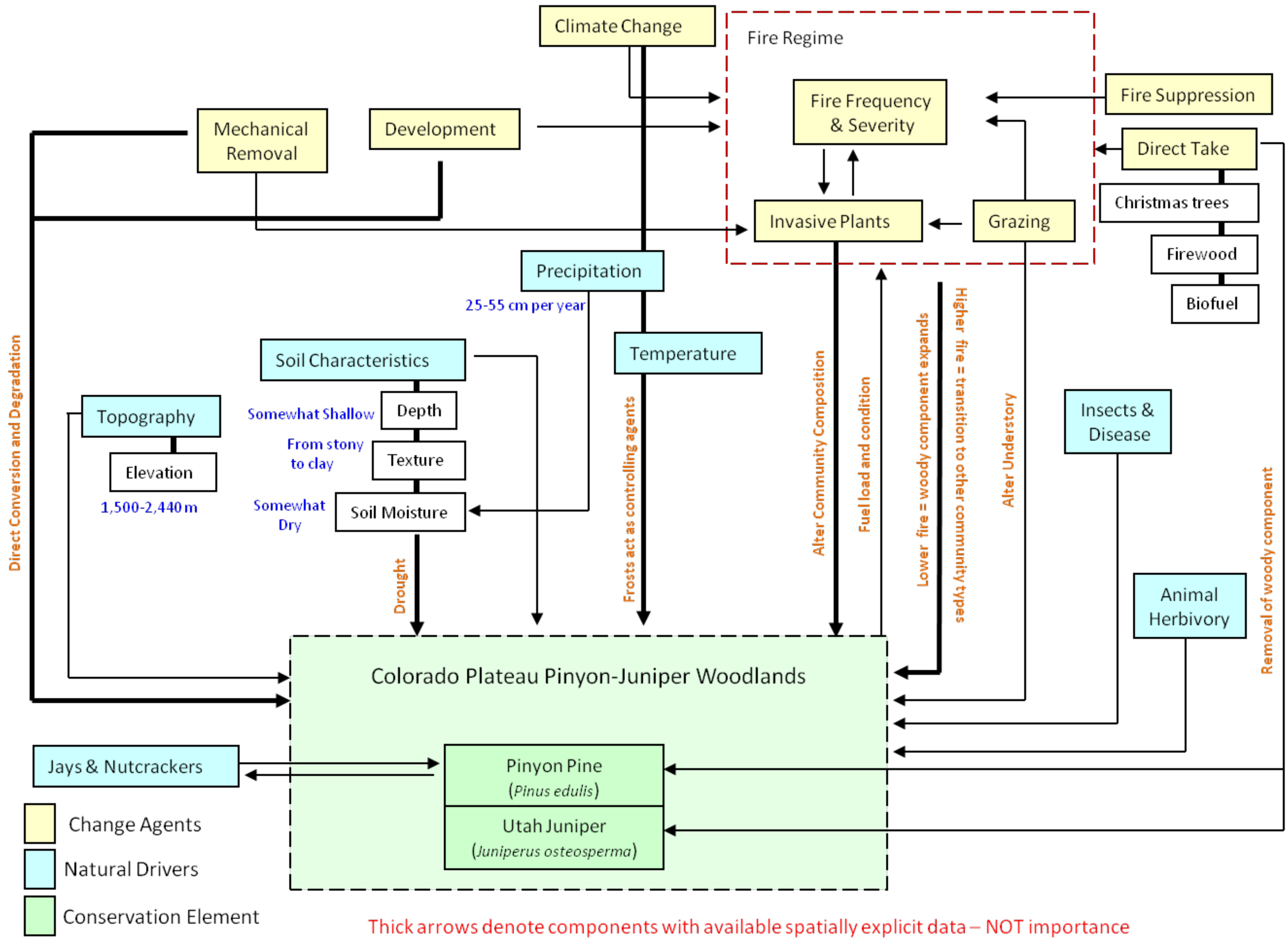
Harris, A.T., G.P. Asner, and M.E. Miller. 2003. Changes in vegetation structure after long-term grazing in pinyon-juniper ecosystems: Integrating imaging spectroscopy and field studies. *Ecosystems* 6: 368–383.

LANDFIRE Biophysical Setting Model. September 2007.

Mueller, R., C.M. Scudder, M.E. Porter, R.T. Trotter III, C.A. Gehring and T.G. Whitman. 2005. Differential tree mortality in response to severe drought: Evidence for long-term vegetation shifts. *Journal of Ecology* 93: 1085–1093.

NatureServe. 2009. International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Database. Arlington, VA.

Rondeau, R. 2001. Ecological system viability specifications for the Southern Rocky Mountain ecoregion. Colorado Natural Heritage Program . 181 pp.

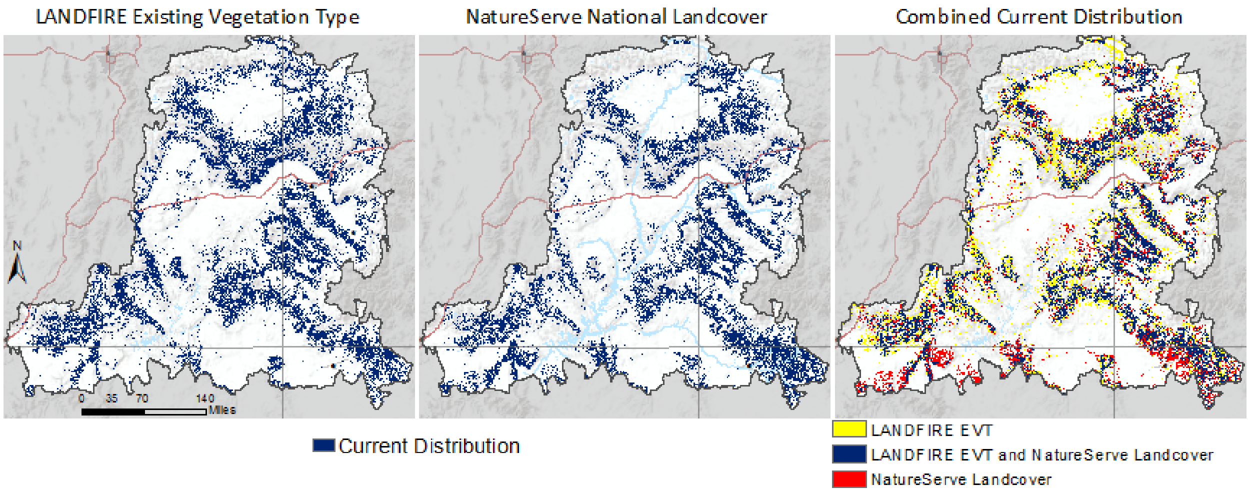


Climate Change
Fire Regime
Fire Frequency & Severity
Fire Suppression
Mechanical Removal
Development
Direct Take
Christmas trees
Firewood
Biofuel
Invasive Plants
Grazing
Precipitation
25-55 cm per year
Temperature
Soil Characteristics
Depth
Somewhat Shallow
Texture
From stony to clay
Soil Moisture
Somewhat Dry
Topography
Elevation
1,500-2,440 m
Direct Conversion and Degradation
Drought
Frosts act as controlling agents
Alter Community Composition
Fuel load and condition
Lower fire = woody component expands
Higher fire = transition to other community types
Alter Understory
Insects & Disease
Animal Herbivory
Removal of woody component
Colorado Plateau Pinyon-Juniper Woodlands
Jays & Nutcrackers
Pinyon Pine (*Pinus edulis*)
Utah Juniper (*Juniperus osteosperma*)
Change Agents
Natural Drivers
Conservation Element
Thick arrows denote components with available spatially explicit data – NOT importance

Results

MQ C1. Where is the current Colorado Plateau Pinyon-Juniper Woodlands community and what is its status?

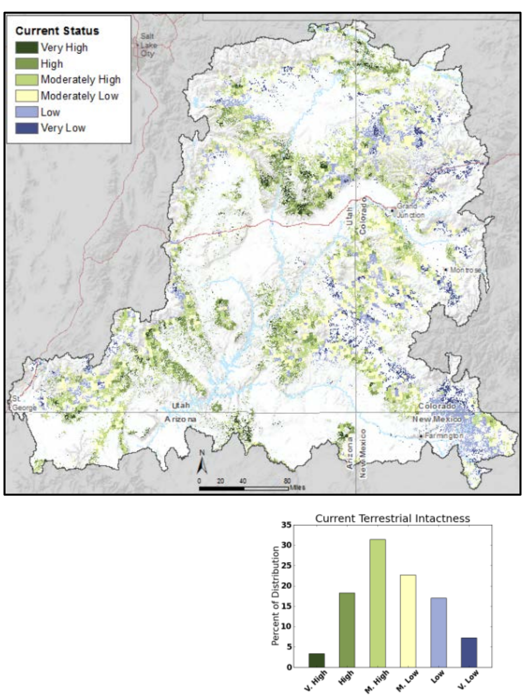
Distribution



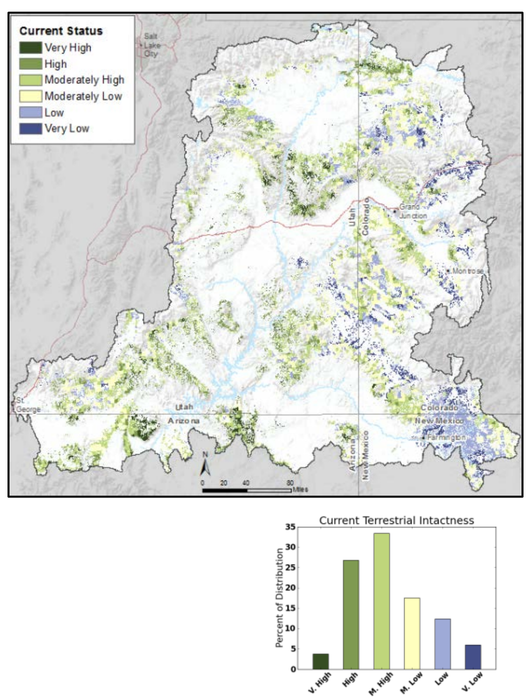
Vegetation Community	LANDFIRE Only (ac)	NatureServe Only (ac)	Both (ac)	Percent Overlap
Colorado Plateau Pinyon-Juniper Woodland	3,664,596	3,664,596	6,078,616	49.27

Status

LANDFIRE

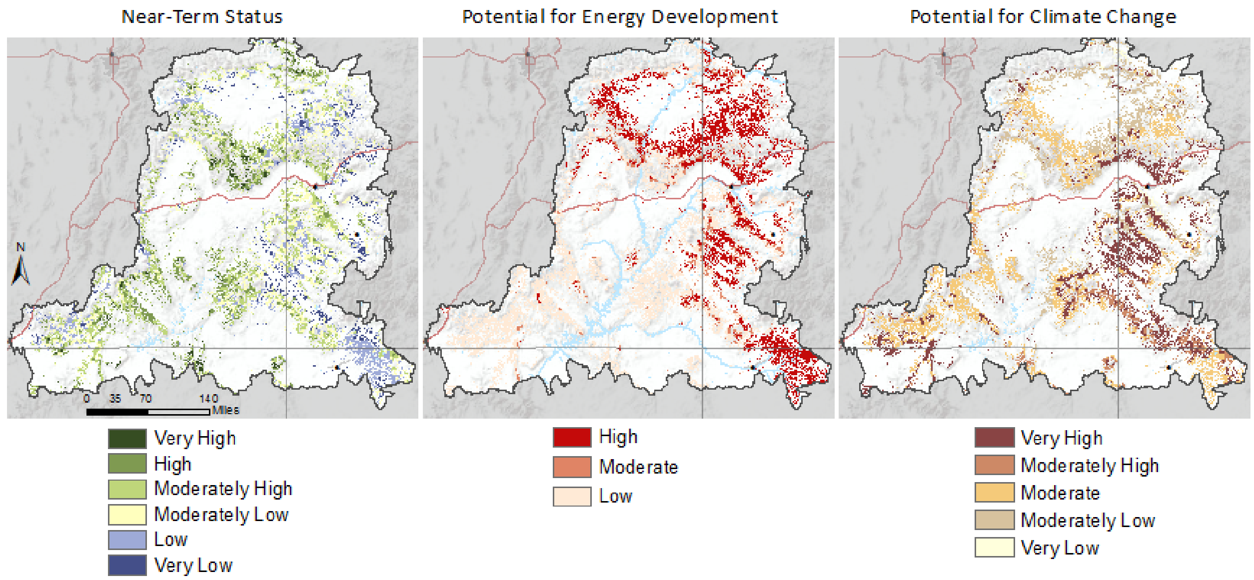


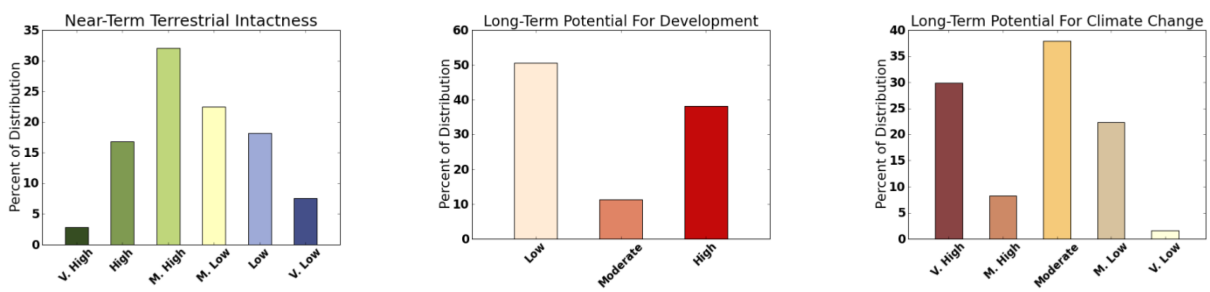
NatureServe



MQ C2. Where are Colorado Plateau Pinyon-Juniper Woodlands vulnerable to change agents in the future?

LANDFIRE Dataset

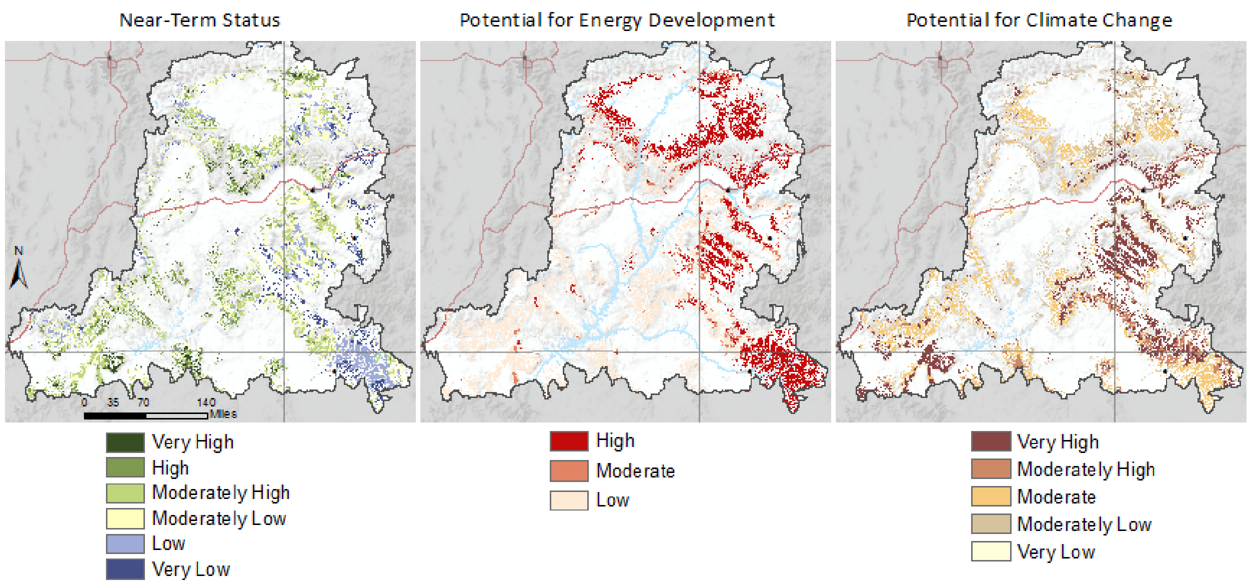


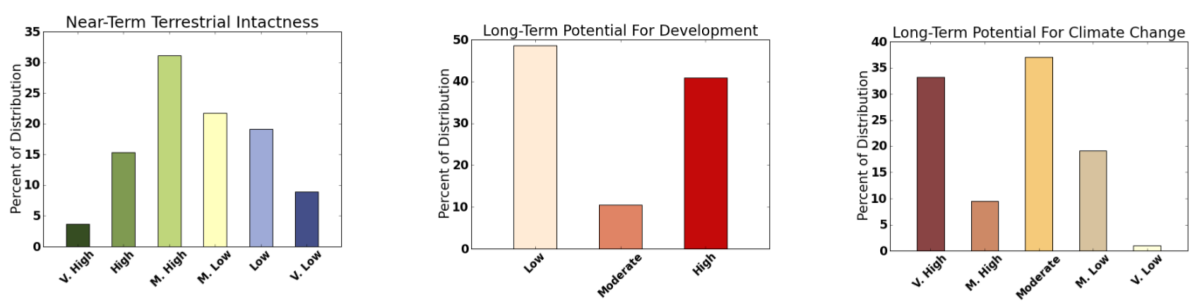


2025 Long Term Maximum Potential 2060

MQ C2. Where are Colorado Plateau Pinyon-Juniper Woodlands vulnerable to change agents in the future?

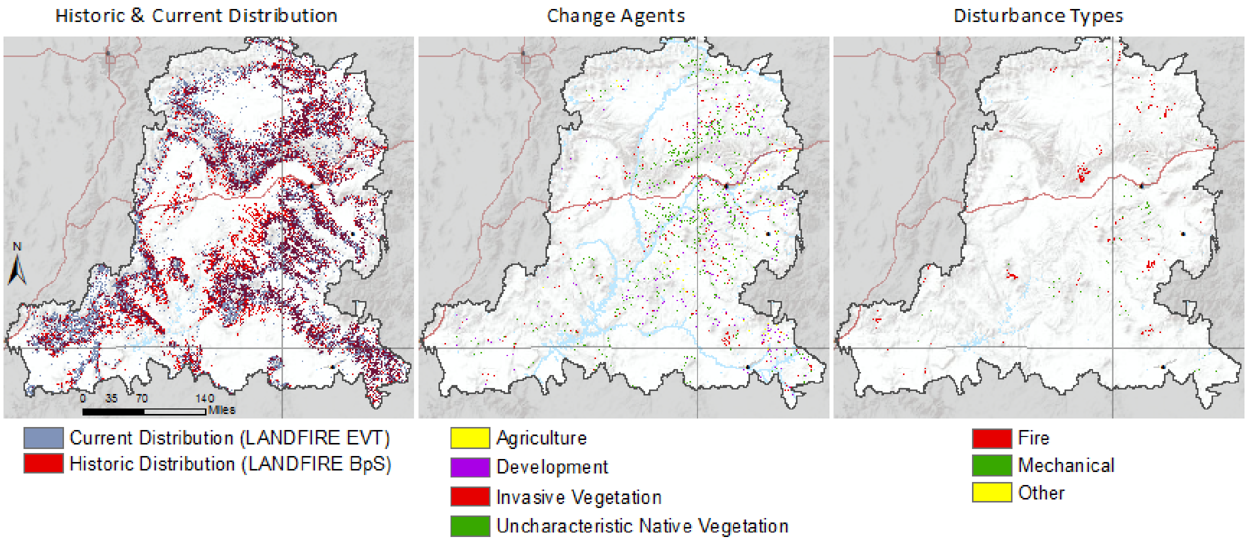
NatureServe Dataset





2025 Long Term Maximum Potential 2060

MQC3. What change agents have affected Colorado Plateau Pinyon-Juniper Woodlands?



Historic Change Agents (change from modeled reference condition [LANDFIRE BpS dataset]

Total BpS Area	Urban & Roads	Agriculture	Invasives	Unchar Native Veg	Total Changed	Percent
7,515,040	229,091	45,740	273,361	634,736	1,182,928	15.74%

Recent Disturbance (1999–2008)

Total BpS Area	Fire	Mechanical	Other	Total Disturbed	Percent
7,515,040	194,113	71,692	763	266,568	3.55%

Conceptual Model

There are six primary natural drivers (cyan boxes) for this ecological system including topography, soil characteristics, precipitation, temperature, insects and disease, and animal herbivory. Specific details on the various environmental conditions characterizing this system (blue text) are provided by NatureServe (2009). The important role jays and nutcrackers play in the life history of pinyon pine (*Pinus edulis*) is natural driver specific for that dominant species.

Climatic events (droughts and frosts) are believed to limit the distribution of this community. Pinyon-juniper shrublands occur at lower elevations than pinyon-juniper woodlands but these two communities largely overlap. The defining factor for woodlands versus shrublands is moisture – shrublands occur under drier conditions. As observed in pinyon-juniper woodlands, there are natural periods of range expansion of this ecological system followed by contraction due to climate stress and insect/disease vectors, especially where there are closed stands (LANDFIRE 2007). Close attention to climate change projections may be particularly important in defining where this community type can occur in the future.

Fire frequency is common but rarely burns more than a small area. Replacement fires are uncommon averaging a fire return interval of 100–500 years. Mixed severity fire, which occurs at the same fire return interval, is characterized as a mosaic of replacement and surface fires that occur over relatively small areas. Surface fires are more commonly where grasses are abundant (LANDFIRE 2007).

Livestock grazing and invasive grasses have altered the understory vegetation and, where fire has removed the woody cover, invasive grasses have been known to take hold eliminating woody vegetation altogether. Where long-term grazing has occurred, there are significantly fewer grasses and cacti and more forbs and shrubs present (Harris et al. 2003).

Drought stress and subsequent insect outbreaks have caused widespread mortality of pinyon pine throughout much of its range, especially on soil types that are more prone to moisture loss (Breshears et al. 2005, Mueller et al. 2005). Soils in regions of very high pinyon pine mortality are generally coarse, sandy, skeletal, with low fertility while rich in calcium (desert caliche layers). They have a torric moisture regime (hot and dry soils) and very little horizon development. Their large pores with little capillary forces promote rapid water evaporation or drainage rather than conservation leading to tree mortality.

For many years, large areas of pinyon-juniper shrublands have been converted to rangeland through mechanical disruption known as chaining. Although not as common as it once was, conversion of this woodland type for agricultural purposes still occurs. Mechanical removal and development (urban and energy) directly convert or degrade this system. Mechanical removal or disturbance of this community can also promote invasive grasses altering the system in significant ways. Direct harvest of the tree dominants in this community are also important change agents but more difficult to track with the data available.

Change agents impacting this ecological system accounted for in the REA process include Development (based on current and projected future extent of urban land cover) and recent disturbance (1999–2008) from Mechanical Removal, Fires, and Insects and Disease. Overall landscape intactness, which includes development from all sources (urban, agriculture, energy, and roads), invasive species, and habitat fragmentation, is used to describe the regional environment that contains this ecosystem type. Climate change projections (including precipitation and temperature changes as well as MAPSS modeling outputs) are also used to predict where existing pinyon-juniper shrublands may be under significant climate stress.

References Cited

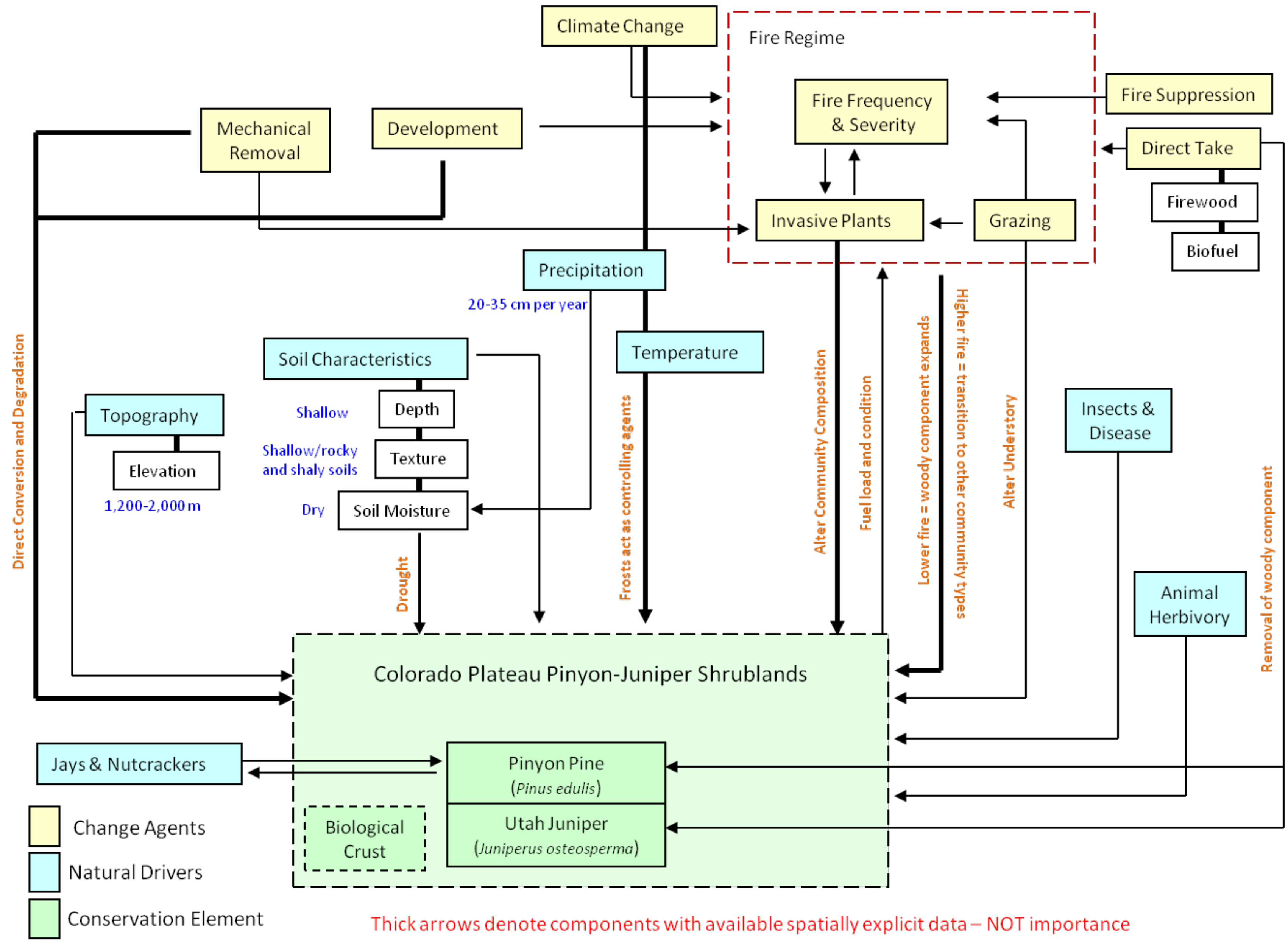
Breshears, D.D., N.S. Cobb, P.M. Price, C.D. Allen, R.G. Balice, W.H. Romme, J.H. Kastens, M.L. Floyd, J. Belnap, J.J. Anderson, O.B. Myers, and C.W. Meyer. 2005. Regional vegetation die-off in response to global change-type-drought. Proceedings of the National Academy of Sciences, USA. 102: 15144-15148.

Harris, A.T., G.P. Asner, and M.E. Miller. 2003. Changes in vegetation structure after long-term grazing in pinyon-juniper ecosystems: integrating imaging spectroscopy and field studies. Ecosystems 6: 368-383.

LANDFIRE Biophysical Setting Model. September 2007.

Mueller, R., C.M. Scudder, M.E. Porter, R.T. Trotter III, C.A. Gehring and T.G. Whitman. 2005. Differential tree mortality in response to severe drought: evidence for long-term vegetation shifts. Journal of Ecology 93: 1085-1093.

NatureServe. 2009. International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Database. Arlington, VA.



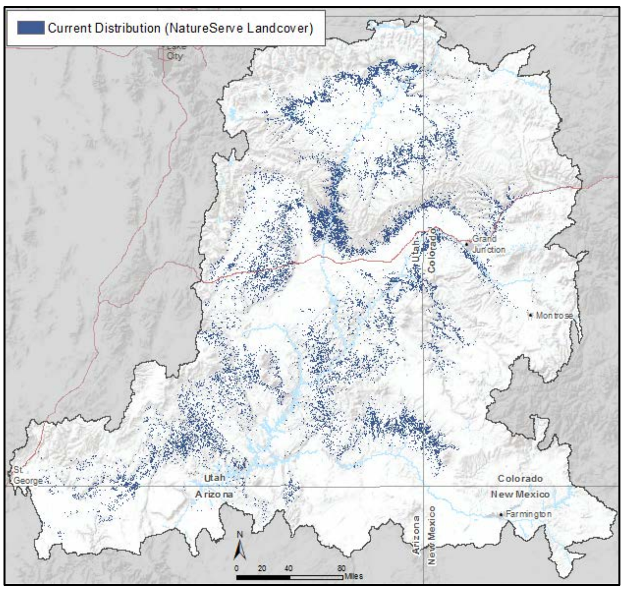
Climate Change
Fire Regime
Fire Frequency & Severity
Fire Suppression
Mechanical Removal
Development
Direct Take
Firewood
Biofuel
Invasive Plants
Grazing
Precipitation
20-35 cm per year
Soil Characteristics
Temperature
Topography
Elevation
1,200-2,000 m
Shallow
Depth
Shallow/rocky and shaly soils
Texture
Dry
Soil Moisture
Drought
Frosts act as controlling agents
Direct Conversion and Degradation
Alter Community Composition
Fuel load and condition
Lower fire = woody component expands
Higher fire = transition to other community types
Alter Understory
Insects & Disease
Animal Herbivory
Removal of woody component
Colorado Plateau Pinyon-Juniper Shrublands
Jays & Nutcrackers
Pinyon Pine (Pinus edulis)
Utah Juniper (Juniperus osteosperma)
Biological Crust
Change Agents
Natural Drivers
Conservation Element
Thick arrows denote components with available spatially explicit data – NOT importance

Results

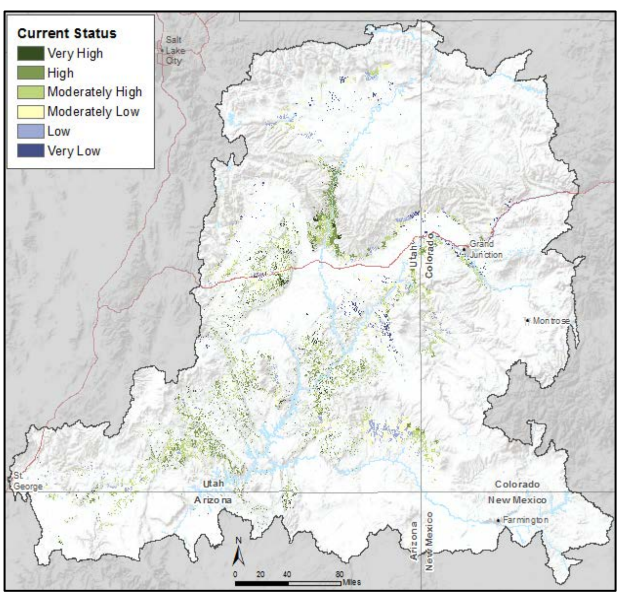
MQ C1. Where is the current Colorado Plateau Pinyon-Juniper Shrublands community and what is its status?

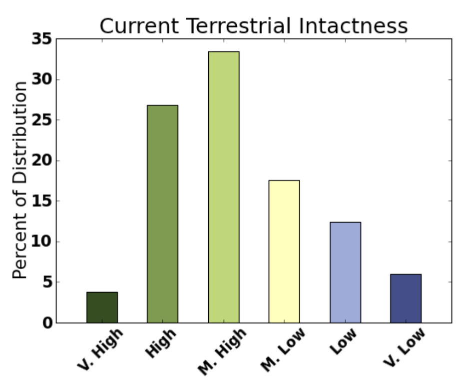
Vegetation Community	LANDFIRE Only (ac)	NatureServe Only (ac)	Both (ac)	Percent Overlap
Colorado Plateau Pinyon-Juniper Shrubland	In PJ Woodlands	2,694,089	0	0.00

Distribution



Status

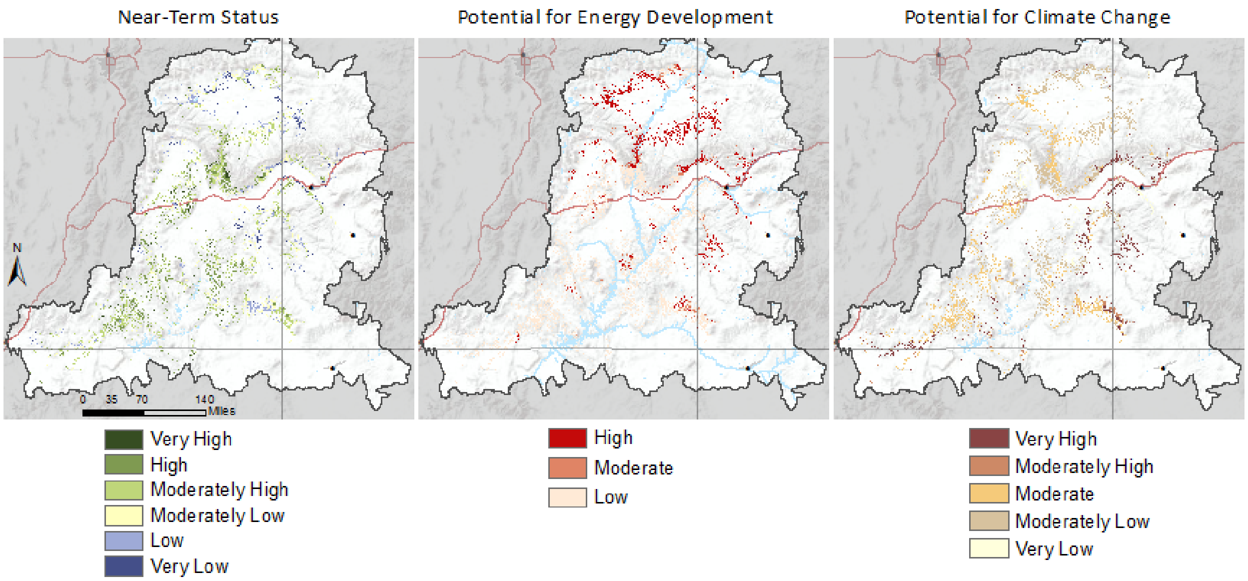


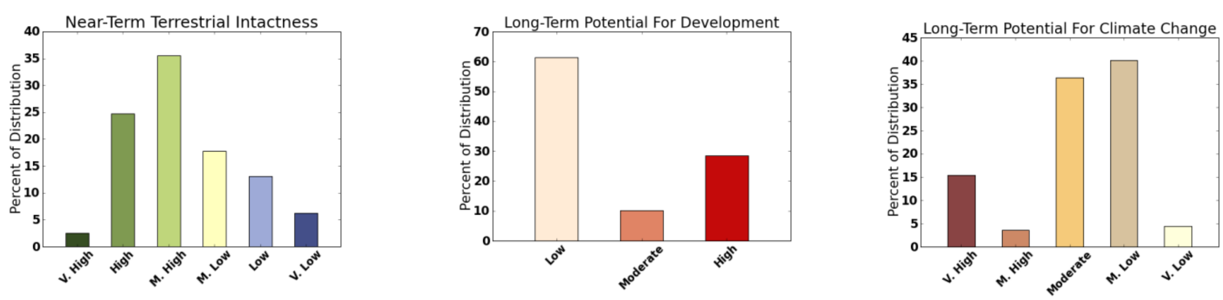


MQ C2. Where are Colorado Plateau Pinyon-Juniper Shrublands vulnerable to change agents in the future?

No LANDFIRE data for Pinyon-Juniper Shrublands

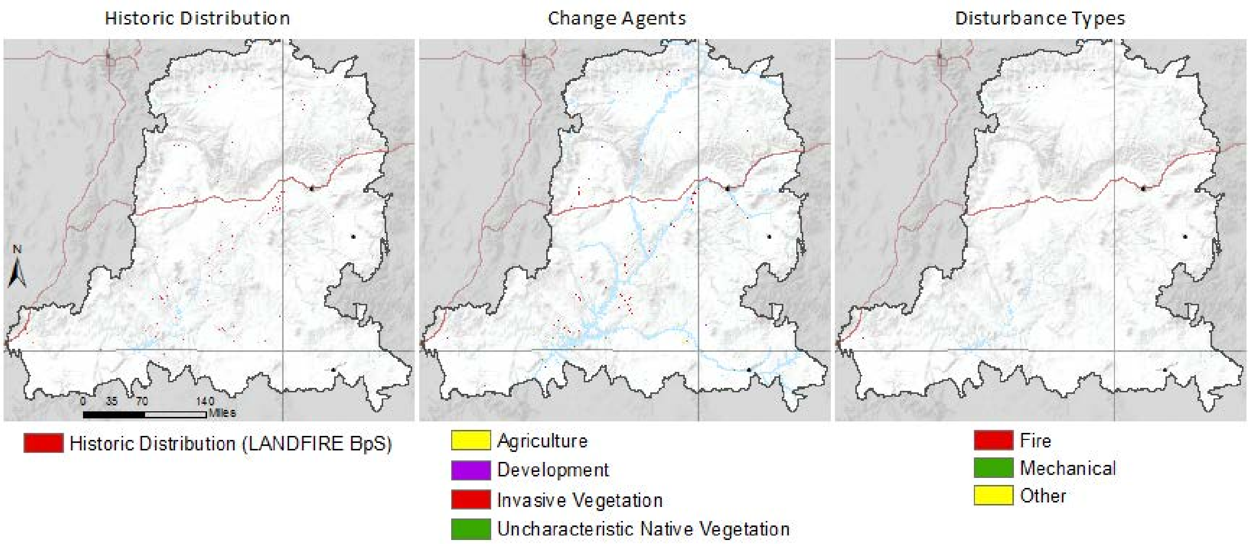
NatureServe Dataset





2025 Long Term Maximum Potential 2060

MQC3. What change agents have affected Colorado Plateau Pinyon-Juniper Shrublands?



Historic Change Agents

Total BpS Area	Urban & Roads	Agriculture	Invasives	Unchar Native Veg	Total Changed	Percent
94,447	5,076	2,269	21,091	9,736	38,172	40.42%

Recent Disturbance

Total BpS Area	Fire	Mechanical	Other	Total Disturbed	Percent
94,447	819	834	0	1,653	1.75%

Conceptual Model

There are six primary natural drivers (cyan boxes) for this ecological system including topography, soil characteristics, precipitation, temperature, insects and disease, and animal herbivory. Specific details on the various environmental conditions characterizing this system (blue text) are provided by NatureServe (2009) and LANDFIRE (2007).

Also called Wyoming big sagebrush semi-desert, inter-mountain basins big sagebrush shrubland is a drier system and more restricted in its environmental setting than sagebrush steppe ecosystems. Big sagebrush (*Artemsia tridentate ssp. wyomingensis*) is the signature species for this ecosystem and it is affected by a number of factors. Climatic events such as periods of excessive moisture (Sturges et al. 1984) as well as long droughts impact this and related species (Anderson and Inouye 2001). The Aroga moth (*Aroga websteri*) and leaf beetles *(Trirhabda pilosa*) can cause significant sagebrush mortality (Pringle 1960, Gates 1964). Mechanical removal or burning of this community to improve grazing conditions has numerous negative ecological consequences (Hormay 1992; Blaisdell et al. 1982; Harniss and Murray 1973). Mechanical removal/burning of this community can also promote invasive grasses altering the system even further.

Stand replacement fires can occur at mid- and late-developmental stages of this shrubland community with a mean fire return interval (FRI) of 500 years. Surface fires are generally uncommon (mean FRI of 200 years), especially where shrub density is low. Where woody encroachment is evident, fire return interval shortens to every 100–125 years. Scale of fire disturbance historically ranged from <10 acres to >1,000 acres with an average disturbance patch size of 250 acres (LANDFIRE 2007). Besides fire frequency, seasonality of fire is also important. Sagebrush generally responds favorably to spring fires, but fall fires tend to cause significant mortality in sagebrush. Recovery of big sagebrush after fire is slow. Fire suppression and livestock grazing has significantly degraded this ecological system throughout the Colorado Plateau (NatureServe 2009). In locations were fire suppression has been successful, woody encroachment (e.g. juniper and pine) has been significant. Due to the dynamic nature and interaction of many Colorado Plateau natural ecological systems and the challenge of accurately mapping vegetation using remote sensing, it is extremely difficult to track woody encroachment into this community over large geographic areas. Likewise, having more detailed data on grazing history and intensity would greatly improve the assessment of the overall condition of this community type. Both of these factors are reported to be extremely important for this community, but data do not exist to reliably assess and map their impacts.

Change agents impacting this ecological system accounted for in the REA process include Development (based on current and projected future extent of urban land cover) and recent disturbance (1999–2008) from Mechanical Removal, Fires, and Insects and Disease. Overall landscape intactness, which includes development from all sources (urban, agriculture, energy, and roads), invasive species, and habitat fragmentation, is used to describe the regional environment that contains this ecosystem type. Climate change projections (including precipitation and temperature changes as well as MAPSS modeling outputs) are also used to predict where current inter-mountain basins big sagebrush shrubland may be under significant climate stress.

References Cited

Anderson, J.E., and R.S. Inouye. 2001. Landscape-scale changes in plant species abundance and biodiversity of sagebrush steppe over 45 years. *Ecological Monographs* 71:531–556.

Blaisdell, J.P. 1953. Ecological effects of planned burning sagebrush-grass range on the upper Snake River Plains. Technical Bulletin #1075, U.S. Department of Agriculture, Washington, D.C. 34 pp.

Gates, D.H. 1964. Sagebrush infested by leaf defoliating moth. *Journal of Range Management* 17:209–210.

Harniss, R.O., and R.B. Murray. 1973. Thirty years of vegetal change following burning of sagebrush-grass range. *Journal of Range Management* 26:322–325.

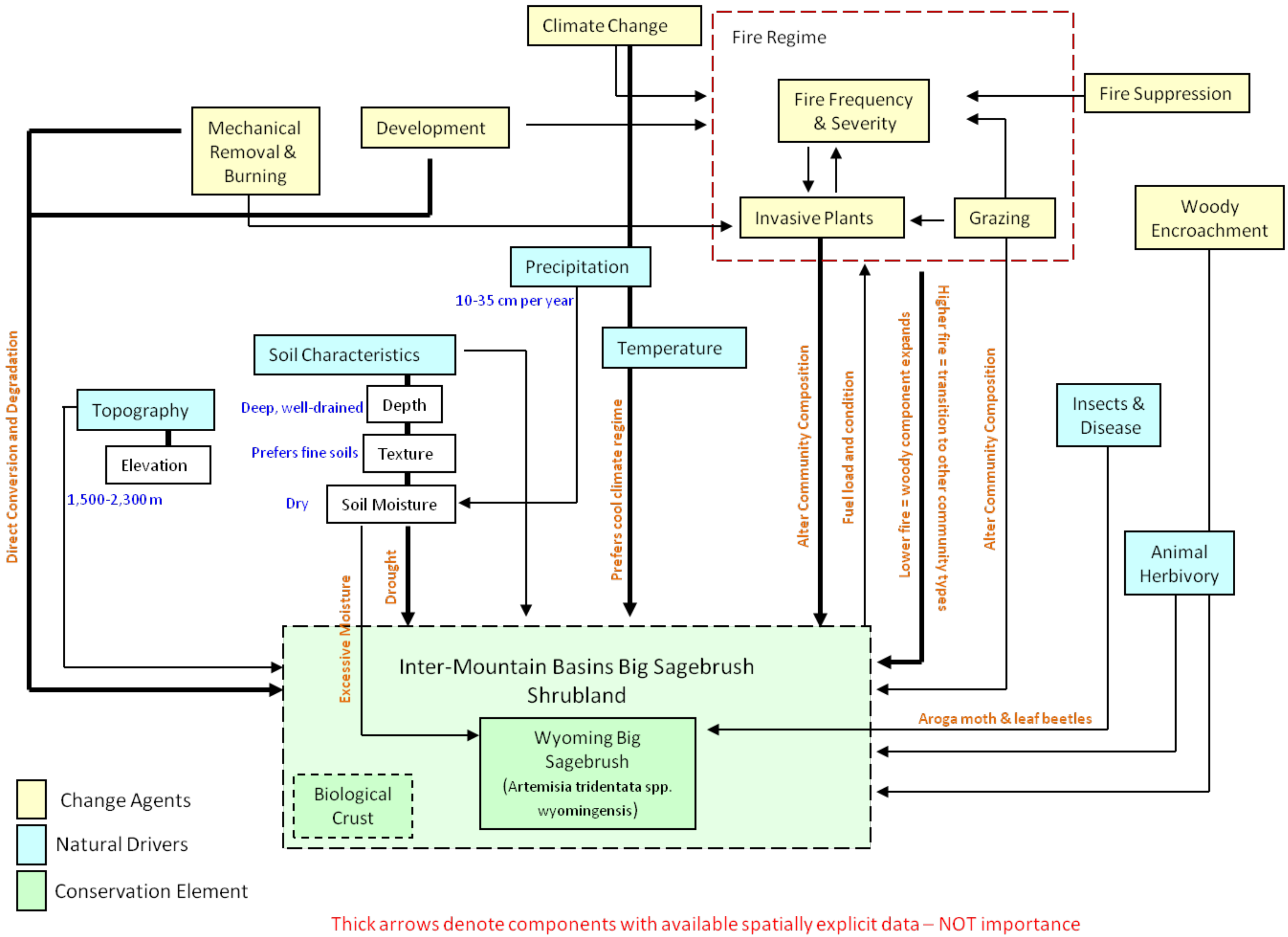
Hormay, A.L. 1970. Principles of rest-rotation grazing and multiple-use land management. USDI/USDA Handbook. 25 pp.

LANDFIRE Biophysical Setting Model. September 2007.

NatureServe. 2009. International ecological classification standard: Terrestrial ecological classifications. NatureServe Central Database. Arlington, VA.

Pringle, W.L. 1960. The effect of a leaf feeding beetle on big sagebrush in British Columbia. *Journal of Range Management* 13:139–142.

Sturges, D.L., and D.L. Nelson. 1986. Snow depth and incidence of a snowmold disease on mountain big sage. Symposium on the Biology of *Artemisia* and *Chrysothamnus*. July 9–13, 1984, Provo, Utah. General Technical Report, INT-200, 1986, Intermountain Forestry and Range Experimental Station, Ogden, Utah.

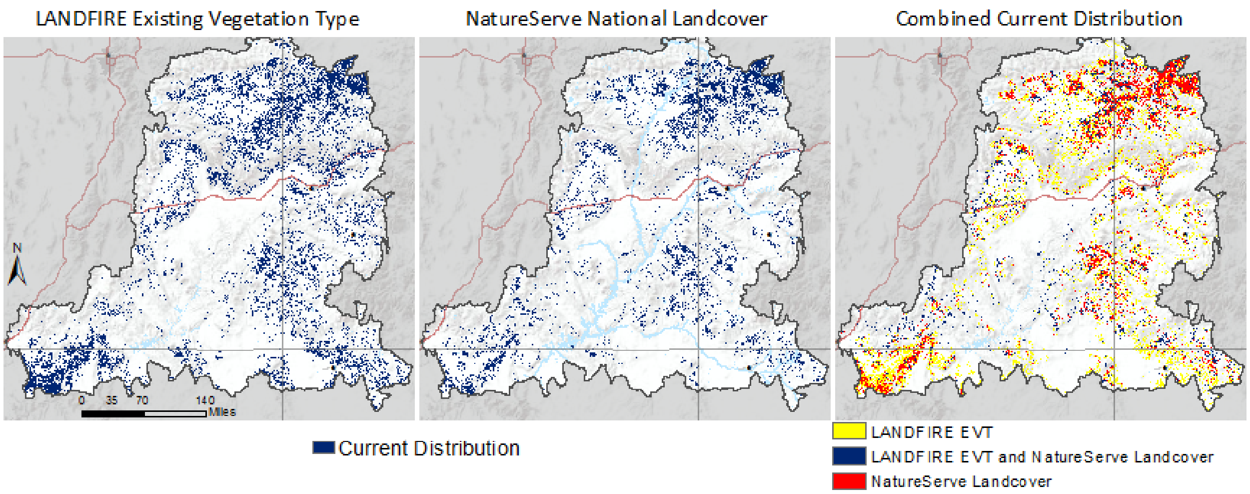


Climate Change
Fire Regime
Fire Frequency & Severity
Fire Suppression
Mechanical Removal & Burning
Development
Invasive Plants
Grazing
Woody Encroachment
Precipitation
10-35 cm per year
Temperature
Soil Characteristics
Depth
Deep, well-drained
Texture
Prefers fine soils
Soil Moisture
Dry
Topography
Elevation
1,500-2,300 m
Direct Conversion and Degradation
Excessive Moisture
Drought
Prefers cool climate regime
Alter Community Composition
Fuel load and condition
Lower fire = woody component expands
Higher fire = transition to other community types
Alter Community Composition
Insects & Disease
Animal Herbivory
Aroga moth & leaf beetles
Inter-Mountain Basins Big Sagebrush Shrubland
Wyoming Big Sagebrush (Artemisia tridentata spp. wyomingensis)
Biological Crust
Change Agents
Natural Drivers
Conservation Element
Thick arrows denote components with available spatially explicit data – NOT importance

Results

MQ C1. Where is existing Inter-Mountain Basins Big Sagebrush Shrubland and what is its status?

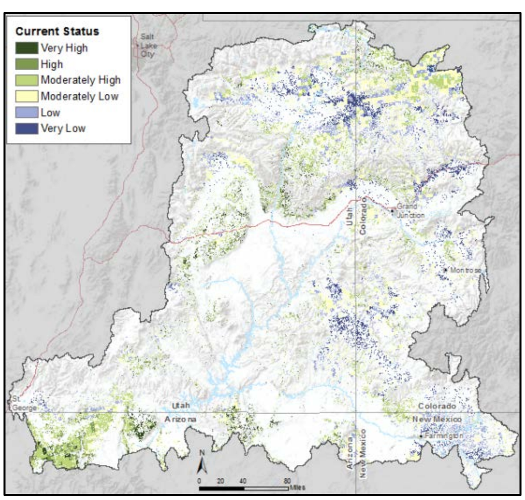
Distribution

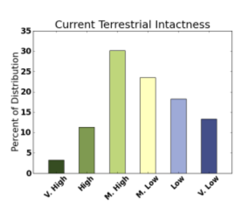


Vegetation Community	LANDFIRE Only (ac)	NatureServe Only (ac)	Both (ac)	Percent Overlap
Inter-Mountains Basins Big Sagebrush Shrubland	3,970,331	1,542,766	2,370,353	30.07

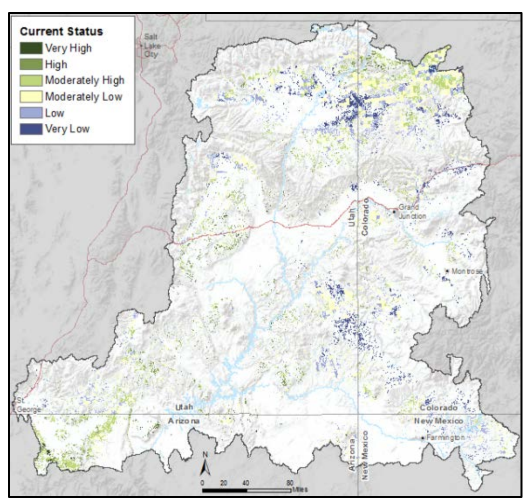
Status

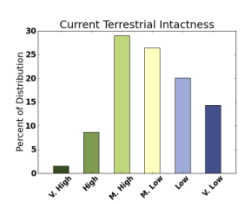
LANDFIRE





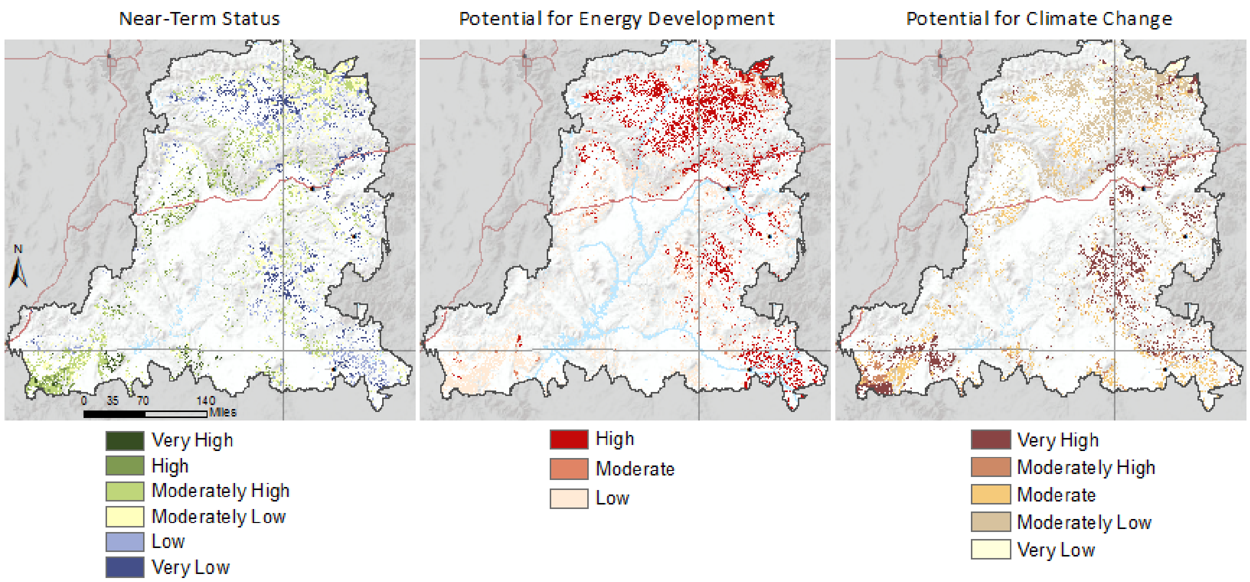
NatureServe

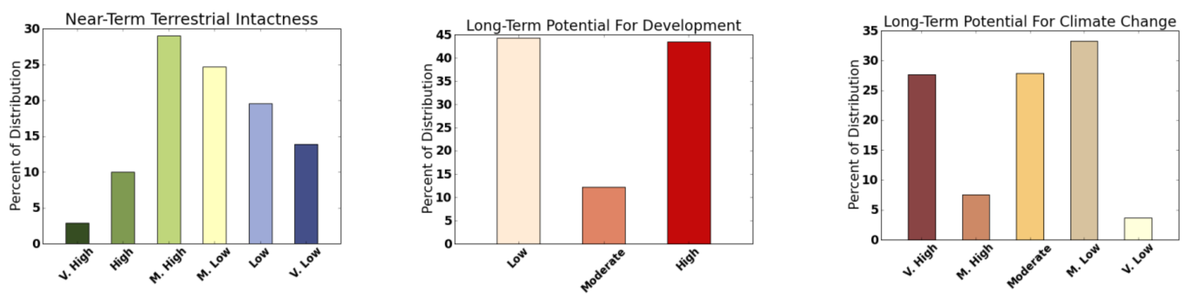




MQ C2. Where are Inter-Mountain Basins Big Sagebrush Shrublands vulnerable to change agents in the future?

LANDFIRE

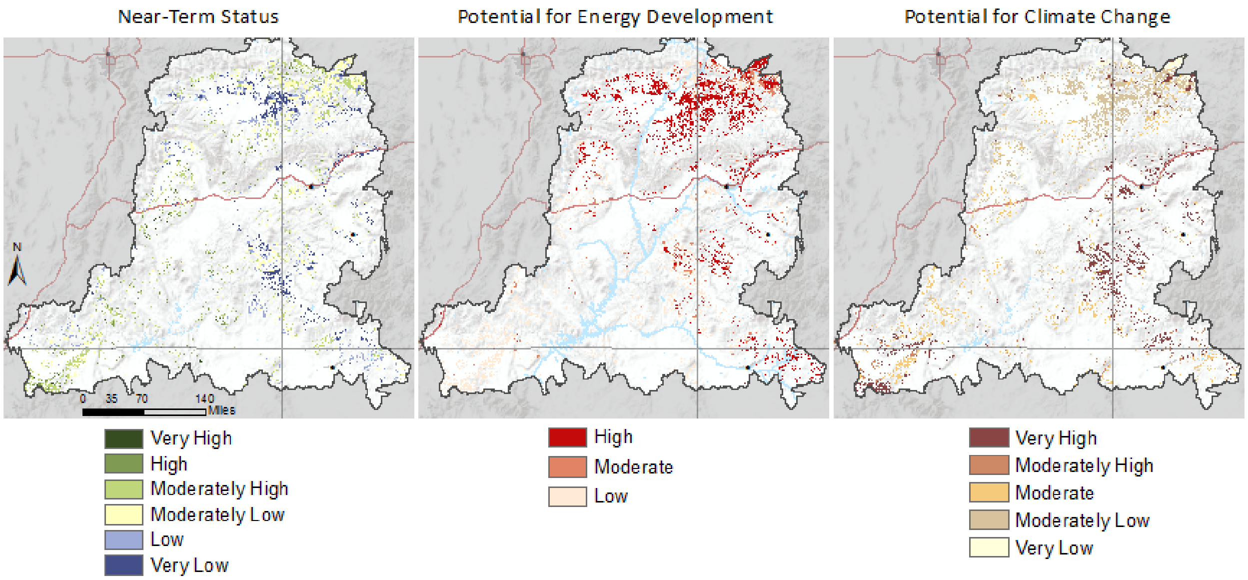


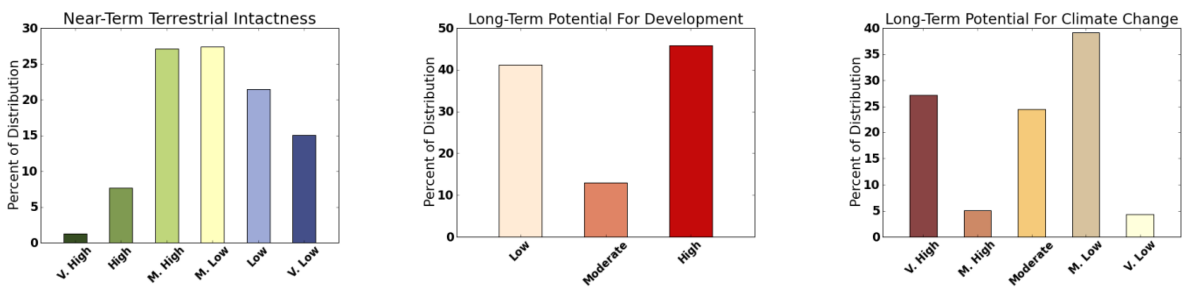


2025 Long Term Maximum Potential 2060

MQ C2. Where are Inter-Mountain Basins Big Sagebrush Shrublands vulnerable to change agents in the future?

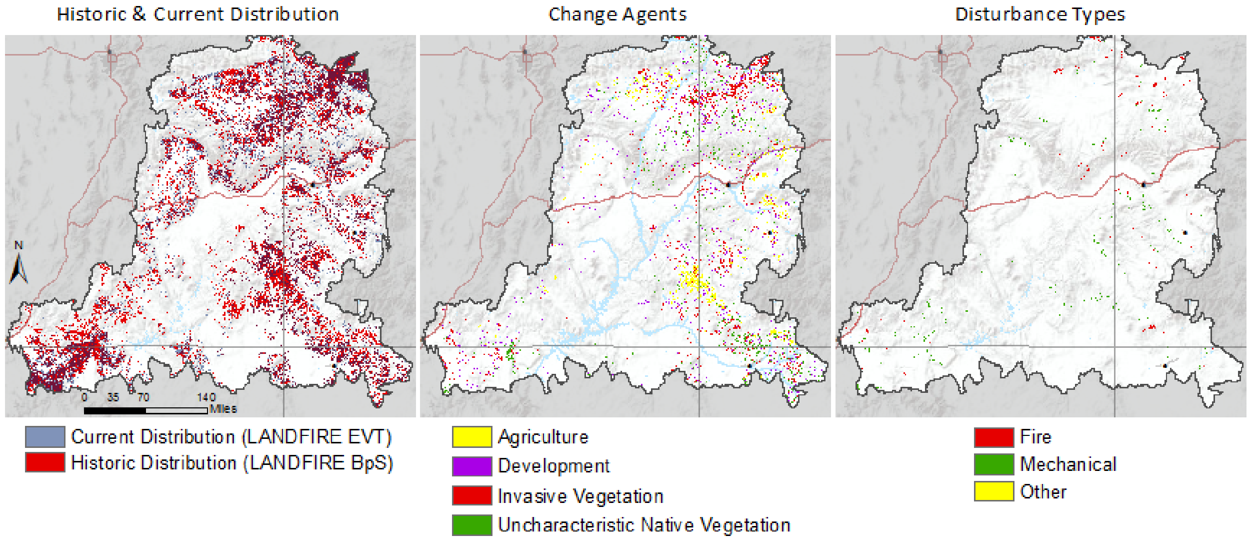
NatureServe





2025 Long Term Maximum Potential 2060

MQC3. What change agents have affected Inter-Mountain Basins Big Sagebrush Shrublands?



Historic Change Agents

Total BpS Area	Urban & Roads	Agriculture	Invasives	Unchar Native Veg	Total Changed	Percent
8,228,472	565,083	494,772	845,638	571,744	2,477,237	30.11%

Recent Disturbance

Total BpS Area	Fire	Mechanical	Other	Total Disturbed	Percent
8,228,472	138,909	231,435	128	370,472	4.50%

Inter-Mountain Basins Montane Sagebrush Steppe

Conceptual Model

There are six primary natural drivers (cyan boxes) for this ecological system including topography, soil characteristics, precipitation, temperature, insects and disease, and animal herbivory. Specific details on the various environmental conditions characterizing this system (blue text) are provided by NatureServe (2009), Tart (1996), and LANDFIRE (2007).

Mountain sagebrush (*Artemsia tridentata ssp. vaseyana*) is the signature species for this ecosystem and it is affected by a number of factors. Climatic events such as periods of excessive moisture (Sturges et al. 1984) as well as droughts impact this and related species (Anderson and Inouye 2001). The Aroga moth (*Aroga websteri*) and leaf beetles (*Trirhabda pilosa*) can cause significant sagebrush mortality (Pringle 1960, Gates 1964). Mechanical removal or burning of this community to improve grazing conditions has numerous negative ecological consequences (Hormay 1992, Blaisdell et al. 1982, Harniss and Murray 1973). Mechanical removal/burning of this community can also promote invasive grasses altering the system even further.

Because it occupies many different kinds of physical zones, the natural fire regime for this community is complex to describe. Mountain big sagebrush historically experienced stand replacing fire with a mean of 10 years at the ponderosa pine ecotone, 40 or more years at the Wyoming big sagebrush ecotone, and up to 80 years where low sagebrush makes up a high proportion of the landscape. LANDFIRE (2007) reported a replacement fire return interval for this community at 40–80 years with a mean of 50 years with the scale of fire disturbance historically ranging from <10 acres to >1,000 acres. Besides fire frequency, seasonality of fire is also important. Sagebrush generally responds favorably to spring fires, but fall fires tend to cause significant mortality. Fire suppression and livestock grazing has significantly degraded this ecological system throughout the Colorado Plateau (NatureServe 2009). In locations were fire suppression has been successful, woody encroachment (e.g. juniper and pinyon pine) has been significant. Due to the dynamic nature and interaction of many Colorado Plateau natural ecological systems and the challenge of accurately mapping vegetation using remote sensing, it is extremely difficult to track woody encroachment into this community over large geographic areas. Likewise, having more detailed data on grazing history and intensity would greatly improve assessing the overall condition of this community type. Both of these factors are reported to be extremely important for this community, but data do not exist to reliably assess and map their impacts.

Change agents affecting this ecological system covered in the REA process include Development (based on current and projected future extent of urban land cover) and recent disturbance (1999–2008) from Mechanical Removal, Fires, and Insects and Disease. Mechanical removal or disturbance of this community can also promote invasive grasses that can alter the system significantly. Overall landscape intactness, which includes development from all sources (urban, agriculture, energy, and roads), invasive species, and habitat fragmentation, is used to describe the regional environment that contains this ecosystem type. Climate change projections (including precipitation and temperature changes as well as MAPSS modeling outputs) are also used to predict where current inter-mountain basins montane sagebrush steppe may be under significant climate stress.

References Cited

Anderson, J.E., and R.S. Inouye. 2001. Landscape-scale changes in plant species abundance and biodiversity of sagebrush steppe over 45 years. *Ecological Monographs* 71:531–556.

Blaisdell, J. P. 1953. Ecological effects of planned burning sagebrush-grass range on the upper Snake River Plains. Technical Bulletin #1075, U.S. Department of Agriculture, Washington, D.C. 34 pp.

Gates, D. H. 1964. Sagebrush infested by leaf defoliating moth. *Journal of Range Management* 17:209–210.

Harniss, R.O., and R.B. Murray. 1973. Thirty years of vegetal change following burning of sagebrush-grass range. *Journal of Range Management* 26:322–325.

Hormay, A.L. 1970. Principles of rest-rotation grazing and multiple-use land management. USDI/USDA Handbook. 25 pp.

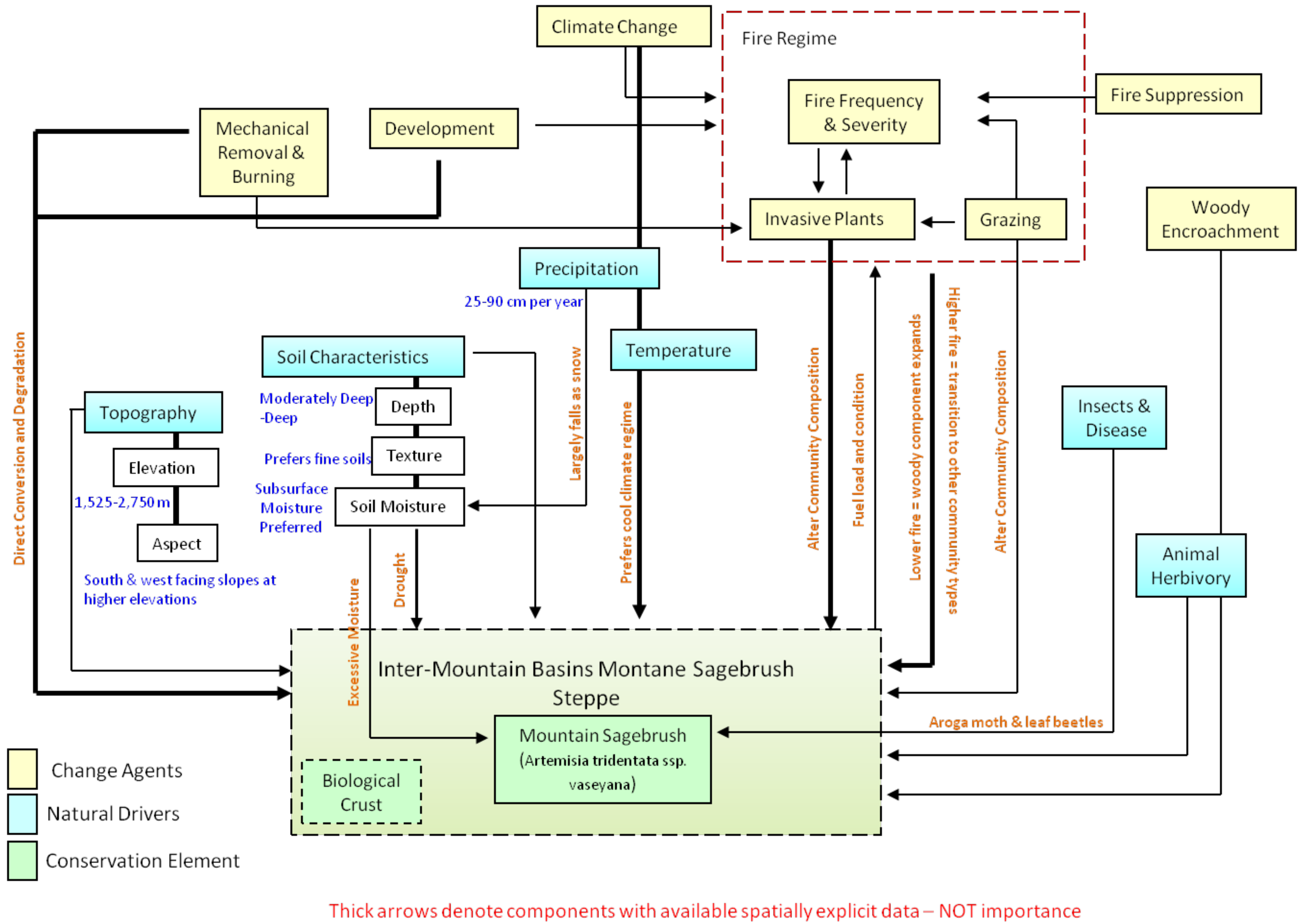
LANDFIRE Biophysical Setting Model. September 2007.

NatureServe. 2009. International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Database. Arlington, VA.

Pringle, W.L. 1960. The effect of a leaf feeding beetle on big sagebrush in British Columbia. *Journal of Range Management* 13:139–142.

Sturges, D.L., and D.L. Nelson. 1986. Snow depth and incidence of a snowmold disease on mountain big sage. Symposium on the Biology of *Artemisia* and *Chrysothamnus*. July 9–13, 1984, Provo, Utah. General Technical Report INT-200, 1986, Intermountain Forestry and Range Experimental Station, Ogden, Utah.

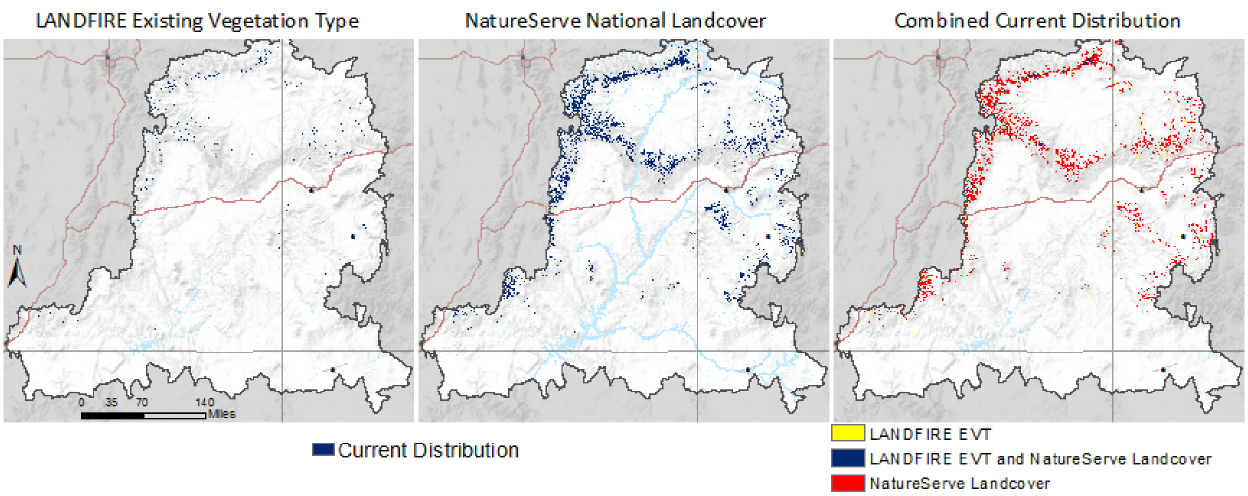
Tart, D.L. 1996. Big sagebrush plant associations of the Pinedale Ranger District, Pinedale, Wyoming. U.S. Forest Service, Bridger-Teton National Forest, Jackson, Wyoming. 97 pp.


Climate Change
Fire Regime
Fire Frequency & Severity
Fire Suppression
Mechanical Removal & Burning
Development
Invasive Plants
Grazing
Woody Encroachment
Precipitation
25-90 cm per year
Soil Characteristics
Temperature
Direct Conversion and Degradation
Largely falls as snow
Prefers cool climate regime
Alter Community Composition
Fuel load and condition
Lower fire = woody component expands
Higher fire = transition to other community types
Alter Community Composition
Topography
Moderately Deep -Deep
Depth
Texture
Prefers fine soils
Subsurface Moisture Preferred
Soil Moisture
Elevation
1,525-2,750 m
Aspect
South & west facing slopes at higher elevations
Insects & Disease
Animal Herbivory
Drought
Excessive Moisture
Inter-Mountain Basins Montane Sagebrush Steppe
Mountain Sagebrush (Artemisia tridentata ssp. vaseyana)
Aroga moth & leaf beetles
Biological Crust
Change Agents
Natural Drivers
Conservation Element
Thick arrows denote components with available spatially explicit data – NOT importance

Results

MQ C1. Where is existing Inter-Mountain Basins Montane Sagebrush Steppe and what is its status?

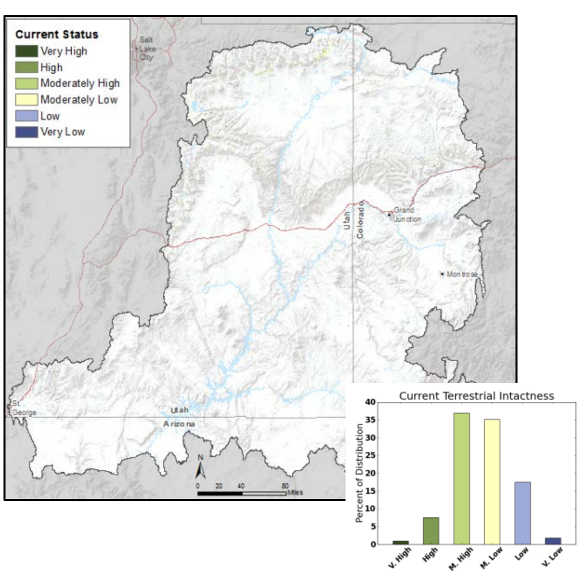
Distribution



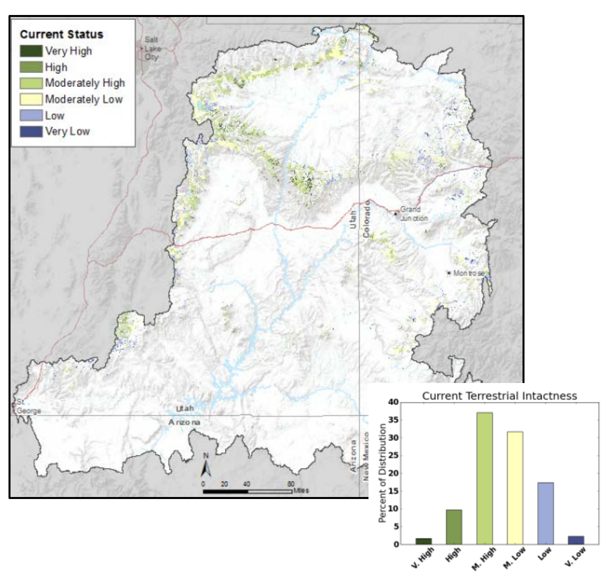
Vegetation Community	LANDFIRE Only (ac)	NatureServe Only (ac)	Both (ac)	Percent Overlap
Inter-Mountain Basins Montane Sagebrush Steppe	61,215	1,550,837	115,313	6.68

Status

LANDFIRE

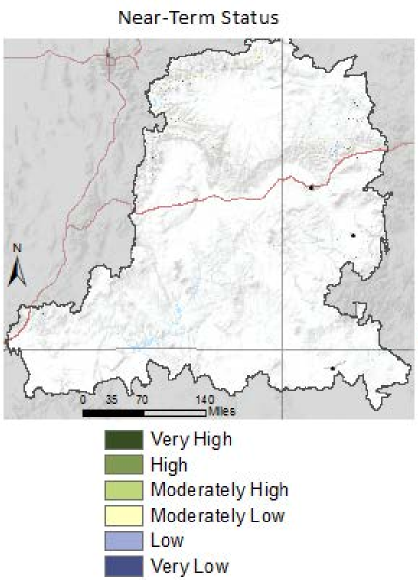


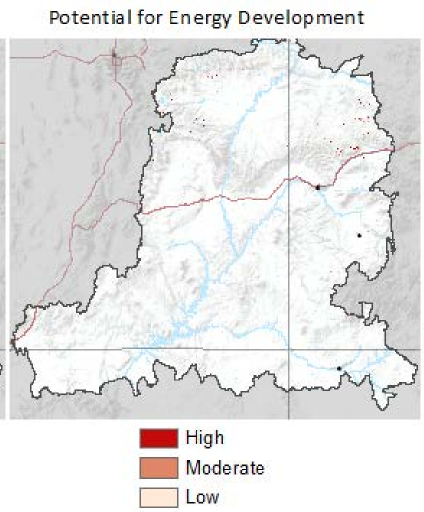
NatureServe

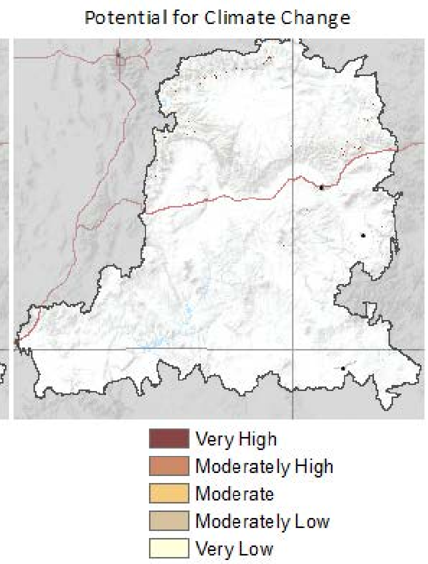


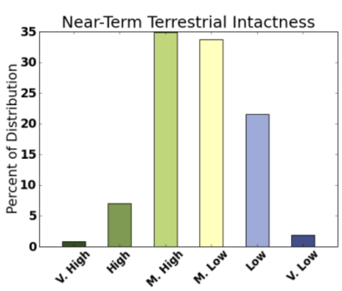
MQ C2. Where is Inter-Mountain Basins Montane Sagebrush Steppe vulnerable to change agents in the future?

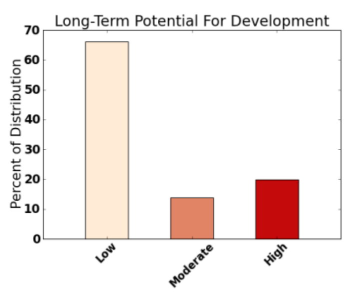
LANDFIRE

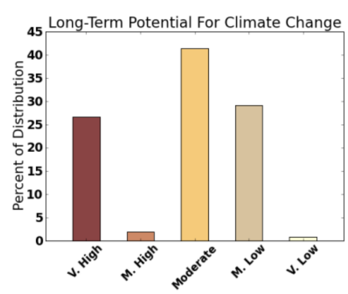








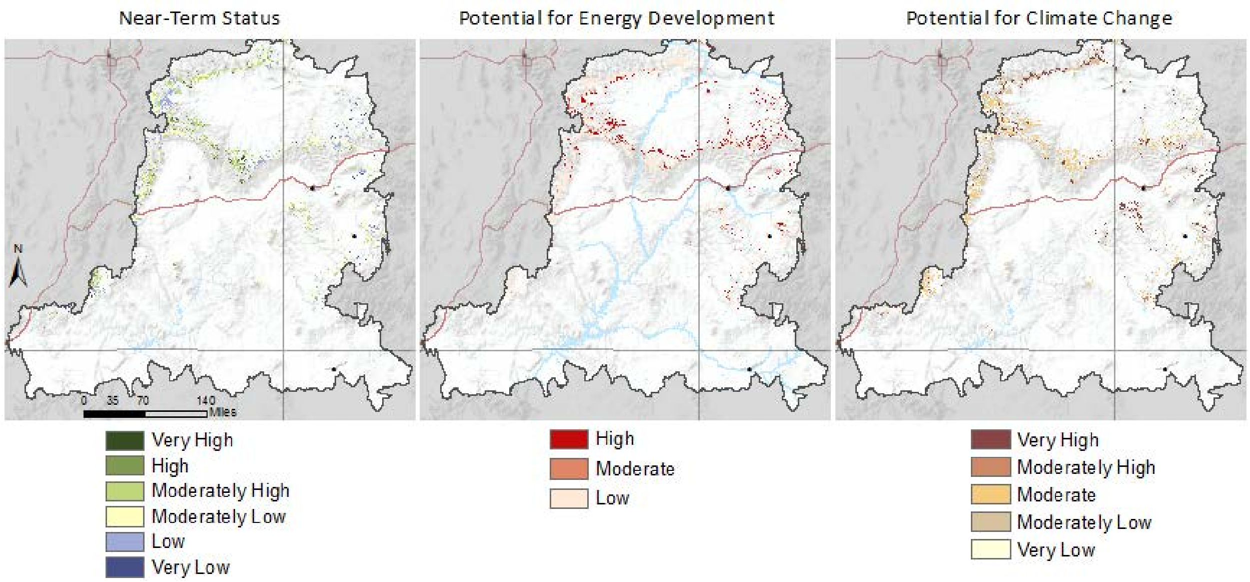


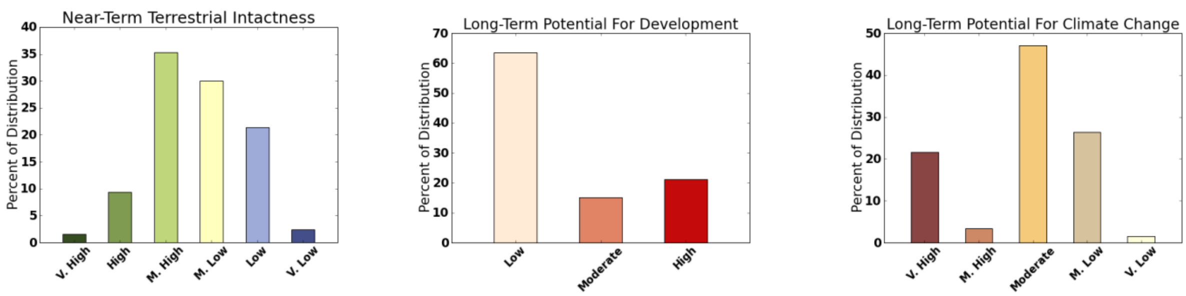


2025 Long Term Maximum Potential 2060

MQ C2. Where is Inter-Mountain Basins Montane Sagebrush Steppe vulnerable to change agents in the future?

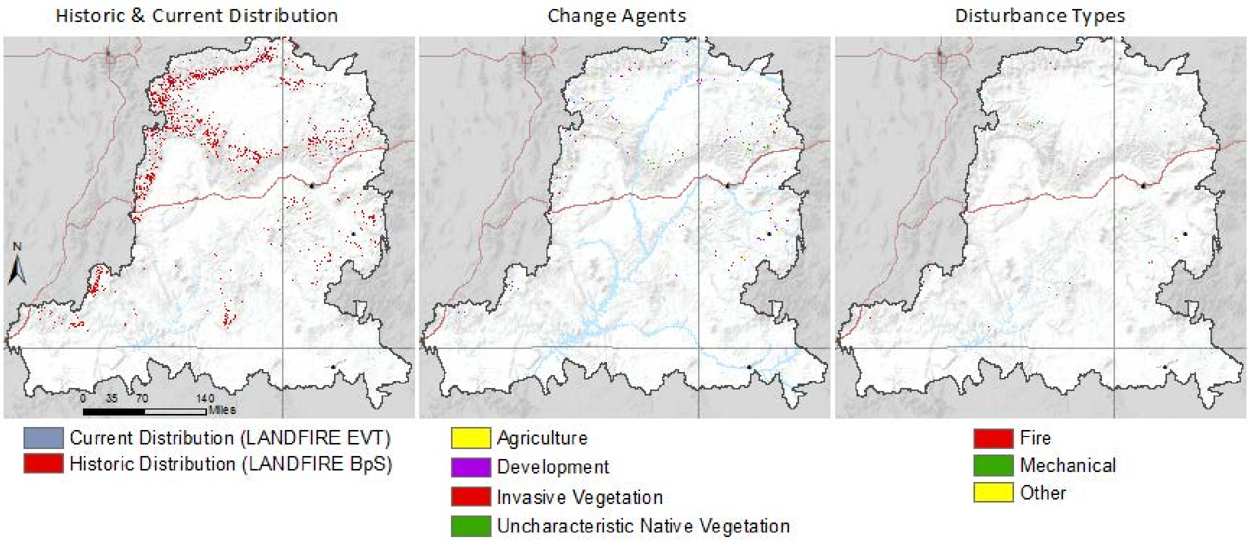
NatureServe





2025 Long Term Maximum Potential 2060

MQC3. What change agents have affected Inter-Mountain Basins Montane Sagebrush Steppe?



Historic Change Agents

Total BpS Area	Urban & Roads	Agriculture	Invasives	Unchar Native Veg	Total Changed	Percent
1,029,623	77,252	17,870	26,342	38,314	159,778	15.52%

Recent Disturbance

Total BpS Area	Fire	Mechanical	Other	Total Disturbed	Percent
1,029,623	28,507	13,877	235	42,619	4.14%

Conceptual Model

There are six primary natural drivers (cyan boxes) for this ecological system including topography, soil characteristics, precipitation, temperature, insects and disease, and animal herbivory. Specific details on the various environmental conditions characterizing this system (blue text) are provided by NatureServe (2009) and LANDFIRE (2007).

Rocky Mountain Gambel Oak-Mixed Montane Shrubland is a large patch shrubland community occurring along the foothills of the southern Rocky Mountains and the Colorado Plateau. Gambel oak (*Quercus gambelii*) is the signature species forming a broadleaved canopy, sometimes forming dense thickets. Numerous other shrubs and grasses comprise the plant community with an herbaceous layer covering as much as 40% of the area. In this semi-arid system, moisture is usually delivered as winter snow or late fall rains. Plants are adapted to extreme summer and winter temperatures.

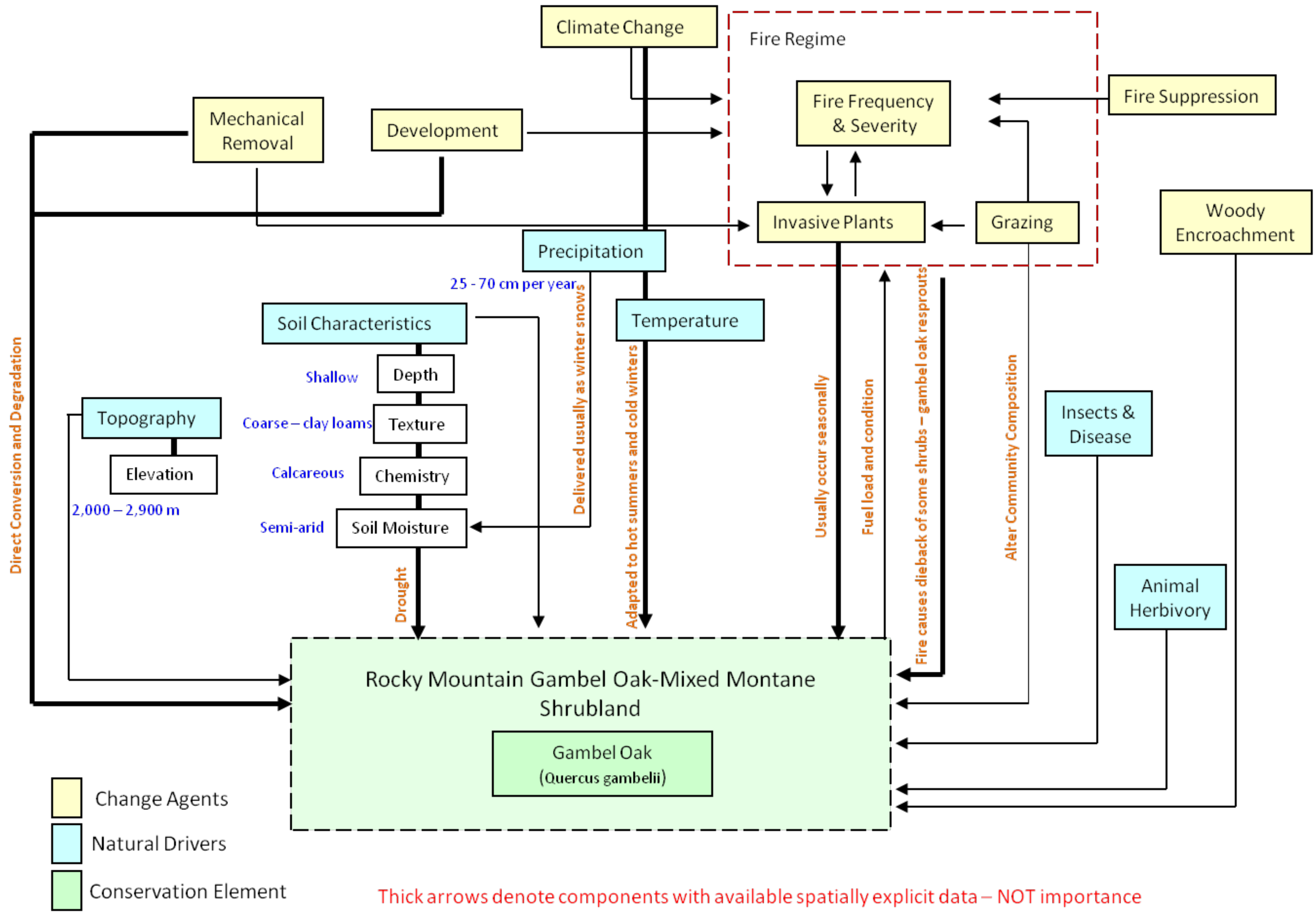
The primary natural disturbance agent is replacement fire, which often results in >75% top kill. Gambel oak responds with extensive sprouting after fire and larger individuals often survive the burn. Mean fire interval for replacement or mixed severity is 35–100 years. Non-native invasive grasses can follow fire, but they are sometimes only expressed seasonally, partially due to the remaining, post-fire resilient woody vegetation. Scale of fire events ranges from 10s to 1,000s of acres (LANDFIRE 2007). More widespread disturbance covering many thousands of acres is the result of periodic, prolonged drought. Livestock grazing occurs in this ecosystem type and management has been used to increase forage for livestock through mechanical treatment followed by goat grazing (Davis et al. 1975). In some areas where disturbance has been absent for long periods, this ecological system can be viewed as a seral stage to more forest species such as Ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*) and white fir (*Abies concolor,* NatureServe 2009). Change agents affecting this ecological system accounted for in the REA process include Development (based on current and projected future extent of urban land cover) and recent disturbance (1999–2008) from Mechanical Treatment, Fires, and Insects and Disease. Overall landscape intactness, which includes development from all sources (urban, agriculture, energy, and roads), invasive species, and habitat fragmentation, is used to describe the regional environment that contains this ecosystem type. Climate change projections (including precipitation and temperature changes as well as MAPSS model outputs) were also used to predict where this community may be under significant future climate stress.

References Cited

Davis, G.G., L.E. Bartel, and C.W. Cook. 1975. Control of gambel oak sprouts by goats. Journal of Rangeland Management 28(3): 216-218.

LANDFIRE Biophysical Setting Model. September 2007.

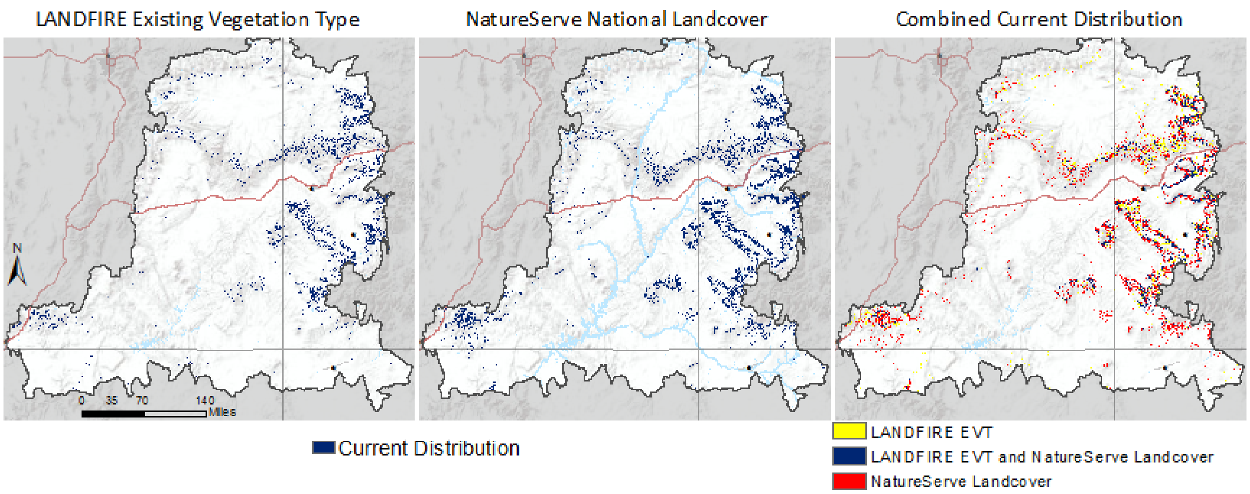
NatureServe. 2009. International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Database. Arlington, VA.


Climate Change
Fire Regime
Fire Frequency & Severity
Fire Suppression
Mechanical Removal
Development
Invasive Plants
Grazing
Woody Encroachment
Precipitation
25 - 70 cm per year
Soil Characteristics
Temperature
Shallow
Depth
Coarse – clay loams
Texture
Calcareous
Chemistry
Semi-arid
Soil Moisture
Topography
Elevation
2,000 – 2,900 m
Direct Conversion and Degradation
Delivered usually as winter snows
Adapted to hot summers and cold winters
Usually occur seasonally
Fuel load and condition
Fire causes dieback of some shrubs – gambel oak resprouts
Alter Community Composition
Drought
Insects & Disease
Animal Herbivory
Rocky Mountain Gambel Oak-Mixed Montane Shrubland
Gambel Oak
(Quercus gambelii)
Change Agents
Natural Drivers
Conservation Element
Thick arrows denote components with available spatially explicit data – NOT importance

Results

MQ C1. Where is existing Rocky Mountain Gambel Oak-Mixed Montane Shrubland and what is its status?

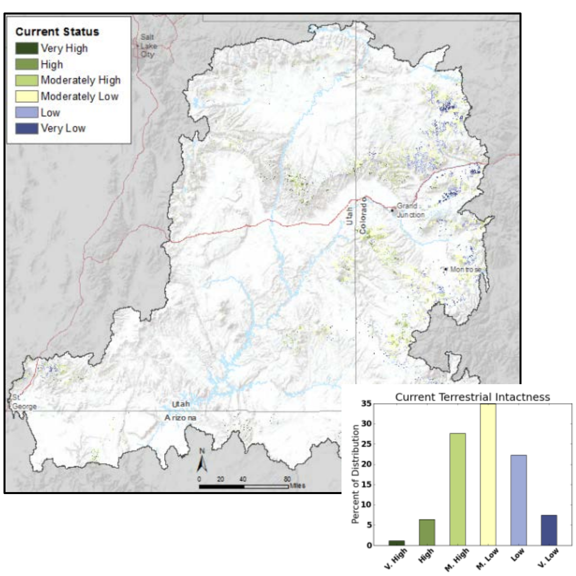
Distribution



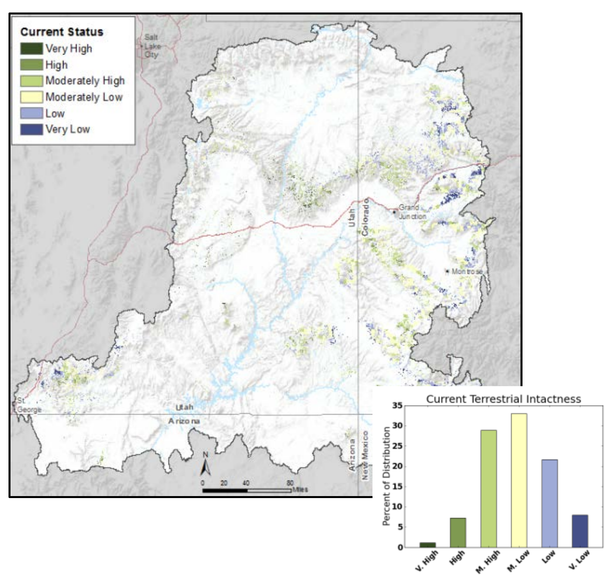
Vegetation Community	LANDFIRE Only (ac)	NatureServe Only (ac)	Both (ac)	Percent Overlap
Rocky Mountain Gambel Oak-Mixed Montane Shrubland	633,644	1,423,998	659,513	24.27

Status

LANDFIRE

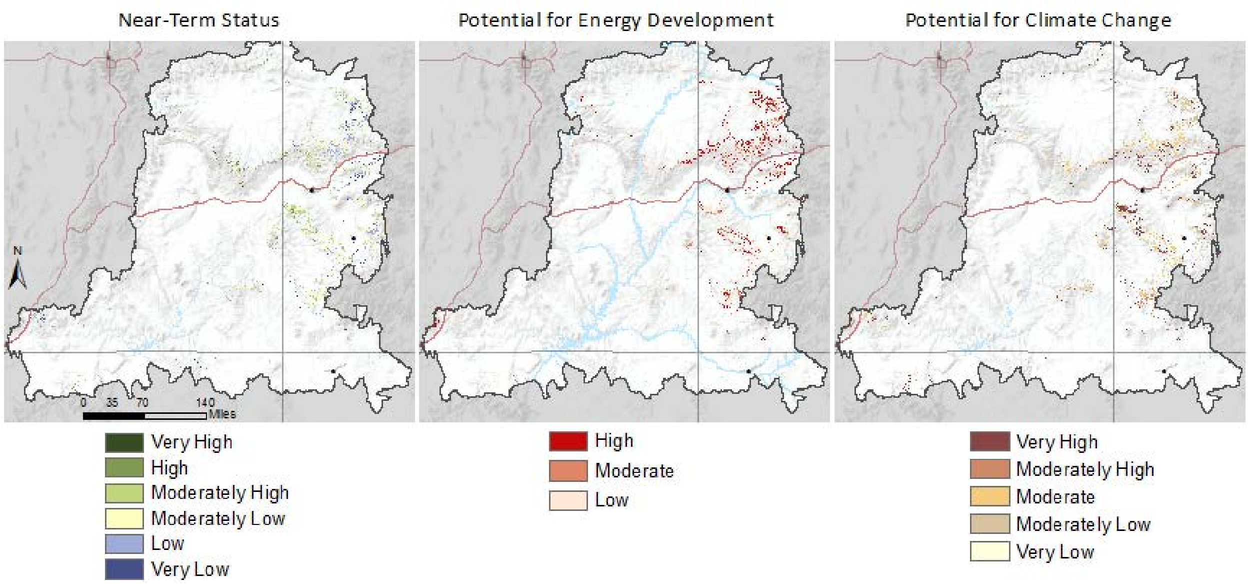


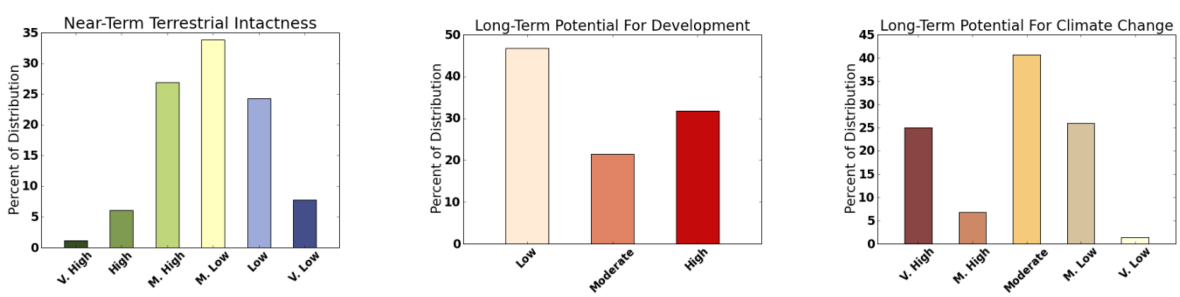
NatureServe



MQ C2. Where is Rocky Mountain Gambel Oak-Mixed Montane Shrubland vulnerable to change agents in the future?

LANDFIRE

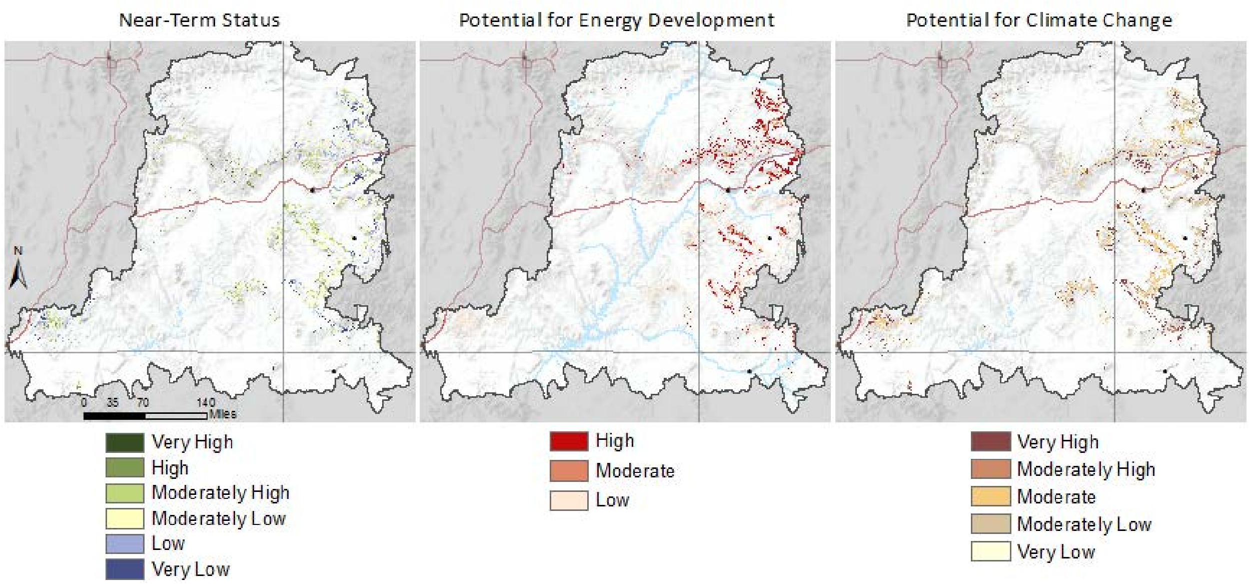


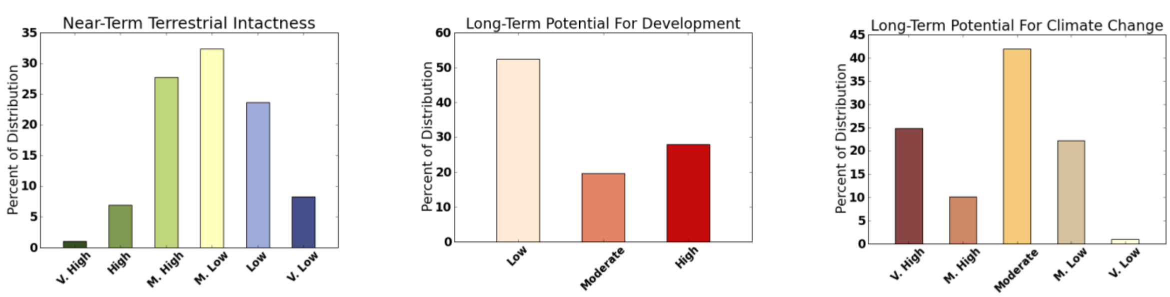


2025 Long Term Maximum Potential 2060

MQ C2. Where is Rocky Mountain Gambel Oak-Mixed Montane Shrubland vulnerable to change agents in the future?

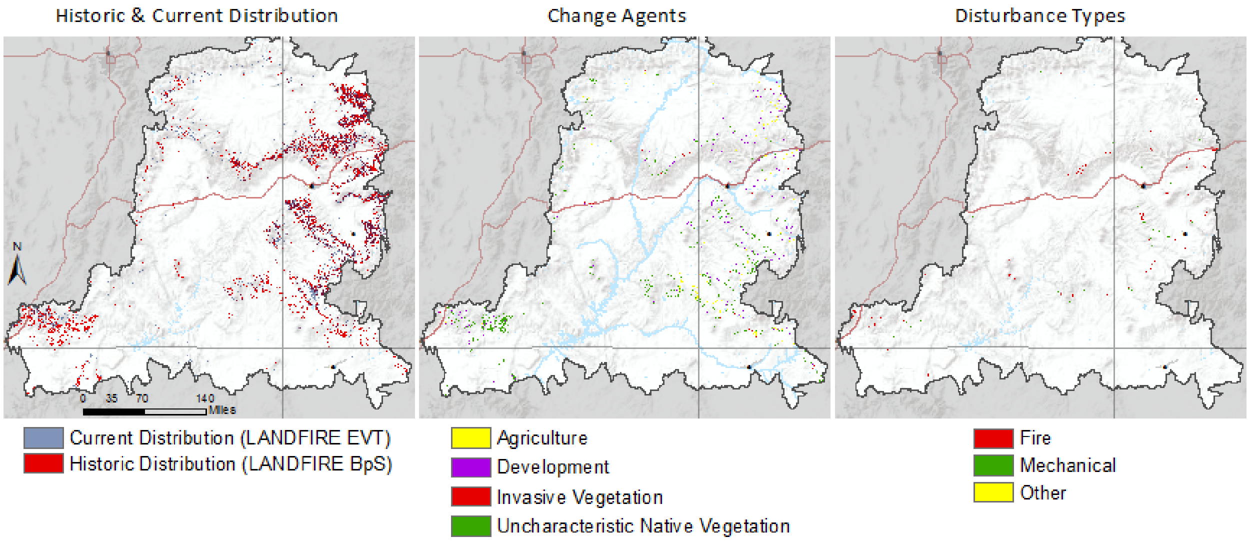
NatureServe





2025 Long Term Maximum Potential 2060

MQC3. What change agents have affected Rocky Mountain Gambel Oak-Mixed Montane Shrubland?



Historic Change Agents

Total BpS Area	Urban & Roads	Agriculture	Invasives	Unchar Native Veg	Total Changed	Percent
2,038,543	130,616	89,257	29,209	335,467	584,549	28.67%

Recent Disturbance

Total BpS Area	Fire	Mechanical	Other	Total Disturbed	Percent
2,038,543	75,484	31,272	1,233	107,989	5.30%

Conceptual Model

There are six primary natural drivers (cyan boxes) for this ecological system including topography, soil characteristics, precipitation, temperature, insects and disease, and animal herbivory. Specific details on the various environmental conditions characterizing this system (blue text) are provided by NatureServe (2009) and LANDFIRE (2007).

Colorado Plateau Blackbrush-Mormon-Tea Shrubland is an extensive dry, open shrubland found at lower elevations and usually dominated by blackbrush (*Coleogyne ramosissima*). An herbaceous layer is sparse covering <15% of the surface area. Topographic breaks dissect the landscape separating vegetated areas from rocky outcrops and steep canyon walls. Moisture is usually delivered in winter and summer storm events and prolonged droughts are common. Plants are adapted to extreme summer and winter temperatures.

Mean fire interval is approximately 75 years with high variability due to weather extremes. High fire years are correlated with high spring moisture when ground fuels build up. Blackbrush is fire intolerant and is extremely slow to recover after fire. Native species richness and cover typically decreases after fire throughout this ecosystem (Brooks and Matchett 2003). Non-native invasive grasses often follow fire throughout this ecosystem and change the fire regime significantly. Scale of fire events ranges from 10s to 100s of acres (LANDFIRE 2007).

More widespread disturbance covering many thousands of acres is the result of periodic, prolonged drought. Livestock grazing occurs in this ecosystem type, but with marginal forage value, especially in dry periods, grazing is not a major factor.

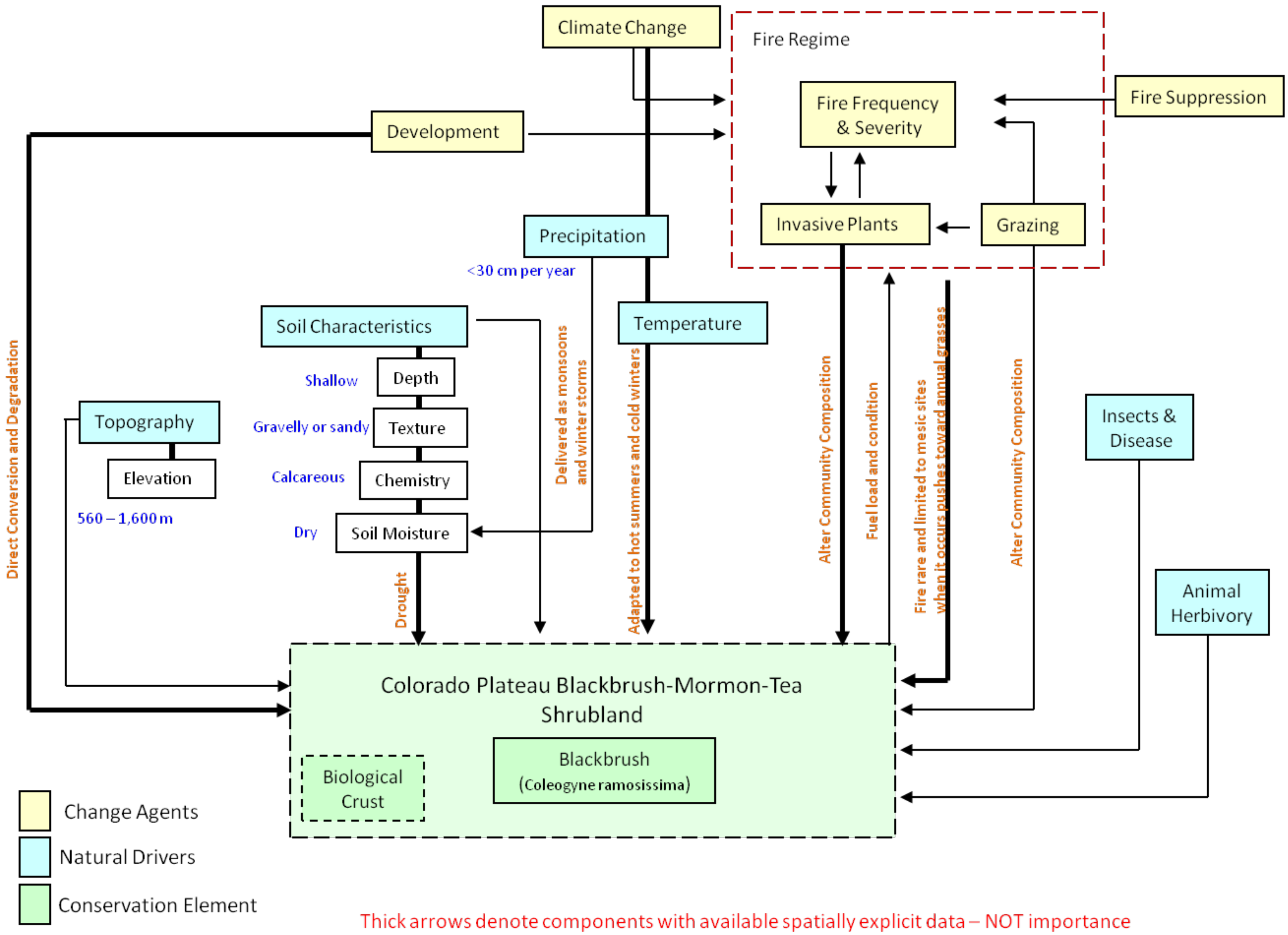
Change agents affecting this ecological system accounted for in the REA process include Development (based on current and projected future extent of urban land cover) and recent disturbance (1999–2008) from Fires and Insects and Disease. Overall landscape intactness, which includes development from all sources (urban, agriculture, energy, and roads), invasive species, and habitat fragmentation, is used to describe the regional environment that contains this ecosystem type. Climate change projections (including precipitation and temperature changes as well as MAPSS modeling outputs) are also used to predict where current Colorado Plateau Blackbrush-Mormon-Tea Shrubland may be under significant climate stress.

References Cited

Brooks, M.L., and J.R. Matchett. 2003. Plant community patterns in unburned and burned blackbrush (*Coleogyne ramosissima*) shrublands in the Mojave Desert. *Western North American Naturalist* 63(3): 283–298.

LANDFIRE Biophysical Setting Model. September 2007.

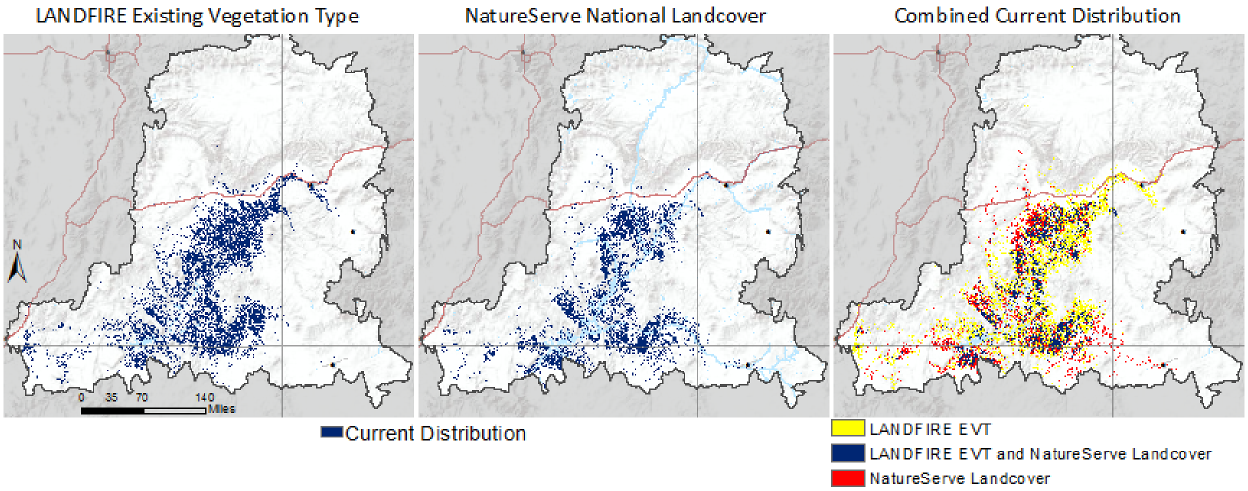
NatureServe. 2009. International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Database. Arlington, VA.


Climate Change
Fire Regime
Fire Frequency & Severity
Fire Suppression
Development
Invasive Plants
Grazing
Precipitation
<30 cm per year
Soil Characteristics
Temperature
Depth
Shallow
Texture
Gravelly or sandy
Chemistry
Calcareous
Soil Moisture
Dry
Topography
Elevation
560 – 1,600 m
Delivered as monsoons and winter storms
Adapted to hot summers and cold winters
Alter Community Composition
Fuel load and condition
Fire rare and limited to mesic sites when it occurs pushes toward annual grasses
Alter Community Composition
Insects & Disease
Animal Herbivory
Direct Conversion and Degradation
Drought
Colorado Plateau Blackbrush-Mormon-Tea Shrubland
Biological Crust
Blackbrush (Coleogyne ramosissima)
Change Agents
Natural Drivers
Conservation Element
Thick arrows denote components with available spatially explicit data – NOT importance

Results

MQ C1. Where is existing Colorado Plateau Blackbrush-Mormon-Tea Shrubland and what is its status?

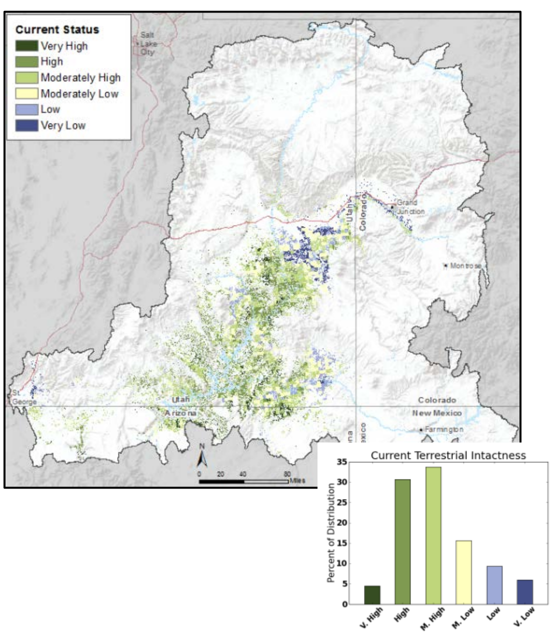
Distribution



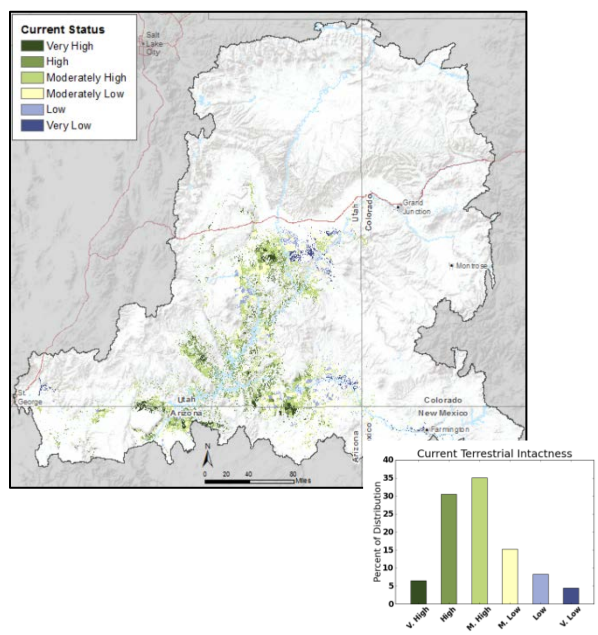
Vegetation Community	LANDFIRE Only (ac)	NatureServe Only (ac)	Both (ac)	Percent Overlap
Colorado Plateau Blackbrush-Mormon-Tea Shrubland	2,568,289	1,293,367	1,459,961	27.43

Status

LANDFIRE

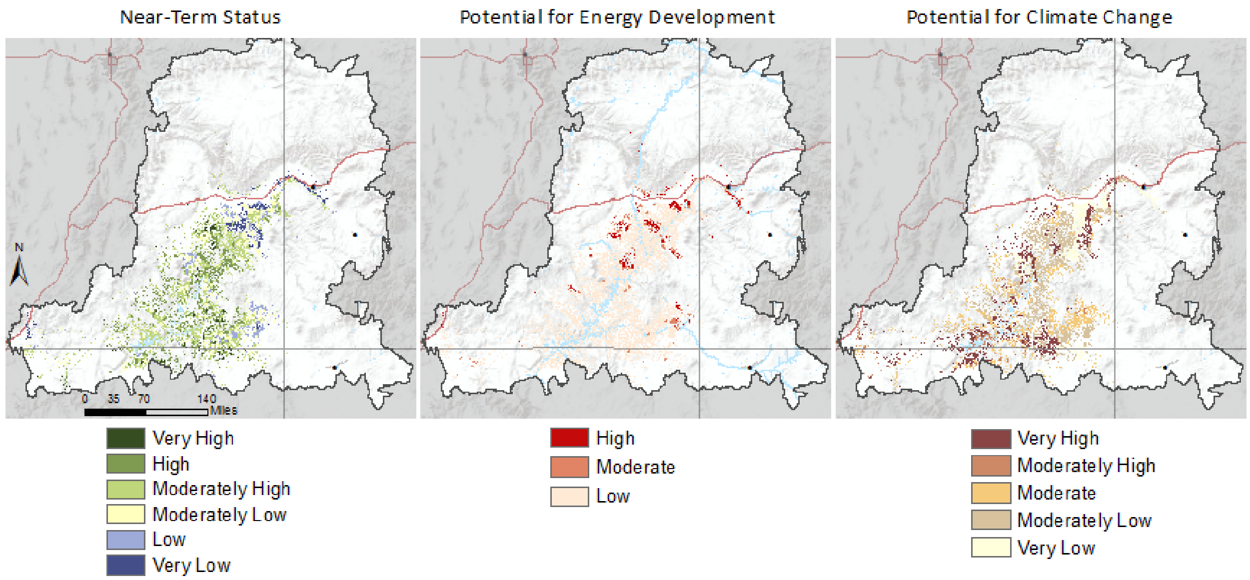


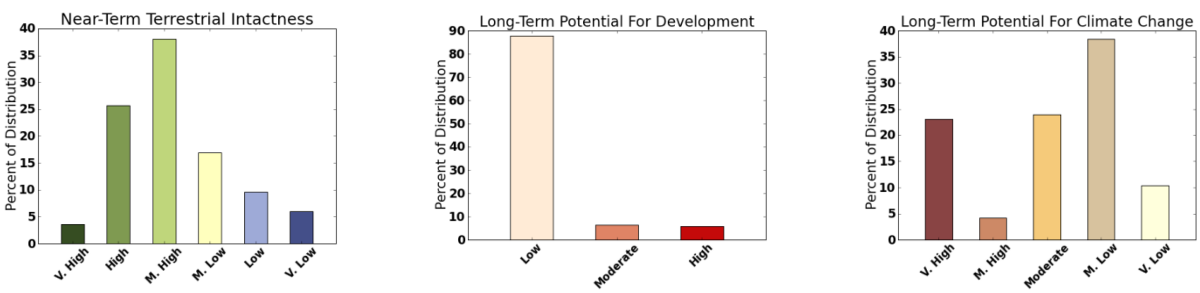
NatureServe



MQ C2. Where are Colorado Plateau Blackbrush-Mormon-Tea Shrublands vulnerable to change agents in the future?

LANDFIRE

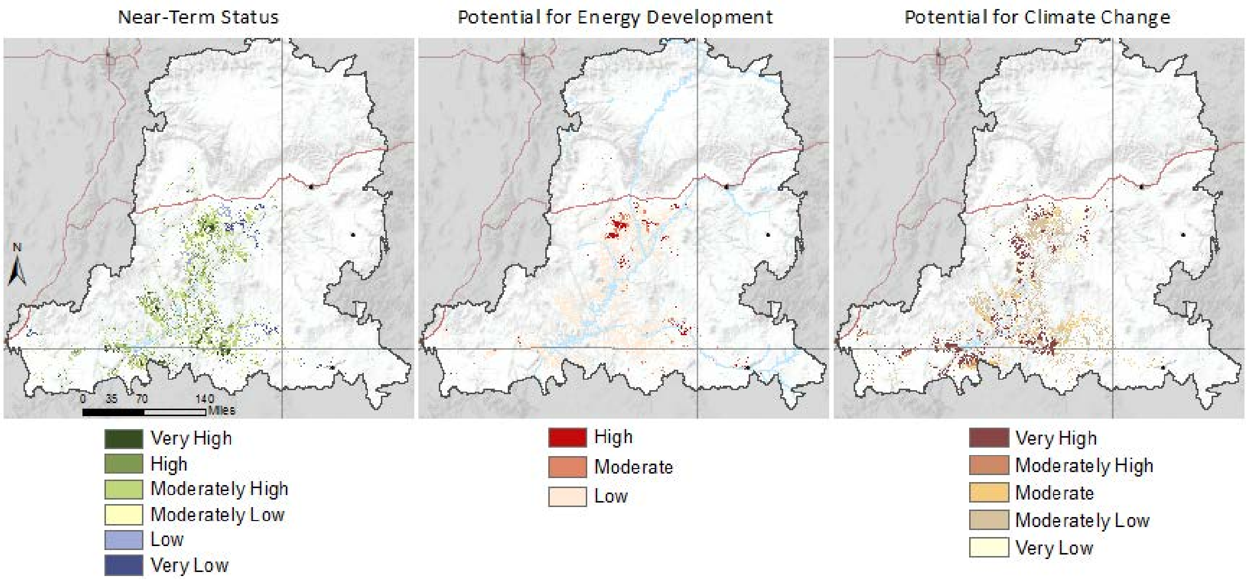


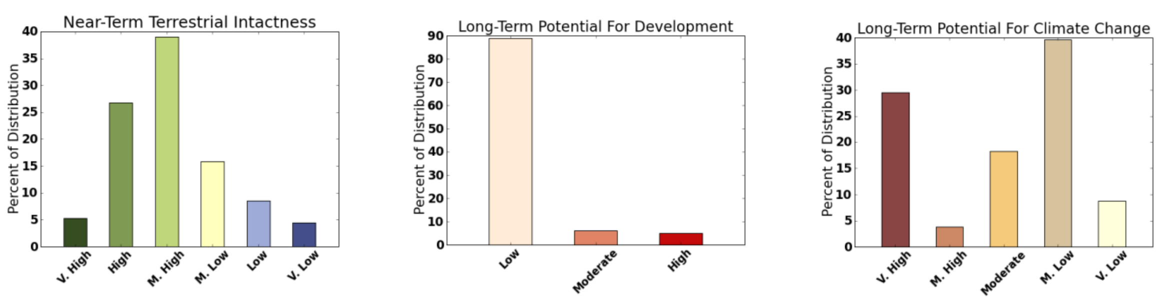


2025 | Long Term Maximum Potential | 2060

MQ C2. Where are Colorado Plateau Blackbrush-Mormon-Tea Shrublands vulnerable to change agents in the future?

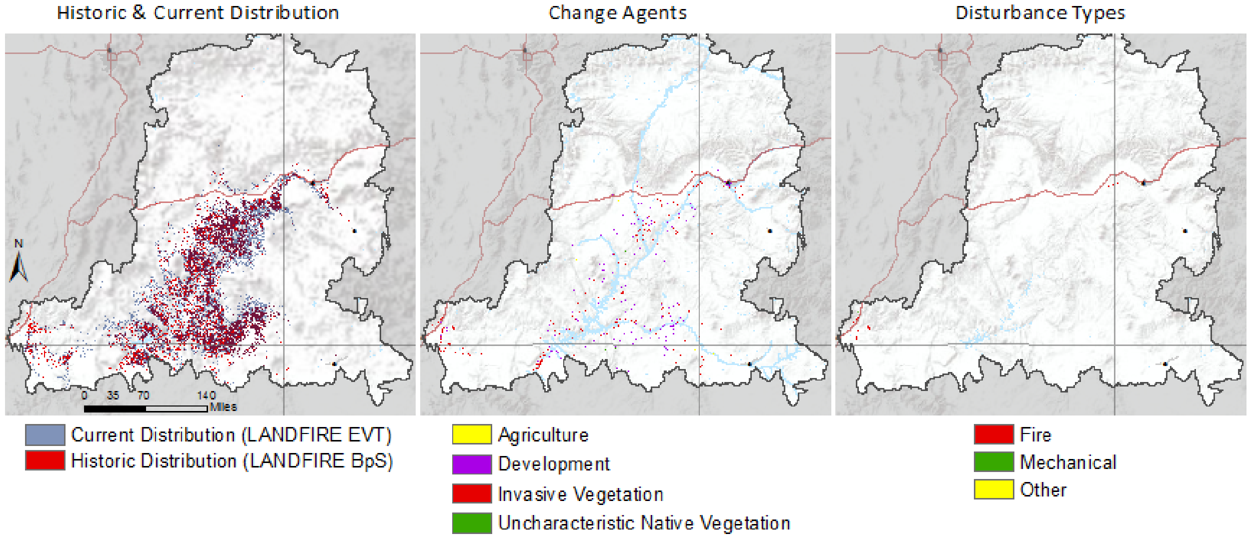
NatureServe





2025 Long Term Maximum Potential 2060

MQC3. What change agents have affected Colorado Plateau Blackbrush-Mormon-Tea Shrublands?



Historic Change Agents

Total BpS Area	Urban & Roads	Agriculture	Invasives	Unchar Native Veg	Total Changed	Percent
3,123,911	132,459	3,624	176,205	6,511	318,799	10.21%

Recent Disturbance

Total BpS Area	Fire	Mechanical	Other	Total Disturbed	Percent
3,123,911	9,396	1,716	0	11,112	0.36%

Conceptual Model

There are seven primary natural drivers (cyan boxes) for this ecological system including topography, erosion, soil characteristics, precipitation, temperature, insects and disease, and animal herbivory. Specific details on the various environmental conditions characterizing this system (blue text) are provided by NatureServe (2009) and LANDFIRE (2007).

Inter-Mountain Basins Mixed Salt Desert Scrub is a compositionally dynamic desert community that occurs at lower elevations throughout the Colorado Plateau. Depending on recent environmental conditions, the species composition and vegetation structure can change from year-to-year and from season-to-season. Some areas will be dominated by a single species (e.g. shadscale [*Atriplex confertifolia*]) while others contain higher species richness.

Vegetation is generally sparse with large open spaces between plants (Blaisdell and Holmgren 1984). Open spaces are typically covered with a biological crust (West 1982). While it is a desert community, wetter periods (usual occurring in the winter in the form of snow) will favor grass species the following spring and drier periods will favor shrubs. Excessive and prolonged drought will create declines in most plant species.

Fires are not a common disturbance agent in this community because of the low vegetative biomass. Only on more mesic sites can biomass accumulate enough to carry a fire; in these areas, mixed severity fire occurs every 500–1,000 years (LANDFIRE 2007). A more regular fire regime can get established in locations where invasive grasses have become established from disturbance and favorable growing conditions.

More common disturbance agents include periodic flooding from extreme weather events, erosion from wind and water to create badlands, and insect outbreaks such as Mormon cricket/grasshopper outbreaks. Scale of disturbance ranges from local to large geographic extents. Livestock grazing occurs in this ecosystem type, but with its marginal forage value, especially in dry periods, grazing is not a major factor.

Change agents affecting this ecological system accounted for in the REA process include Development (based on current and projected future extent of urban land cover) and recent disturbance (1999–2008) from Fires and Insects and Disease. Overall landscape intactness, which includes development from all sources (urban, agriculture, energy, and roads), invasive species, and habitat fragmentation, is used to describe the regional environment that contains this ecosystem type. Climate change projections (including precipitation and temperature changes as well as MAPSS modeling outputs) are also used to predict where current inter-mountain basins mixed salt desert scrub may be under significant climate stress.

References Cited

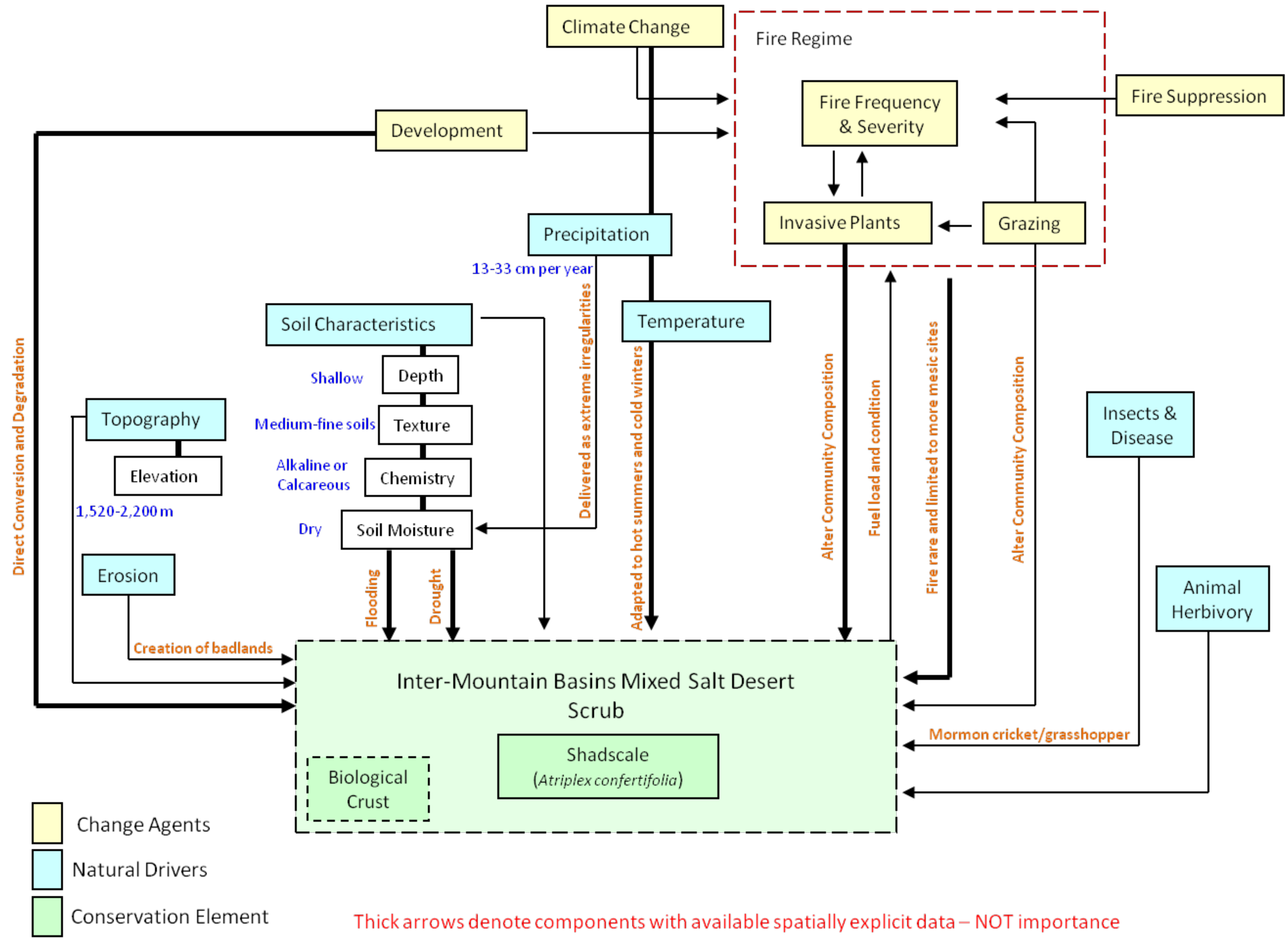
Blaisdell, J. P. and R.C. Holmgren. 1984. Managing intermountain rangelands-salt-desert shrub ranges. General technical Report INT-163. USDA Forest Service, Intermountain and Range Experiment Station, Ogden, UT. 52 pp.

LANDFIRE Biophysical Setting Model. September 2007.

NatureServe. 2009. International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Database. Arlington, VA.

West, N.E. 1982. Approaches to synecological characterization of wildlands in the Intermountain West. Pages 633–643 *in* In-place resource inventories: Principles and practices. August 9–14, 1981, University of Maine, Orono. Society of American Foresters, Mc Clean, Virginia.

Photo: Head of Sinbad, San Rafael Swell. Bureau of Land Management.

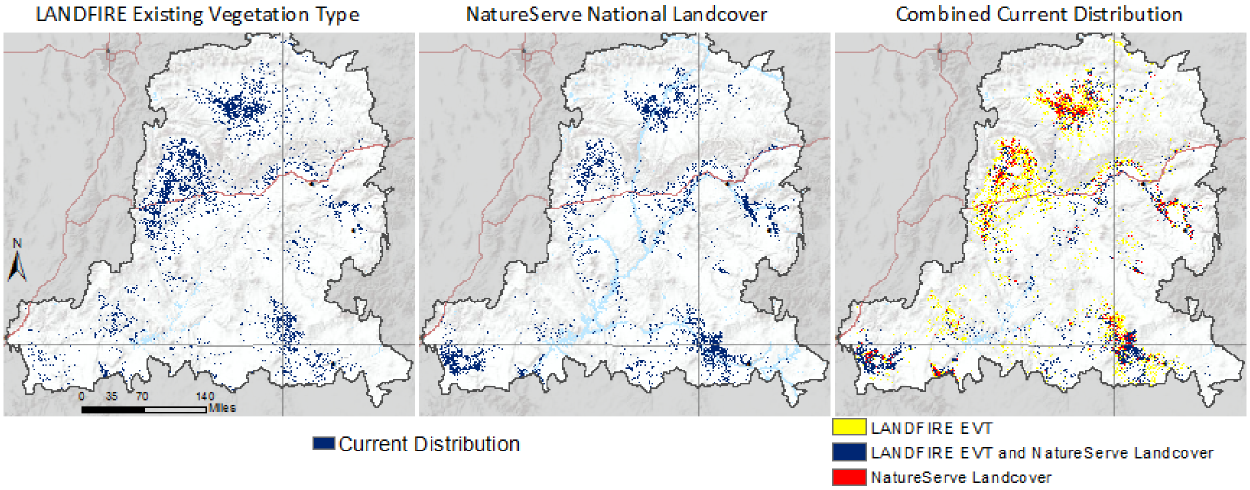


Climate Change
Fire Regime
Fire Frequency & Severity
Fire Suppression
Development
Invasive Plants
Grazing
Precipitation
13-33 cm per year
Delivered as extreme irregularities
Soil Characteristics
Temperature
Shallow
Depth
Medium-fine soils
Texture
Alkaline or Calcareous
Chemistry
Dry
Soil Moisture
Topography
Elevation
1,520-2,200 m
Erosion
Creation of badlands
Direct Conversion and Degradation
Flooding
Drought
Adapted to hot summers and cold winters
Alter Community Composition
Fuel load and condition
Fire rare and limited to more mesic sites
Alter Community Composition
Insects & Disease
Animal Herbivory
Mormon cricket/grasshopper
Inter-Mountain Basins Mixed Salt Desert Scrub
Biological Crust
Shadscale (Atriplex confertifolia)
Change Agents
Natural Drivers
Conservation Element
Thick arrows denote components with available spatially explicit data – NOT importance

Results

MQ C1. Where is existing Inter-Mountain Basins Mixed Salt Desert Scrub and what is its status?

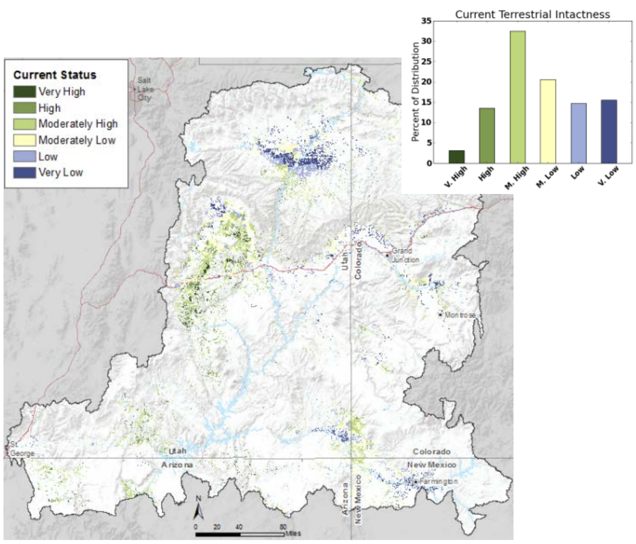
Distribution



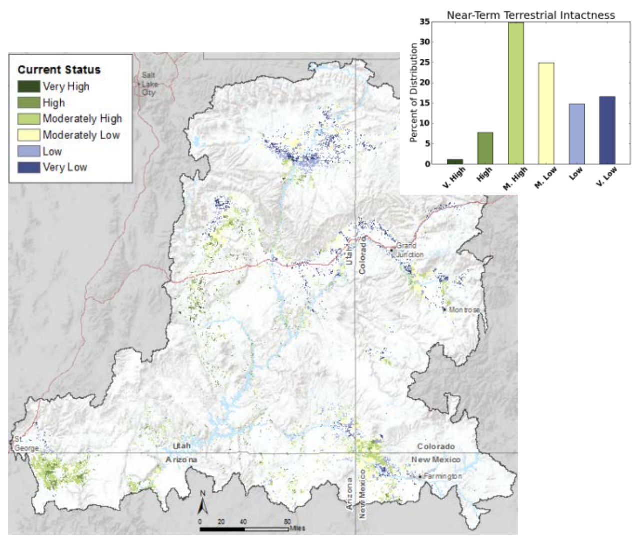
Vegetation Community	LANDFIRE Only (ac)	NatureServe Only (ac)	Both (ac)	Percent Overlap
Inter-Mountains Basins Mixed Salt Desert Scrub	1,964,350	1,645,308	680,837	15.87

Status

LANDFIRE

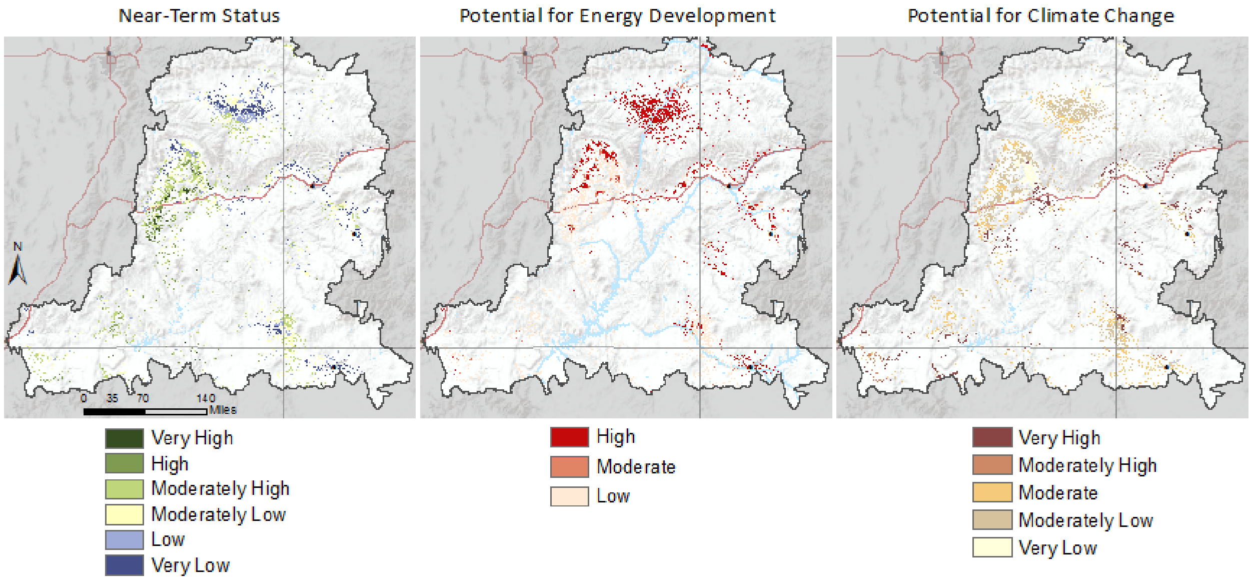


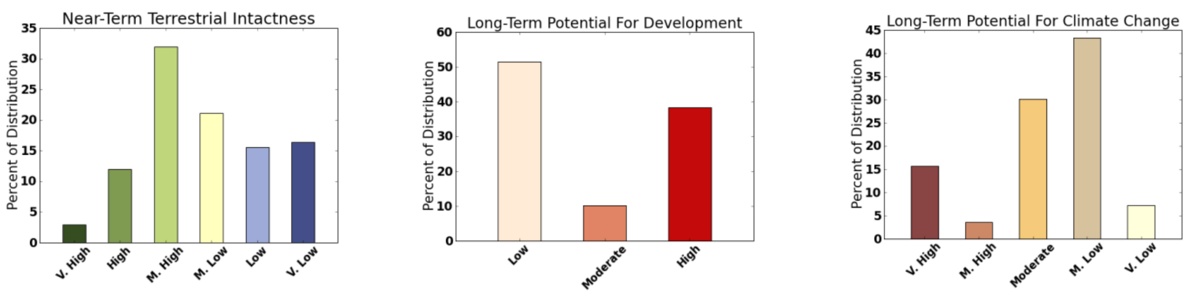
NatureServe



MQ C2. Where is Inter-Mountain Basins Mixed Salt Desert Scrub vulnerable to change agents in the future?

LANDFIRE

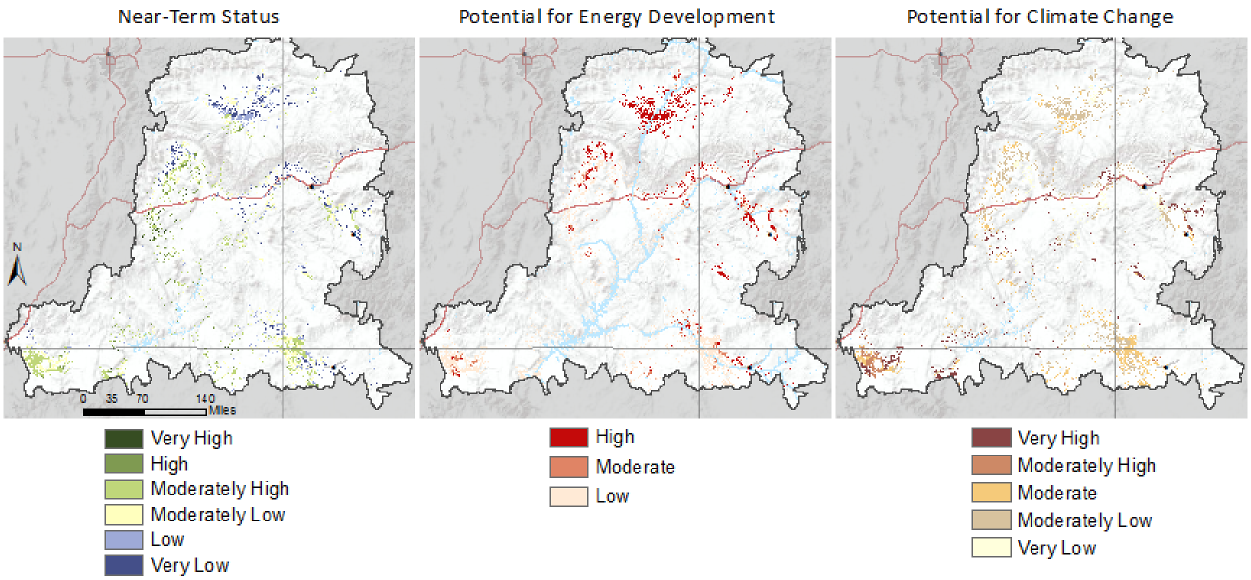


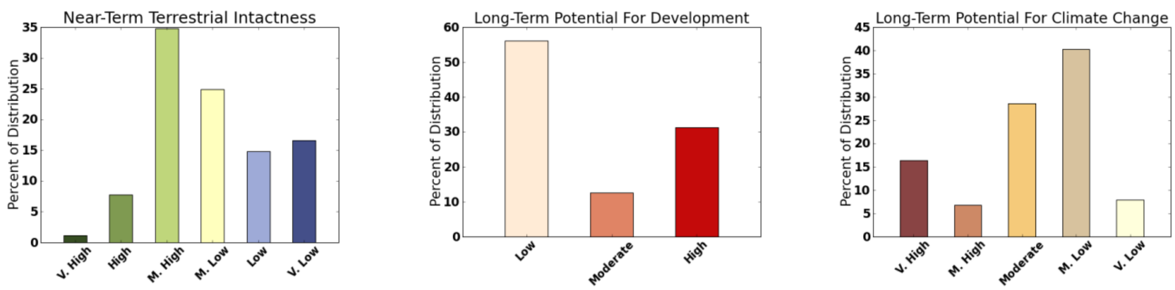


2025 Long Term Maximum Potential 2060

MQ C2. Where is Inter-Mountain Basins Mixed Salt Desert Scrub vulnerable to change agents in the future?

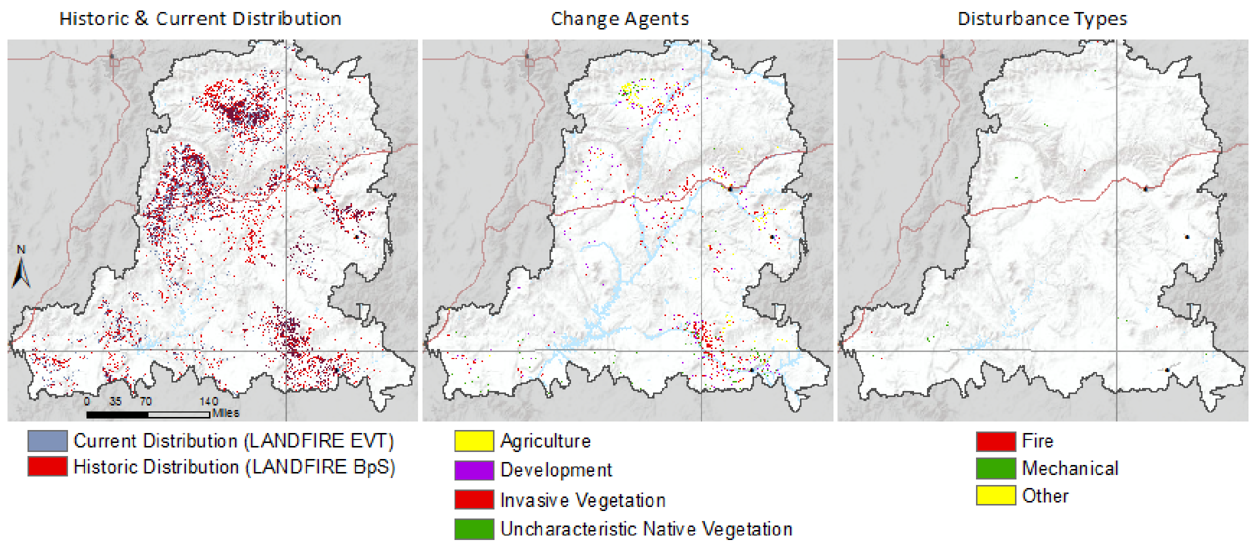
NatureServe





2025 Long Term Maximum Potential 2060

MQC3. What change agents have affected Inter-Mountain Basins Mixed Salt Desert Scrub?



Historic Change Agents

Total BpS Area	Urban & Roads	Agriculture	Invasives	Unchar Native Veg	Total Changed	Percent
3,155,282	178,112	109,125	402,992	117,076	807,305	25.59%

Recent Disturbance

Total BpS Area	Fire	Mechanical	Other	Total Disturbed	Percent
3,155,282	5,694	15,176	9	20,879	0.66%

Colorado Plateau Mixed Bedrock Canyon and Tablelands

Conceptual Model

There are seven primary natural drivers (cyan boxes) for this ecological system including topography, erosion, soil characteristics, precipitation, temperature, insects and disease, and animal herbivory. Specific details on the various environmental conditions characterizing this system (blue text) are provided by NatureServe (2009) and LANDFIRE (2007).

Colorado Plateau Mixed Bedrock Canyon and Tableland is a matrix community of the Colorado Plateau that is sparsely vegetated (<10% cover). Littleleaf Mountain Mahogany (*Cercocarpus intricatus*) is the signature species growing in scattered crevices across the dominating rocky substrate. When shrub and herbaceous layers exist at all, they are comprised of drought tolerant species that cover very limited areas. Classified as a semi-arid system, the canyonlands and tablelands receive moisture usually as winter snow. Plants are adapted to extreme summer and winter temperatures. Because of the harsh environment and geographic isolation, this ecological system is noted for its high levels of species endemism, especially in the forbs class (NatureServe 2009).

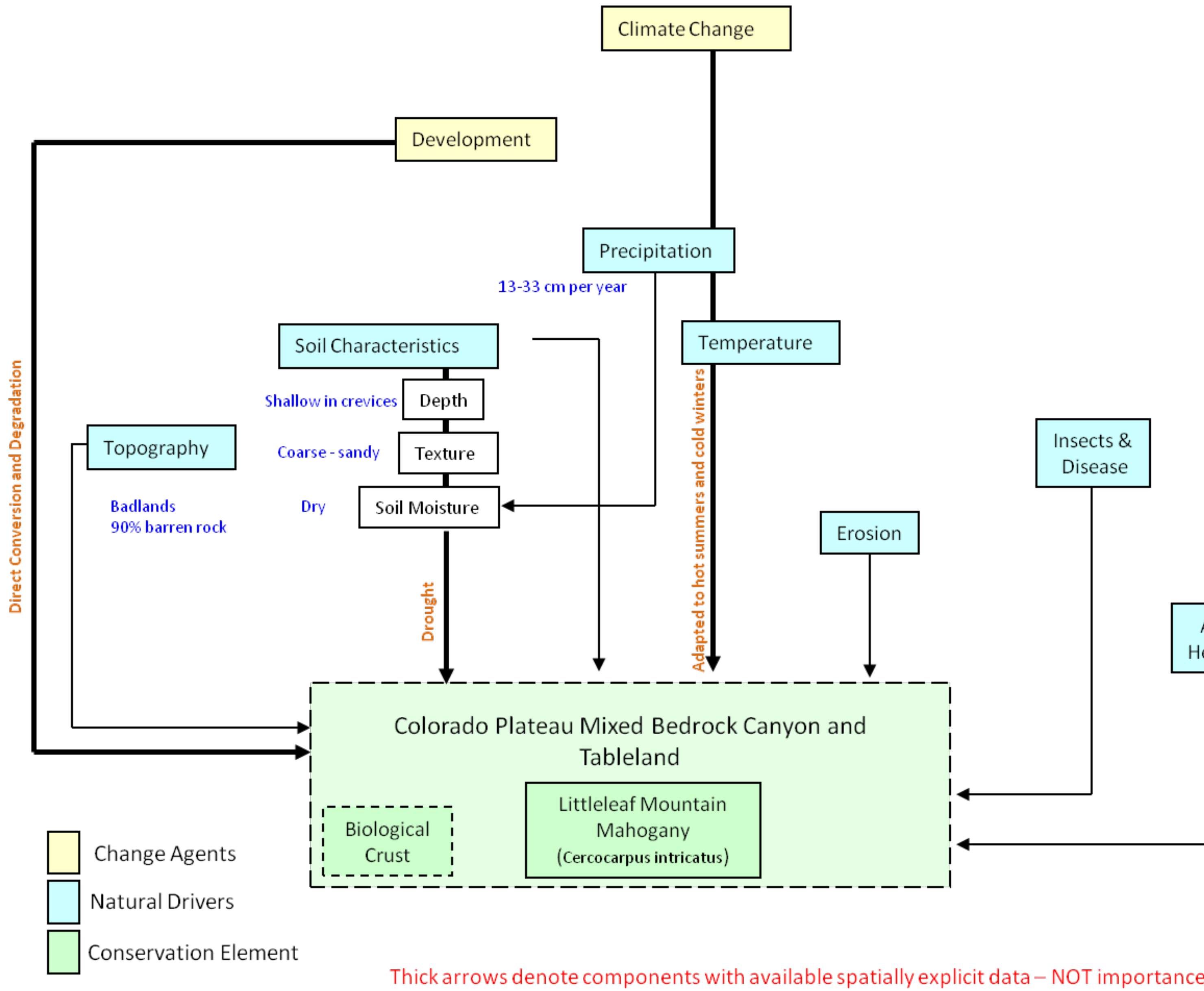
This ecological system is most frequently disturbed by erosion and freeze-thaw cycles on south-facing slopes. Fires are infrequent and do not play an important role.

Change agents affecting this ecological system accounted for in the REA process include Development (based on current and projected future extent of urban land cover). Overall landscape intactness, which includes development from all sources (urban, agriculture, energy, and roads), invasive species, and habitat fragmentation, is used to describe the regional environment that contains this ecosystem type. Climate change projections (including precipitation and temperature changes as well as MAPSS modeling outputs) are also used to predict where the current Colorado Plateau Mixed Bedrock Canyon and Tableland may be under significant climate stress.

References Cited

LANDFIRE Biophysical Setting Model. September 2007.

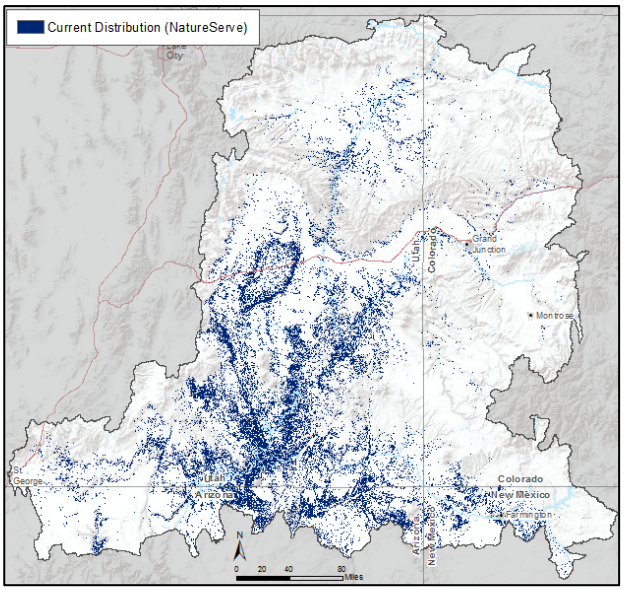
NatureServe. 2009. International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Database. Arlington, VA.


Climate Change
Development
Precipitation
13-33 cm per year
Soil Characteristics
Temperature
Shallow in crevices
Depth
Coarse - sandy
Texture
Topography
Insects & Disease
Badlands
90% barren rock
Dry
Soil Moisture
Erosion
Direct Conversion and Degradation
Adapted to hot summers and cold winters
Drought
Animal Herbivory
Colorado Plateau Mixed Bedrock Canyon and Tableland
Biological Crust
Littleleaf Mountain Mahogany (Cercocarpus intricatus)
Change Agents
Natural Drivers
Conservation Element
Thick arrows denote components with available spatially explicit data – NOT importance

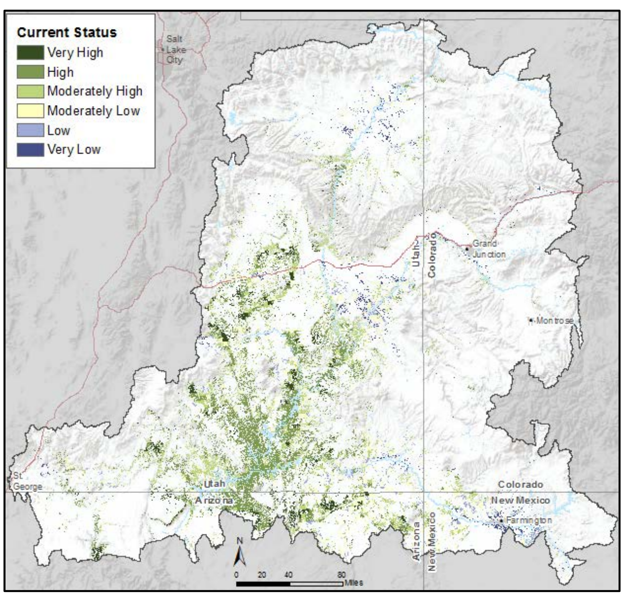
Results

MQ C1. Where is existing Colorado Plateau Mixed Bedrock Canyon and Tableland and what is its status?

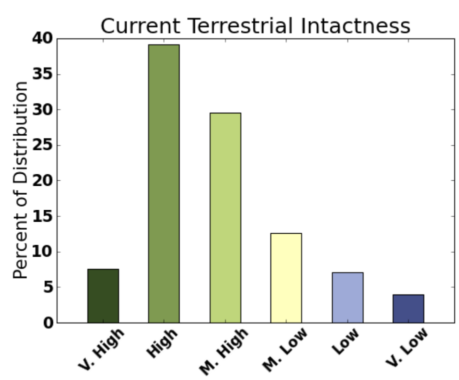
Vegetation Community	LANDFIRE Only (ac)	NatureServe Only (ac)	Both (ac)	Percent Overlap
Colorado Plateau Mixed Bedrock Canyon and Tableland	Not mapped	4,598,445	0	0.00



Distribution



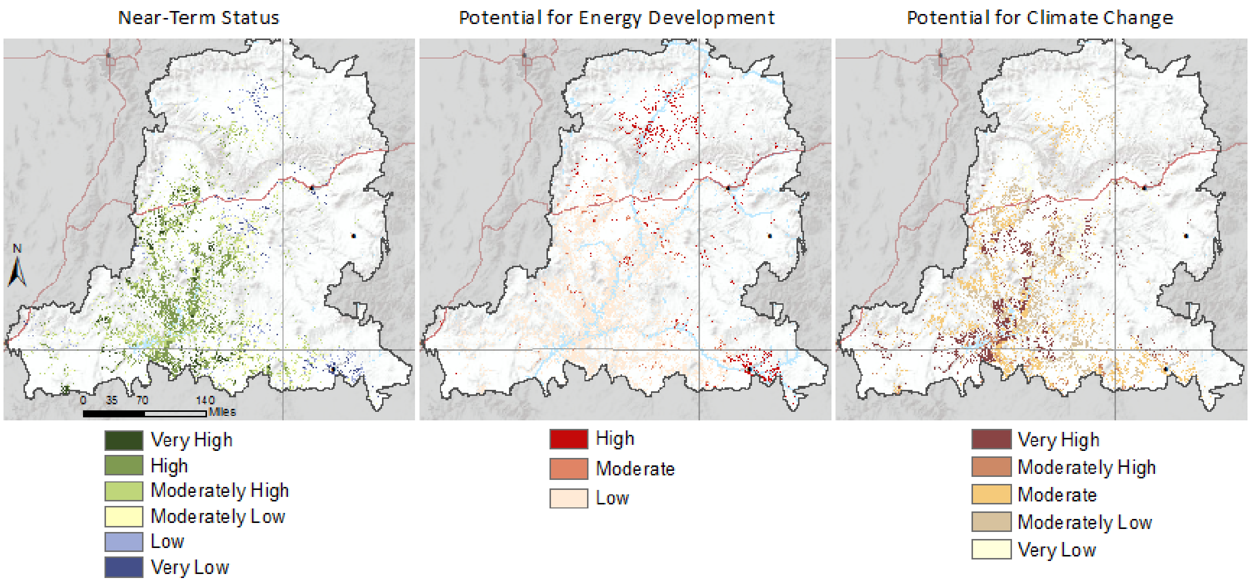
Status

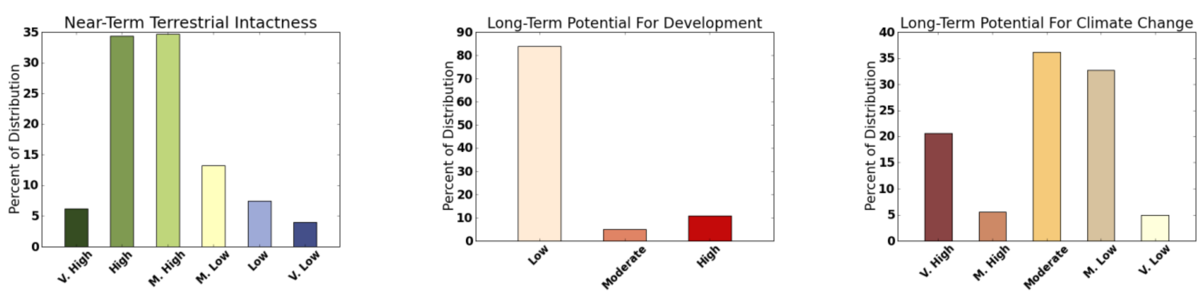


MQ C2. Where are Colorado Plateau Mixed Bedrock Canyon and Tableland vulnerable to change agents in the future?

No LANDFIRE data

NatureServe





2025 Long Term Maximum Potential 2060

MQC3. What change agents have affected Colorado Plateau Mixed Bedrock Canyon and Tableland?

Not Applicable – BpS data does not exist for this community type

Conceptual Model

Riparian ecological systems have undergone significant physical and biological changes throughout the ecoregion due to numerous factors, including: conversion to other uses; changes in the natural flow regimes and suppression of fluvial processes (Stromberg 2001, Stromberg et al. 2007); livestock grazing (Armour et al. 1994); and invasive species dominance (tamarisk, Horton 1977, Graf 1978, Friedman et al. 2005, Merritt and Poff 2010). As much as 90% of pre-settlement riparian ecosystems have been lost (LUHNA 2011).

There are six primary natural drivers highlighted in the conceptual diagram: groundwater, channel geomorphology and soils, precipitation, temperature, stream hydrology, and animal herbivory. Together these shape the composition, structure, and function of riparian ecosystems.

The yellow boxes in the diagram, which denote the major change agents, impact these drivers in a number of ways. Some development directly converts riparian vegetation to other land uses, especially irrigated agricultural lands in this arid or semi-arid region. Development also affects riparian ecosystems in other ways including drawdown of groundwater lowering the water table, water use and contamination of surface water, and diversion from dams and various water management practices.

The climate regime (precipitation and temperature) regulates the water quantity and delivery to the system. In this ecoregion, moisture tends to be seasonal and flashy, and any significant departure from this pattern can degrade riparian ecosystems.

Fire regime is influenced by a complex interaction of factors—fuel load and condition, grazing, invasive species, and fire frequency (natural, a function of climate, and human-caused, a function of development). In the case of riparian vegetation, the fuel load and condition of surrounding vegetation is as much or more of a factor than the condition of the riparian vegetation itself, which is obviously wetter than surrounding conditions. Fire suppression is another influencing factor on the fire regime. Riparian vegetation is affected by fire in two ways. There is the outright burning of the vegetation and, more broadly, there are changes in water retention and runoff over the larger burn area outside the riparian zone resulting in alterations in the amount of water and sediment that reaches the riparian zone.

Livestock grazing has damaged approximately 80% of stream and riparian ecosystems in the western US (Belsky et al. 1999). Grazing alters streamside morphology, increases sedimentation, degrades riparian vegetation through trampling and consumption and causes nutrient loading to the system. Invasive plants such as tamarisk often successfully out-compete native species such as willows, because of its reproductive capacity and its tolerance to drought and flooding events (Stevens and Waring 1985, Glenn et al. 1998, Stromberg et al. 2007).

Mapping riparian systems is difficult to do using satellite remote sensing. The narrow linear nature of the community makes it difficult to delineate with high levels of accuracy. The most recent landcover edited by NatureServe was used for the REA assessment to assess current distribution. There was ample data for development, fire, tamarisk, and dams and diversions to assess current and future condition and to address the management questions related to this topic. An aquatic intactness model was also developed to describe the upland impacts to aquatic environments more accurately: the aquatic intactness model can be overlaid against the existing riparian habitat data throughout the ecoregion.

References Cited

Armour, C., D. Duff, and W. Elmore. 1994. The effects of livestock grazing on western riparian and stream ecosystems. *Fisheries* 19(9): 9–12.

Belsky, A.J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. *Journal of Soil and Water Conservation* 54: 419–431.

Friedman, J.M., G.T. Auble, P.B. Shafroth, M.L. Scott, M.F. Meriglianno, M.D. Freehling, and E.R. Griffin. 2005. Dominance of non-native riparian trees in western USA. *Biological Invasions* 7:747–751.

Glenn, E., R. Tanner, S. Mendez, T. Kehret, D. Moore, J. Garcia, and C. Valdes. 1998. Growth rates, salt tolerance, and water use characteristics of native and invasive riparian plants from the delta of the Colorado River, Mexico. *Journal of Arid Environments* 40:281–294.

Graf, W.F. 1978. Fluvial adjustment to the spread of tamarisk in the Colorado Plateau region. *Geological Society of America Bulletin* 89**:** 1491–1501.

Horton, J.S. 1977. The development and perpetuation of the permanent tamarisk type in the phreatophyte zone of the southwest. Pages 124–127 *in* Importance, preservation, and management of riparian habitat: A symposium. General Technical Report RM-43, U.S. Forest Service, Washington, D.C.

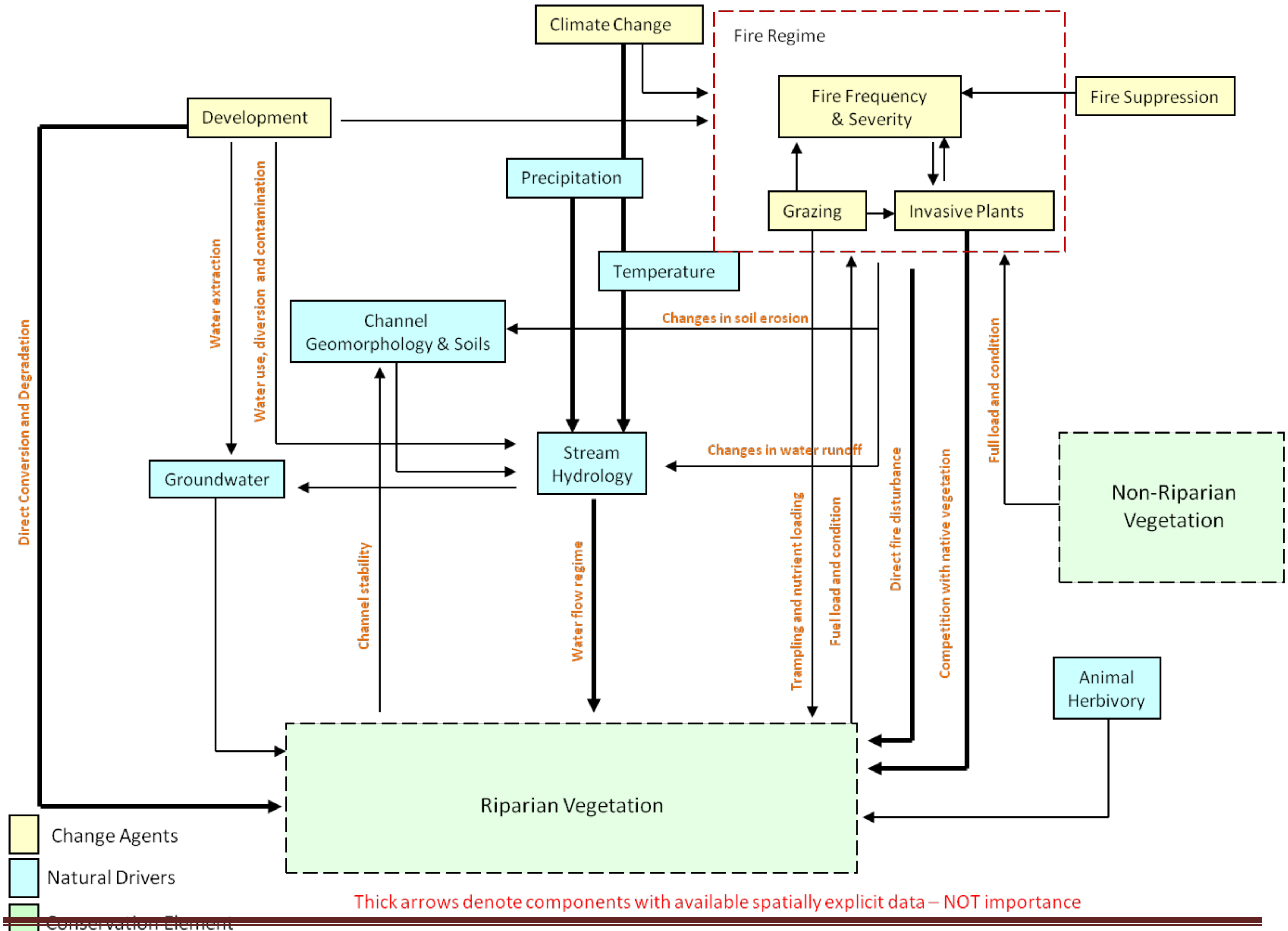
LUHNA. 2011. Land Use History of North America: Colorado Plateau. U.S. Geological Survey http://cpluhna.nau.edu/Biota/riparian_communities.htm.

Merrit, D.M., and N.L. Poff. 2010. Shifting dominance of riparian *Populus* and *Tamarix* along gradients of flow alteration in western North American rivers. *Ecological Applications* 20(1):135–152.

Stromberg, J.C. 2001. Restoration of riparian vegetation in the southwestern United States: Importance of flow regimes and fluvial dynamism. *Journal of Arid Environments* 49:17–34.

Stromberg, J.C., V.B. Beauchamp, M.D. Dixon, S.J. Lite, and C. Paradzick. 2007. Importance of low-flow and high-flow characteristics to restoration of riparian vegetation along rivers in arid south-western United States. *Freshwater Biology* 52:651–679.

Stevens, L.E., and G.W. Waring. 1985. The effects of prolonged flooding on the riparian plant community in Grand Canyon. Pages 81–86 *in* Johnson, R.R., C.D. Ziebell, D.R. Patten, P.F. Ffolliot, and R.H. Hamre (eds.), Riparian ecosystems and their management: Reconciling conflicting uses. General Technical Report RM-120, U.S. Forest Service, Tucson, Arizona. 523 pp.

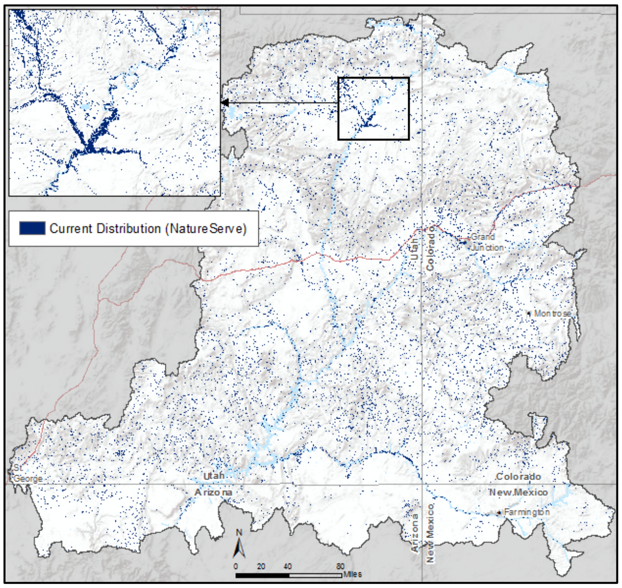


Thick arrows denote components with available spatially explicit data – NOT importance

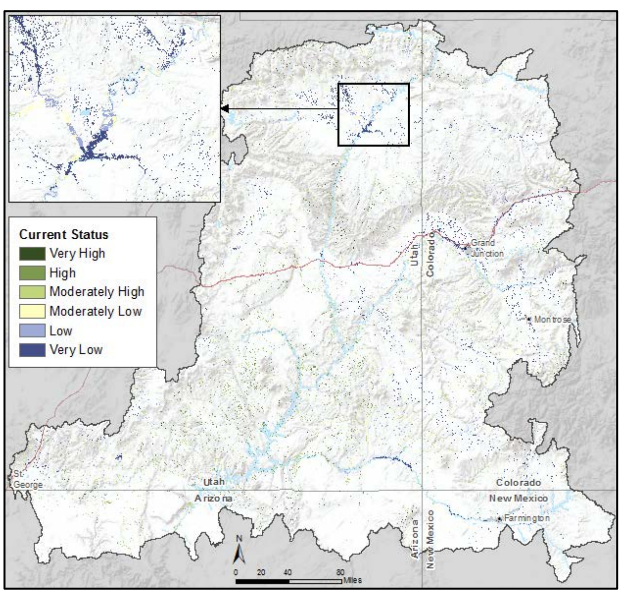
Results

MQ C1. Where is existing Riparian Vegetation and what is its status?

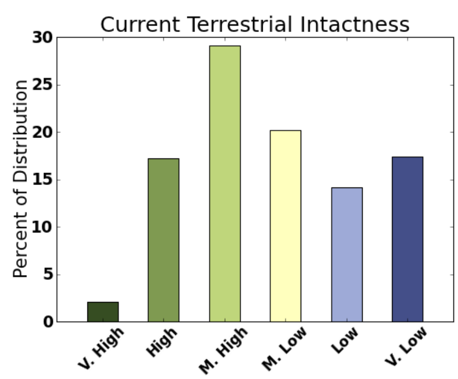
NatureServe



Distribution



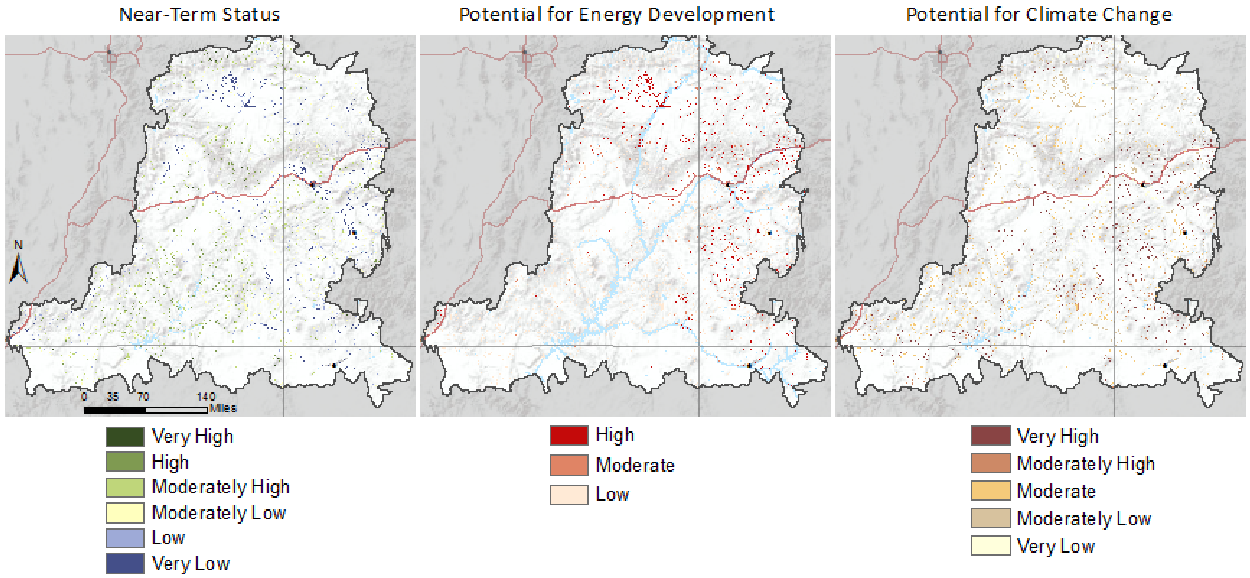
Status

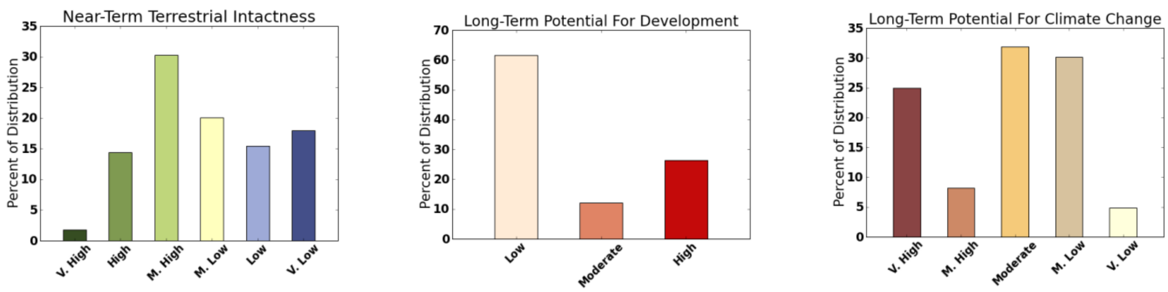


MQ C2. Where is Riparian Vegetation vulnerable to change agents in the future?

No LANDFIRE data

NatureServe





2025 Long Term Maximum Potential 2060

MQC3. What change agents have affected Riparian Vegetation?

Not Applicable – BpS data does not exist for this community type

Appendix C – Species Conservation Elements

Organization of Appendix C

For each conservation element, we provide some background information, a conceptual model, description of the analytical process (including source data) and/or a Process Model for each management question, and results in the form of maps and other supporting graphics.

Species Conceptual Models

Conceptual models attempt to organize and articulate the relationship between the various change agents and natural drivers for each conservation element. Not all of the relationships identified lend themselves well to measurement or monitoring, but they are still important to include, as they add to our general understanding of complex interactions.

All conceptual models include a series of change agents (depicted with yellow boxes) and natural drivers (cyan boxes). Specifics regarding some of the factors are presented in blue text. Arrows represent relationships between the various change agents and natural drivers on the community overall and, where appropriate, on the dominant species more directly. More specific information is provided by the orange text. Thicknesses of the arrows **DO NOT** represent degree of importance. Rather, bold lines represent those factors that are tracked or modeled to varying degrees of certainty throughout the REA analysis.

Species Process Models

Two basic management questions were addressed for each species conservation element. The first question pertained to current distribution and status. The second question referred to potential impact on the species from near-term (2025) future change, impact from potential energy development, and finally long-term potential-for-change (2060) from climate change. The basic method for each species was similar, but, in the case of current distribution, input data varied in source and quality. Source data for each is provided in the introduction for each species. Current status was determined by overlaying current distribution against terrestrial landscape intactness (Chapter 4) for terrestrial species and aquatic intactness (Appendix E) for the fishes.

For potential future condition, current distribution was evaluated in a similar fashion against potential energy development (Chapter 5, Section 5.2), near-term (2025) terrestrial landscape intactness (Chapter 5, Section 5.3), and climate change model results (Chapter 5, Section 5.4).

Black-footed Ferret – *Mustela nigripes*

Black-footed ferrets are the only extant ferret species native to North America. The species reached near extinction by the 1980s and it has been sustained only through captive breeding and reintroduction efforts. The connection between black-footed ferrets and prairie dogs is inextricable—from habitat to food to shelter (USFWS 2008). Historically, ferret habitat coincided with the North American shortgrass and mixed-grass prairie lands associated with that of the Gunnison's, white-tailed, and black-tailed prairie dogs (Biggins et al. 1997, USFWS 2008). Currently, less than 2% of the ferrets' original geographic distribution remains occupied, and wild black-footed ferrets can only be found at reintroduction sites (Black-footed ferret Recovery Program). As of 2010, the number of individuals living in the wild is estimated to be around 1,000 – all in states where releases have occurred – and another 300 in captive breeding facilities (Black-footed Ferret Recovery Implementation Team 2012).

Black-footed ferrets are highly specialized predators and rely almost completely on prairie dogs for food. The species spends the majority of its time in vacated prairie dog burrows, coming above ground mostly at night to look for prey (Black-footed Ferret Recovery Program 2012). Prairie dogs comprise over 90% of the ferrets' diet (Houston et al. 1986, Biggins et al. 1993). While the most common predators of the black-footed ferret are owls, coyotes, and badgers, the greatest threats they face are habitat loss and the loss of their prairie dog prey base from sylvatic plague infestations and/or intentional poisoning of prairie dog colonies by humans (USFWS 2008). Large expanses of native prairie grasslands were converted to farmland with Euro-American settlement (U.S. Fish and Wildlife Service Report, 2008). The sylvatic plague, a non-native disease introduced to the Americas in the early 1900's, affects black-footed ferret populations directly through infestation and high mortality rates (up to 90% in some populations) in prairie dog colonies (USFWS 2008). With the decline of all prairie dog species in the U.S., there has been a concurrent and predictable decline of black-footed ferret populations (Hoffmeister 1986, USFWS 2008).

Attributes and Indicators

Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
prey	Prairie dog density	<3.63/ha	3.63–5/ha	5–7/ha	>7/ha	Houston et al. (1986), Biggins et al. (1993)
prey	Area prairie dog colonies	<800 ha	800–1,900 ha	1,900–3,000 ha	>3,000 ha	Houston et al. (1986), Biggins et al. (1993)
dispersal	Prairie dog inter-colony distance	>4.3 km	3.2–4.3 km	2.1–3.2 km	<2.1 km	Minta and Clark (1989)

References Cited

Biggins, D.E., B.J. Miller, L.R. Hanebury, B. Oakleaf, A.H. Farmer, R. Crete and A. Dood. 1993. A technique for evaluating black-footed ferret habitat. Pages 73–88 *in* Oldemeyer, J.L., D.E. Biggins, B.J. Miller, and R. Crete (eds.), Proceedings of the symposium on management of prairie dog complexes for the reintroduction of the black-footed ferret, Biological Report 13, U. S. Fish and Wildlife Service, Washington, D.C.

Biggins, D.E., B.J. Miller, T.W. Clark, and R.P. Reading. 1997. Management of an endangered species: The black-footed ferret. Pages 420–424 *in* Meffe, G.K., and C.R. Carroll (eds.), Principles of Conservation Biology, 2nd edition, Sinauer Associates, Sunderland, Massachusetts.

Black-footed Ferret Recovery Implementation Team 2012. www.blackfootedferret.org

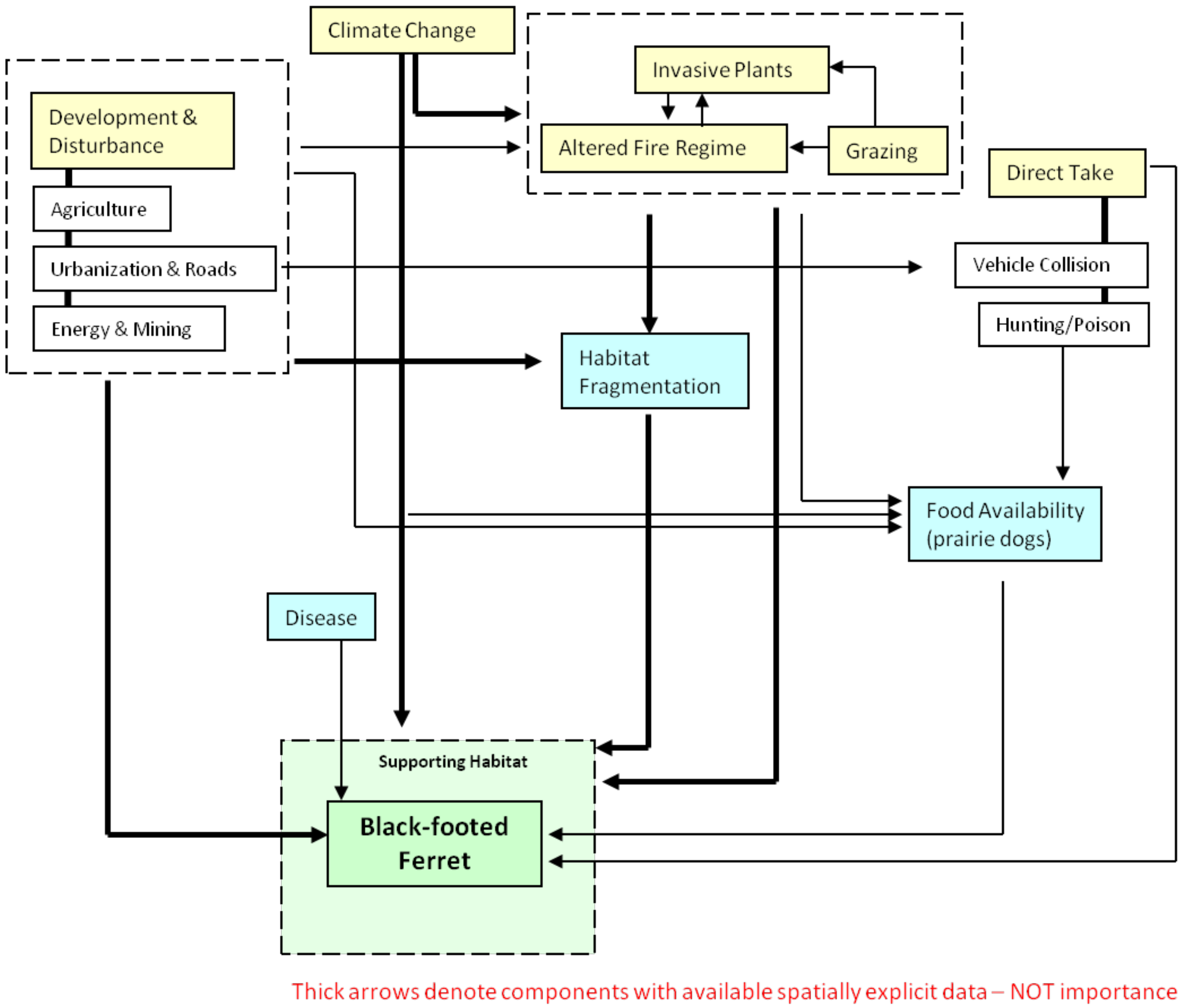
Hoffmeister, D.F. 1986. Mammals of Arizona. University of Arizona Press and Arizona Game and Fish Department, Tucson.

Houston, B.R., T.W. Clark, and S.C. Minta. 1986. Habitat suitability index model for the black-footed ferret: A method to locate transplant sites. *Great Basin Naturalist Memoirs* 8: 99–114.

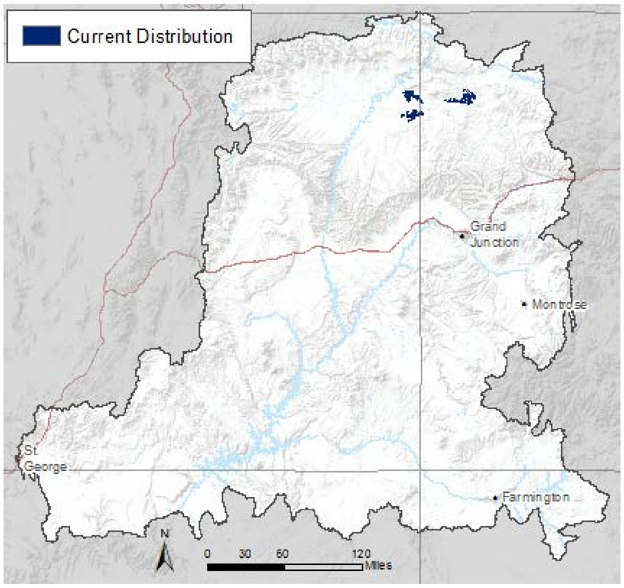
Minta, S.C., and T.W. Clark. 1989. Habitat suitability analysis of potential translocation sites for black-footed ferrets in north central Montana. Pages 29–45 *in* Clark, T.W., D. Hinckley, and T. Rich (eds.), The prairie dog ecosystem: Managing for biological diversity. Montana BLM Wildlife Technical Bulletin No. 2, Bureau of Land Management, Billings, Montana.

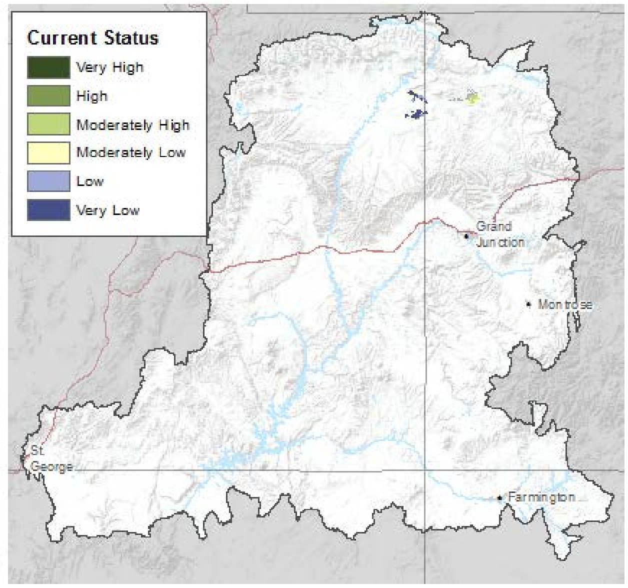
USFWS (U.S. Fish and Wildlife Service). 2008. Black-footed ferret five year status review: Summary and evaluation. USFWS, South Dakota Field Office, Pierre, South Dakota.

Black-Footed Ferret Conceptual Model



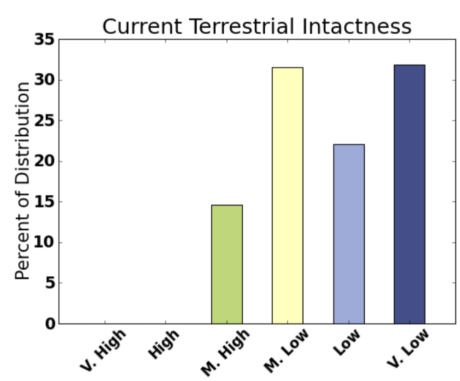
MQ D1. What are the current distribution and status of black-footed ferret (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?





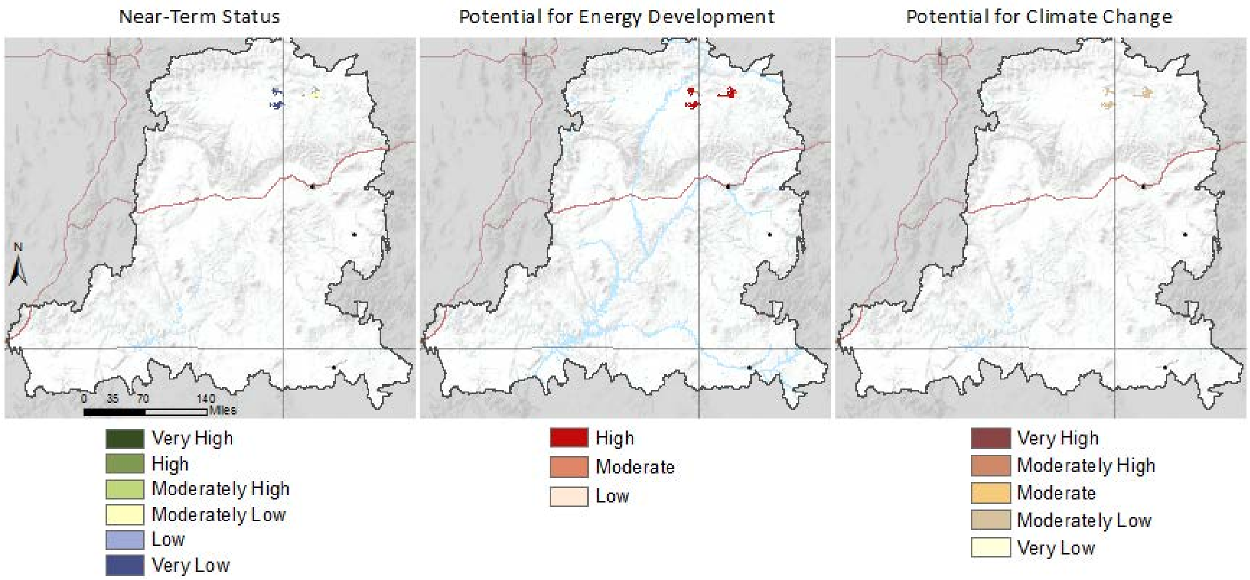
Data Sources:

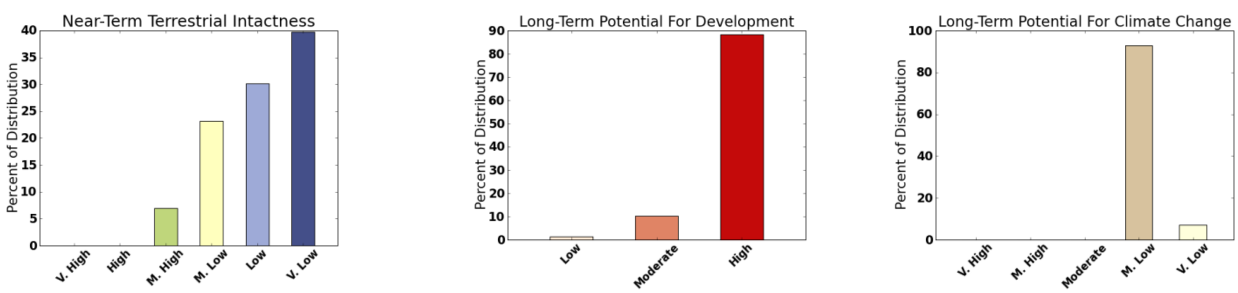
Black-footed ferret: polygons of white-tailed prairie dog selected out based on natural heritage element occurrences and reintroduction sites referenced in http://www.blm.gov/nstc/library/pdf/TN426.pdf



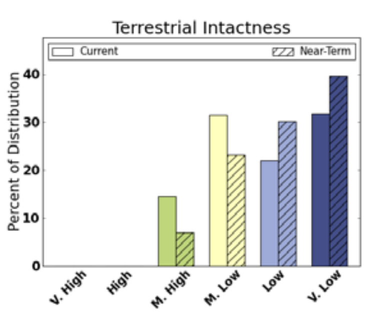
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

Black-Footed Ferret Potential for Change





Current & Near-term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

Desert Bighorn Sheep – *Ovis canadensis nelsoni*

Attributes and Indicators

Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
Habitat	Cover & terrain	Forest/thick brush; lack of precipitous escape terrain			Visually open with steep, rocky slopes	Sierra Nevada Bighorn Sheep Foundation; Beecham et al 2007
Disease	Proximity to domestic livestock				A minimum of 13.5 km between sheep & domestic livestock	Beecham et al, 2007; Singer et al, 2001
Habitat	Habitat fragmentation	Increased human disturbance			Little to no human disturbance	Beecham et al, 2007; King 1985
Climate	Effect on vegetation	Higher temperatures - decreased precipitation			Normal to higher levels of rainfall	Beecham et al, 2007

References Cited

Beecham, J.J. Jr., C.P. Collins, and T.D. Reynolds. 2007. Rocky Mountain bighorn sheep (*Ovis canadensis*): A technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/rockymountainbighornsheep.pdf

Graham, V.K. 1997. Desert bighorn sheep plan, Colorado Division of Wildlife Desert Bighorn Sheep Management Plan. 17pp.

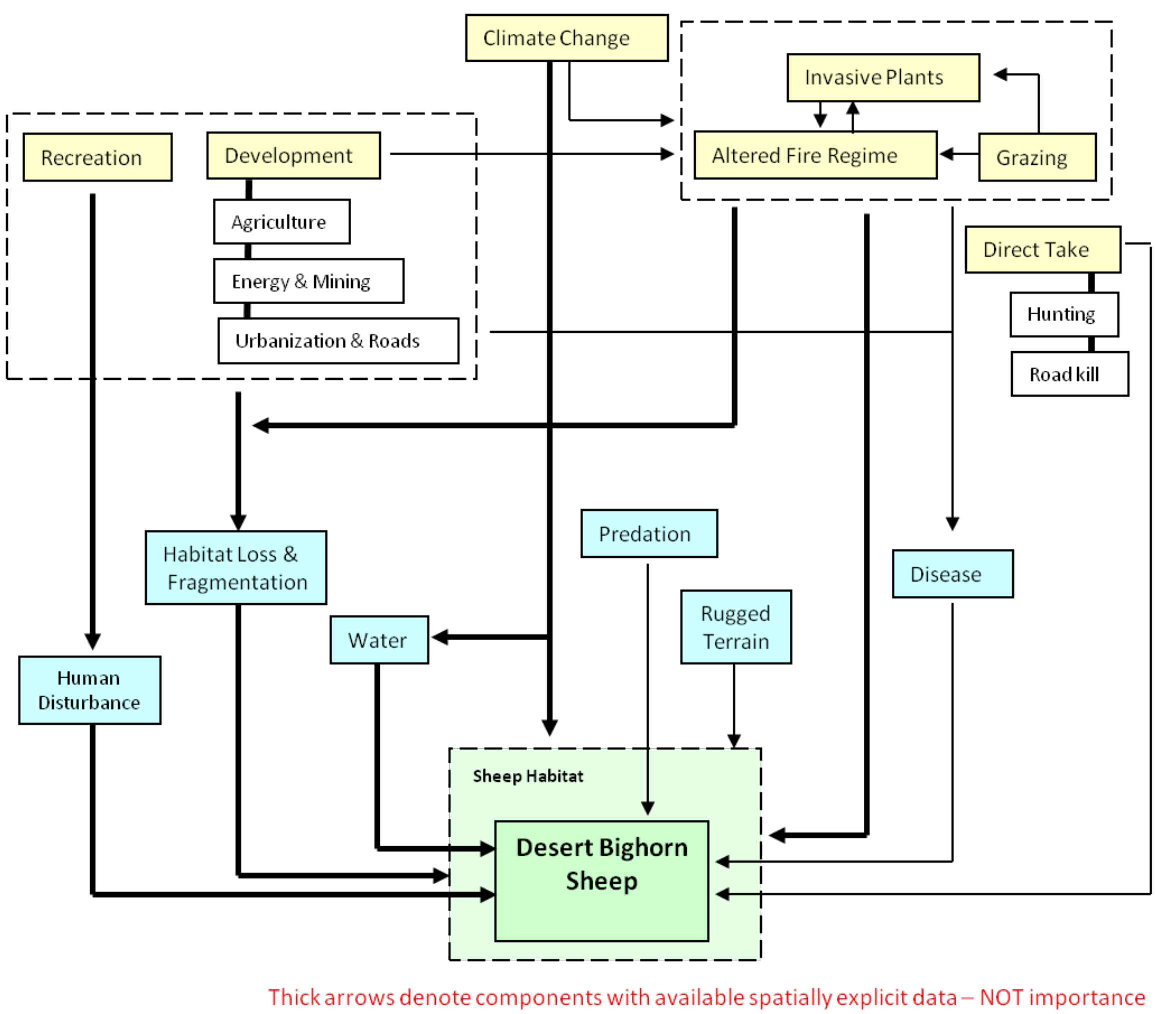
King, M.M. and G.W. Workman. 1985. Response of desert bighorn sheep to human harassment: Management implications. *Transactions of the 51st North American Wildlife and Natural Resources Conference* 51: 74–85.

Sierra Nevada Bighorn Sheep Foundation; http://www.sierrabighorn.org/Pages/S-NHistory.htm

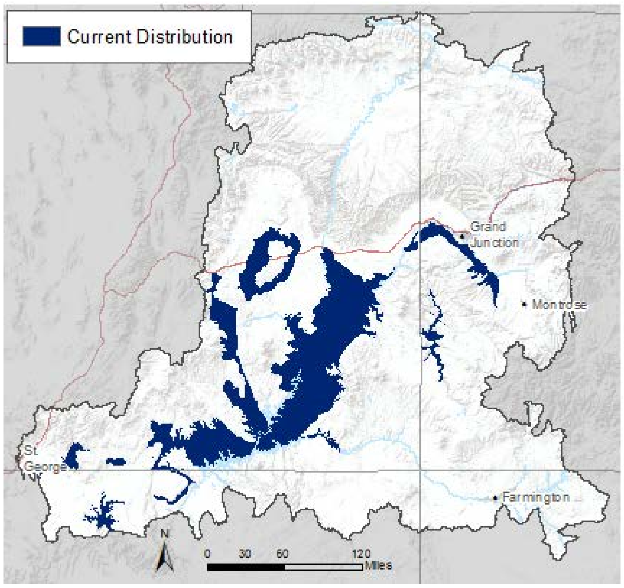
Singer, F.J., L.C. Zeigenfuss, and L. Spicer. 2001. Role of patch size, disease, and movement in rapid extinction of bighorn sheep. *Conservation Biology* 15(5): 1347–1354.

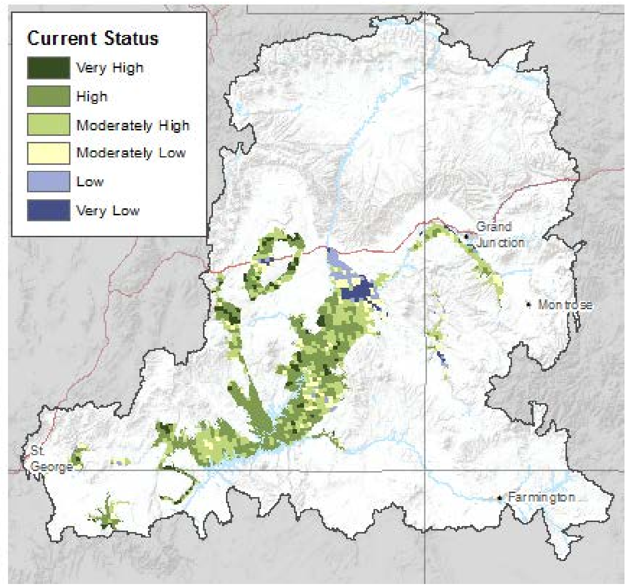
UDWR (Utah Division of Wildlife Resources). 2008. Utah Bighorn Sheep Statewide Management Plan, Utah Division of Wildlife Resources, Salt Lake City, Utah. 25pp.

Desert Bighorn Sheep Conceptual Model



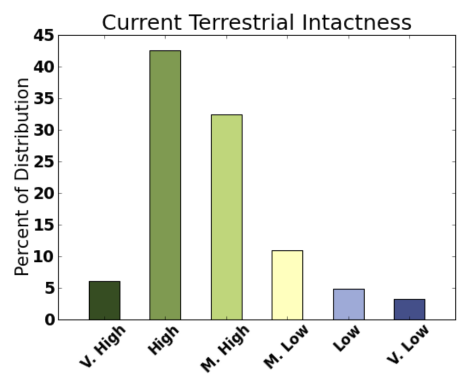
MQ D1. What are the current distribution and status of desert bighorn sheep (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?





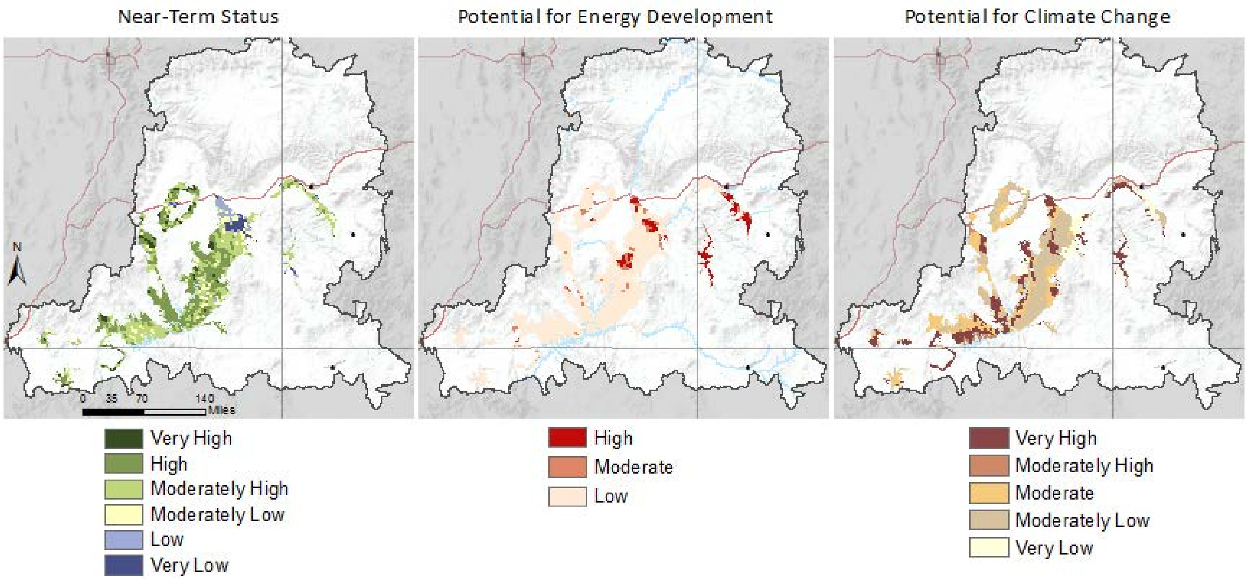
Data Sources:

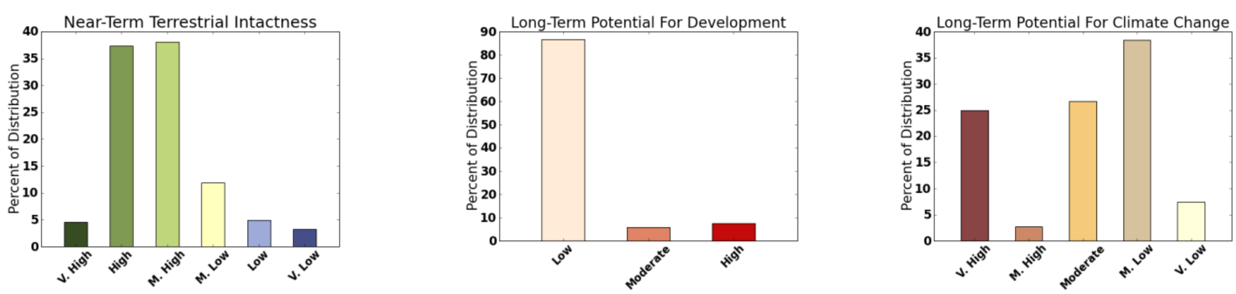
Desert bighorn sheep: Arizona Department of Fish & Game, Utah Division of Wildlife Resources, and reintroduction sites w/in polygons mapped by Colorado Division of Wildlife



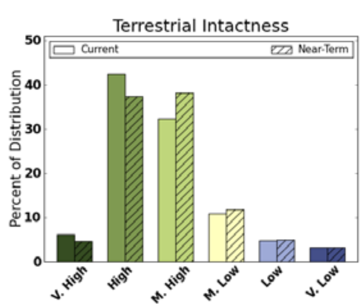
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

Desert Bighorn Sheep Potential for Change





Current & Near-term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

Gunnison's Prairie Dog – *Cynomys gunnisoni*

Gunnison's prairie dogs reside in both grasslands and (montane) high-desert scrub (Linzey et al. 2008, Lupis et al. 2007). The species typically burrows on slopes or in hummocks and prefers elevations of 1,550–3,660 meters (Longhurst 1944, Pizzimenti and Hoffman 1973, Linzey et al. 2008). They require well drained, deep soils for burrow construction and, because the species hibernates, they rely on placement of hibernacula below the frost line (Linzey et al. 2008). Grasses are, by far, the species' most important food item, though forbs, insects, and shrubs are consumed occasionally (Shalaway and Slobodchikoff 1988, Linzey et al. 2008).

Gunnison's prairie dogs are considered a keystone species of the sagebrush and prairie ecosystems because they are a top prey species and they also create habitat and keep soil and plant communities healthy (Lupis et al. 2007). They are one of five prairie dog species considered to be critical to the structure and function of their native ecosystems (Kotliar et al. 1999). Gunnison's prairie dog burrows provide homes for a host of animals including snakes, cottontail rabbits, burrowing owls, beetles, and salamanders. In addition, they are prey for numerous species including the black-footed ferret (*Mustela nigripes*), one of the most endangered mammals in North America (Rocke 2011 that depends on the Gunnison's prairie dog (as well as the black-tailed and white-tailed prairie dogs) for food and burrows. Population numbers for the Gunnison's prairie dogs have been drastically reduced from historic levels, resulting in the near extinction of the black-footed ferret (Rocke, 2011). In 1916, colonies of Gunnison's prairie dogs covered 24 million acres—currently they occupy less than 500,000 acres (Lupis et al. 2007). In Utah, Gunnison's prairie dogs inhabited 100,000 acres of habitat in 1961 that has declined to only 3,687 acres by 2002 (Lupis et al. 2007). The major threat to colonies of Gunnison's prairie dogs is their high susceptibility to outbreaks of plague. Specifically, sylvatic plague, a bacterial disease transferred by fleas and common among mammals, is a serious mortality threat to the species (Rocke 2011). The sylvatic plague is not native to North America, and, as a consequence, native mammals have no immunity and quickly succumb to the disease. Prairie dogs seem to be particularly susceptible to the disease and suffer very high mortality rates, up to 90% during outbreaks (Rocke 2011, Linzey et al. 2008).

Attributes and Indicators

Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
Forage	Available foods	shrubs	insects	forbs	grasses	Shalaway and Slobodchikoff (1988)
Habitat	Elevation	<4,500 ft or >11,000 ft	4,500–5,000 ft or 10,000–11,000 ft	5,000–6,000 ft or 8,500–10,000 ft	6,000–8,500 ft	Longhurst (1944), Pizzimenti and Hoffman (1973)
Disease	Sylvatic plague	exposed			no exposure	Linzey et al. (2008)
Habitat	Slope	>15%	5–15%	2–5%	0–2%	Fitzgerald and Lechleitner (1974)

References Cited

Fitzgerald, J.P., and R.P. Lechleitner. 1974. Observations on the biology of Gunnison's prairie dog in central Colorado. *American Midland Naturalist* 92:146–163.

Kotliar, N.B., B.W. Baker, A.D. Whicker, and G. Plumb. 1999. A critical review of assumptions about the prairie dog as a keystone species. *Environmental Management* 24: 177–192.

Linzey, A.V., Mabee, T., Cannings, S. & Hammerson, G. 2008. *Cynomys gunnisoni in* IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1. www.iucnredlist.org

Longhurst, W. 1944. Observations on the ecology of the Gunnison prairie dog in Colorado. *Journal of Mammalogy* 25: 24–36.

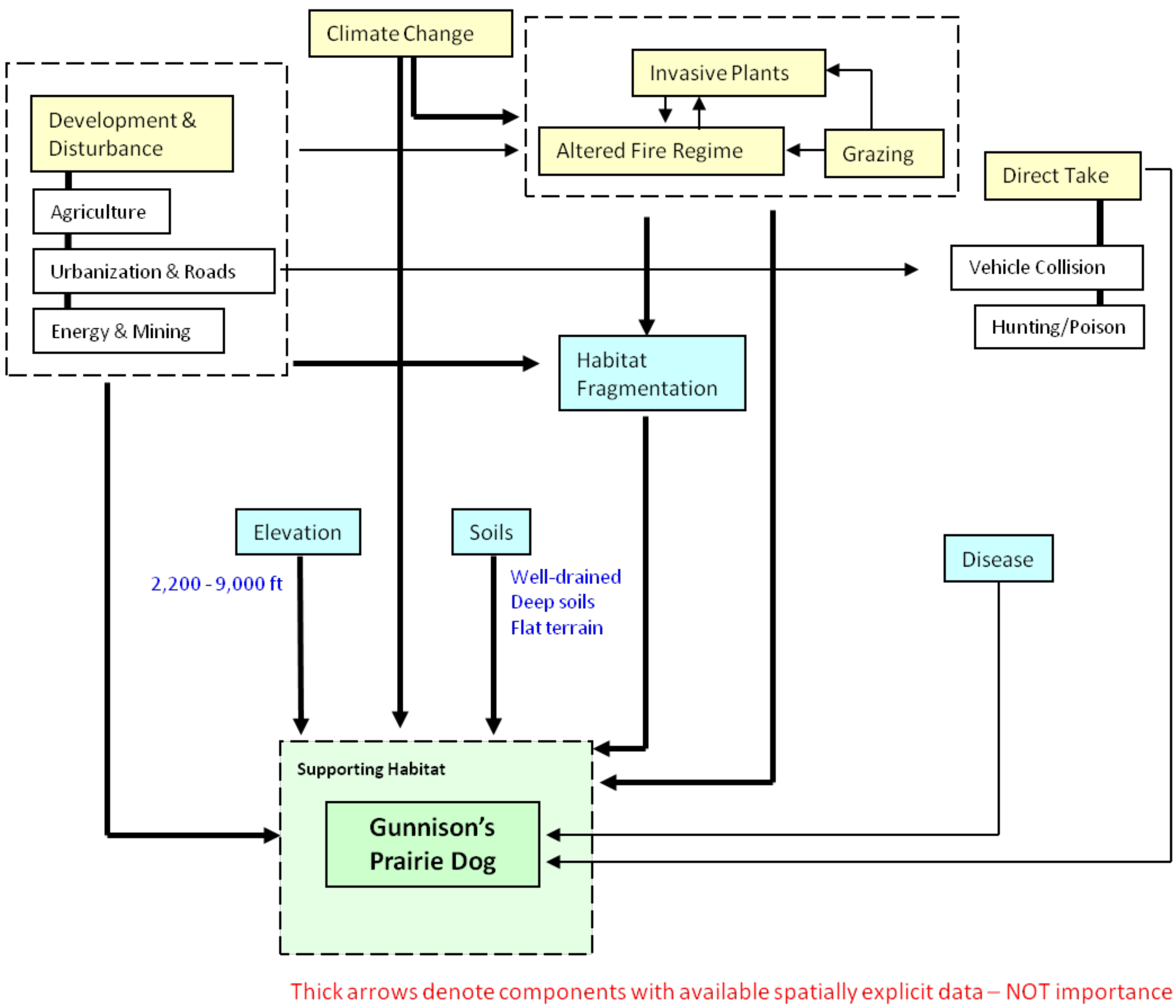
Lupis, S.G., K.D. Bunnell, T.A. Black, and T.A. Messmer. 2007. Utah Gunnison's prairie dog and white-tailed prairie dog conservation plan: Draft #5. Utah Division of Wildlife Resources, Salt Lake City, Utah.

Pizzimenti, J. J., and R.S. Hoffmann. 1973. *Cynomys gunnisoni*. *Mammalian Species* 25: 1–4.

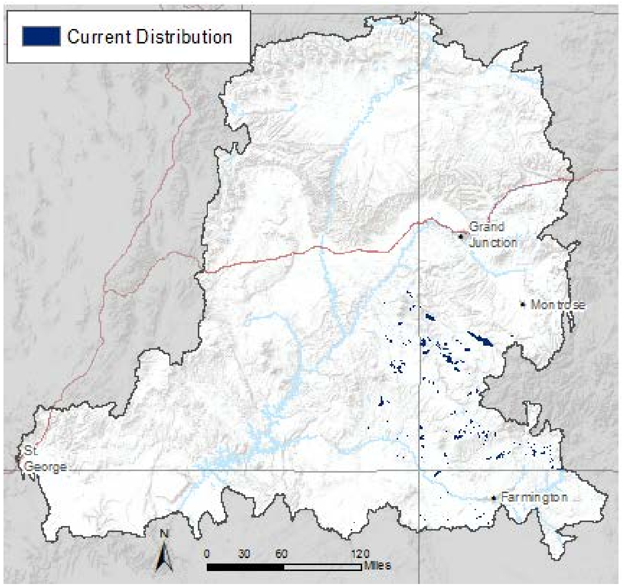
Rocke, T.E. 2011. Protecting black-footed ferrets and prairie dogs against sylvatic plague. U.S. Geological Survey Fact Sheet 2008-3087, Revised 2011, 2p.

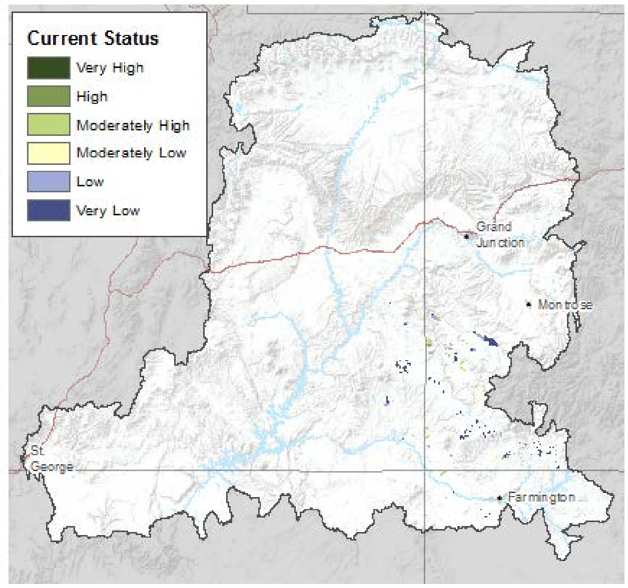
Shalaway, S., and C.N. Slobodchikoff. 1988. Seasonal changes in the diet of Gunnison's prairie dog. *Journal of Mammalogy* 69: 835–841.

Gunnison's Prairie Dog Conceptual Model



MQ D1. What are the current distribution and status of Gunnison's prairie dog (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?

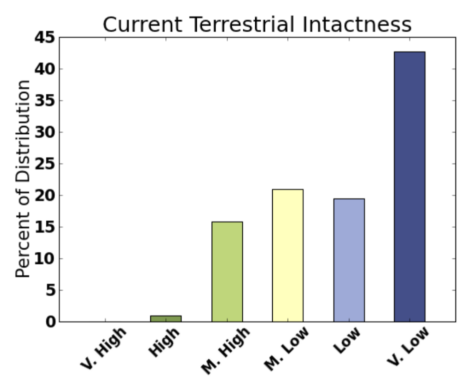




Data Sources:

Gunnison's Prairie Dog: Gunnison's Prairie Dog Colonies (2002) digitized from Seglund et al. (2005).

New Mexico Natural Heritage Program: Distributional analysis of Gunnison's Prairie Dog (*Cynomys gunnisoni*) on the Navajo Nation and Reservation of the Hopi Tribe (Johnson et al. 2010).

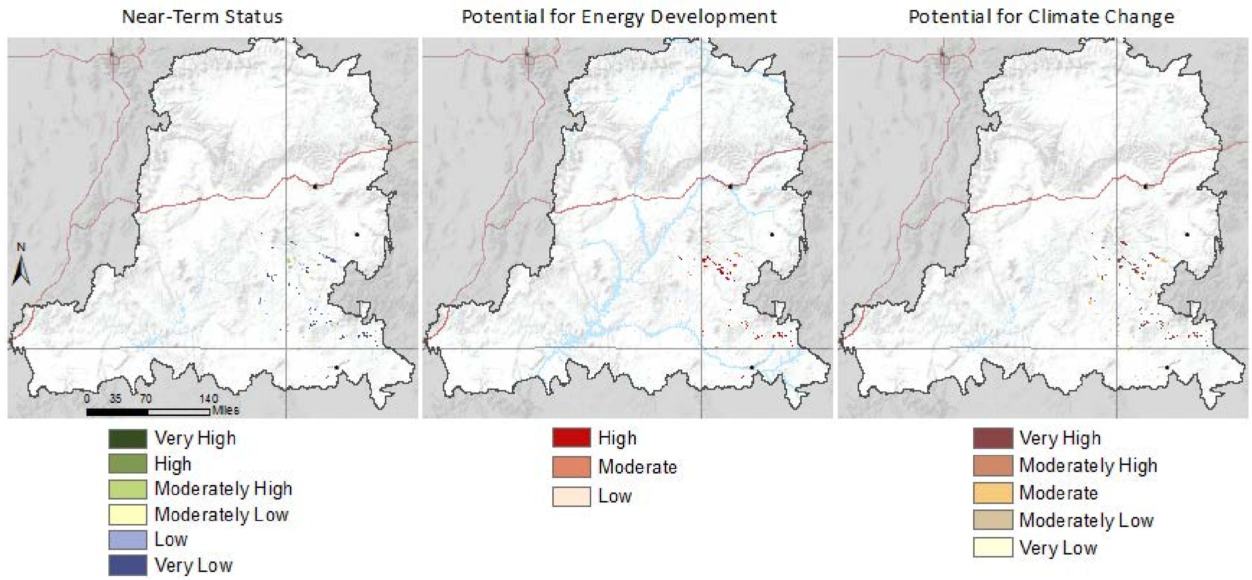


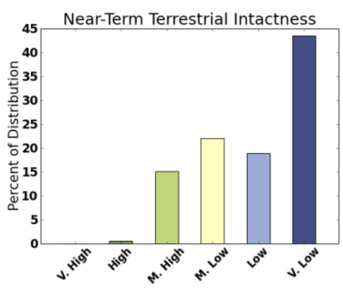
Johnson, K., T. Neville, D. Mikesic, and D. Talayumptewa. 2010. Distributional analysis of Gunnison's Prairie Dog (Cynomys gunnisoni) on the Navajo Nation and Reservation of the Hopi Tribe. Natural Heritage New Mexico Publ. No. 10-GTR-357. Natural Heritage New Mexico, University of New Mexico, Albuquerque, NM. 33 p.

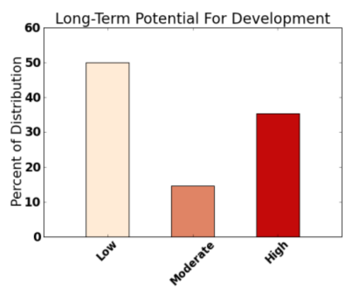
Seglund, A.E., A.E. Ernst, and D.M. O'Neill. 2005. Gunnison's prairie dog conservation assessment. Western Association of Fish and Wildlife Agencies. Laramie, Wyoming. Unpublished Report. 87 pp. (http://wildlife.state.co.us/SiteCollectionDocuments/DOW/WildlifeSpecies/Profiles/GPD_Assessment2005.pdf)

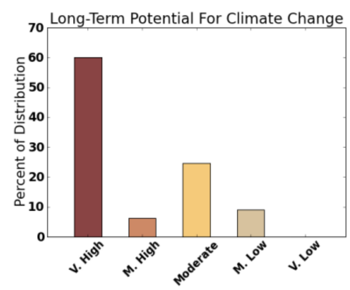
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

Gunnison Prairie Dog Potential for Change

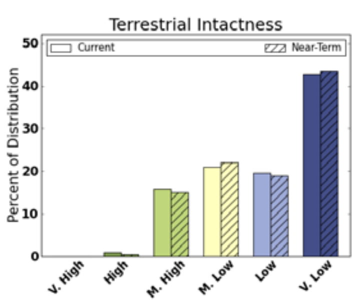








Current and Near-Term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

Mountain Lion – *Puma concolor*

Mountain lions are habitat generalists that have adapted to a wide range of environmental conditions (Weaver et al. 1996). The three main components defining high quality mountain lion habitat are abundance of prey species (e.g., mule deer, elk, and bighorn sheep), steep, rugged terrain, and vegetative cover to allow for the successful stalking of prey (Hornocker 1970, Koehler and Hornocker 1991). Mountain lions can inhabit all elevations, but they prefer open mixed hardwood and coniferous forest vegetation zones below timberline. Terrain ruggedness is a better predictor than vegetation cover in some landscapes such as the Colorado Plateau, meaning that the species is fairly widespread throughout the ecoregion. However, availability of abundant prey (especially in winter) is the most important factor in supporting a strong lion population. Mountain lions are highly territorial, solitary predators that display a wide variability in home range sizes (males 25 to more than 500 sq mi and females 8 to more than 400 sq mi). Territory size, which often shifts seasonally, is determined by a number of ecological and allometric factors including abundance of prey—higher prey densities often result in smaller home ranges (Grigione et al. 2002). Hemker et al. (1984) reported some of the largest known home range sizes for mountain lions in southern Utah with males occupying up to 513 sq mi and females up to 426 sq mi. A typical mountain lion population consists of resident males and females in occupied territories, transient males and females moving across the landscape looking to establish their own territories, and dependent kittens of resident females (Lynch 1989).

At the ecoregion level, mountain lions require fairly large home ranges with ample food and cover (provided by vegetation cover and/or rugged terrain). They also require the ability to disperse widely in search of prey and new territories as this is important component of their life history. Mountain lions can tolerate significant human disturbance (Weaver et al. 1996); however, they do avoid developed and semi-developed areas unless dispersing to new territories, which is normally conducted at night when under more stressful circumstances (Beier 1995). The most important threat to mountain lions in the ecoregion is overall habitat degradation due to residential development, recreational development, and road building. For example, Van Dyke et al. (1986) reported road densities > 0.6 km/sq km as poor for mountain lion due to avoidance behavior and direct mortality through increased conflict with humans.

Attributes and Indicators

Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
Prey	Ungulate density	Low	Medium	High	Very high	Julander and Jeffrey (1964)
Habitat degradation	Road density	.6 km/sq km	0.4	0.2	0	Van Dyke et al. (1986)
Habitat	Cover & terrain	Very dense or open cover	-	-	Rugged terrain with mixed cover	Riley (1998)
Habitat	Human	Highly	Moderately	Minimally	No	Van Dyke et

degradation	development	developed	developed	developed	development	al. (1986)

References Cited

Beier, P. 1995. Dispersal of juvenile cougars in fragmented habitat. *Journal of Wildlife Management* 59: 228–237.

Grigione, M.M., P. Beier, R.A. Hopkins, D. Neal, W.D. Padley, C.M. Schonewald, and M.L. Johnson. 2002. Ecological and allometric determinants of home-range size for mountain lions (*Puma concolor*). *Animal Conservation* 5: 317–324.

Hemker, T.P., F.G. Lindzey, and B.B. Ackerman. 1984. Population characteristics and movement patterns of cougars in southern Utah. *Journal of Wildlife Management* 48(4): 1275-–1284.

Hornocker, M.G. 1970. An analysis of mountain lion predation upon mule deer and elk in the Idaho Primitive Area. *Wildlife Monographs* 21:1–39.

Julander, O. and D.E. Jeffrey. 1964. Deer, elk, and cattle relations on summer range in Utah. Transactions of the North American Wildlands and Natural resources Conference 29: 404–413.

Koehler, G.M., and M.G. Hornocker. 1991. Seasonal resource use among mountain lions, bobcats, and coyotes. *Journal of Mammalogy* 72: 391–396.

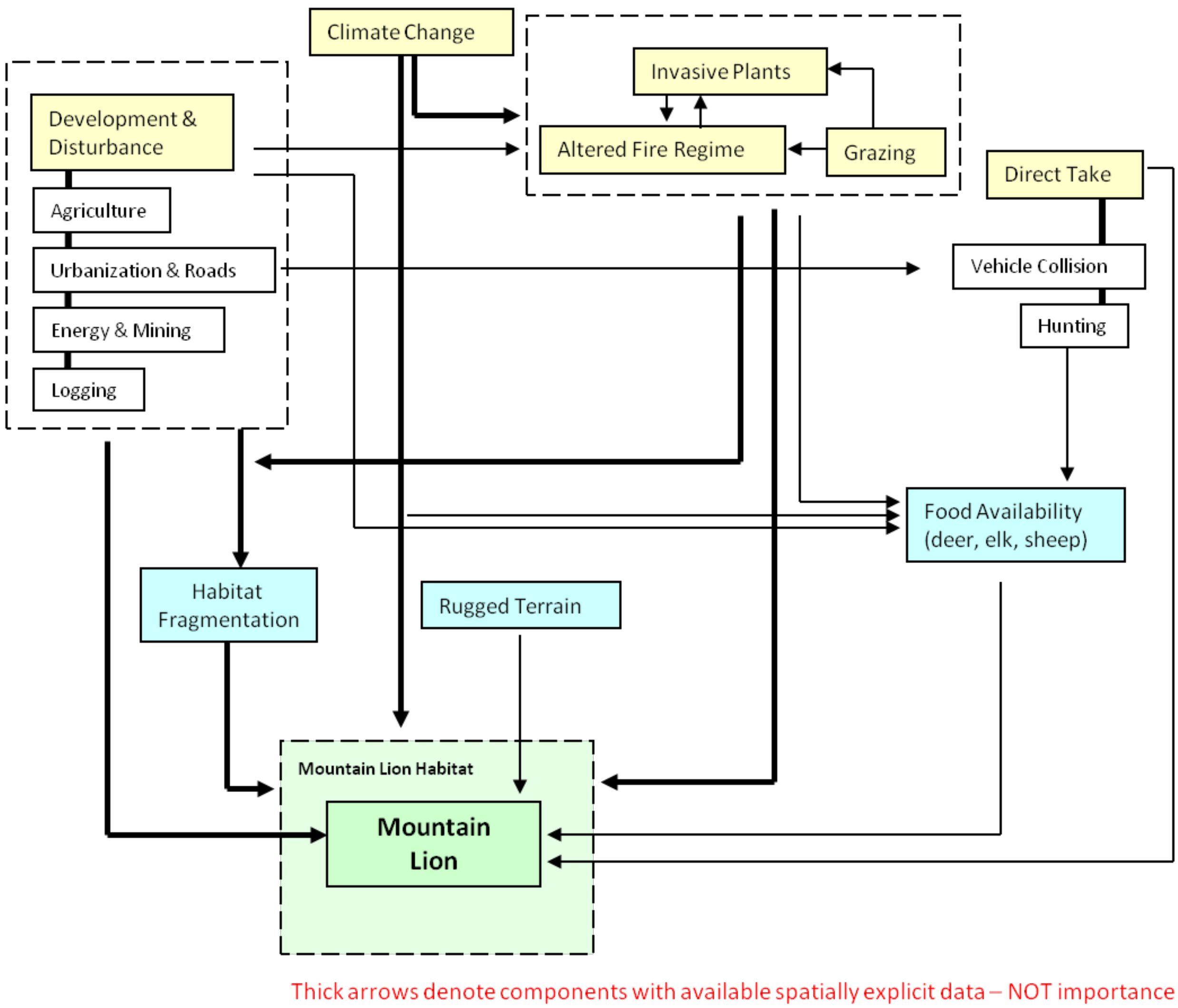
Lynch, W. 1989. The elusive cougar. *Canadian Geographic* August/September: 24–31.

Riley, S.J. 1998. Integration of environmental, biological, and human dimensions for management of mountain lions (*Puma concolor*) in Montana. Ph.D. Dissertation, Cornell University, Ithaca, New York.

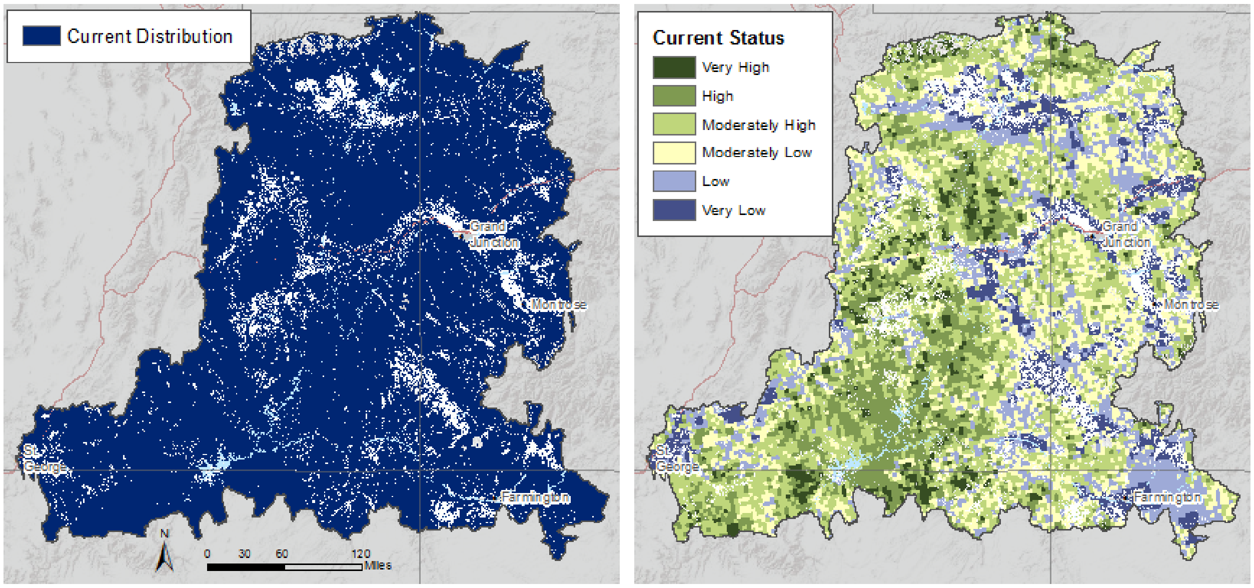
Van Dyke, F.G., R.H. Brocke, H.G. Shaw, B.B. Ackerman, T.P. Hemker, and F.G. Lindzey. 1986. Reactions of mountain lions to logging and human activity. *Journal of Wildlife Management* 50: 95–102.

Weaver, J.L., P.C. Paquet, and L.F. Ruggiero. 1996. Resilience and conservation of large carnivores in the Rocky Mountains. *Conservation Biology* 10: 964–976.

Mountain Lion Conceptual Model

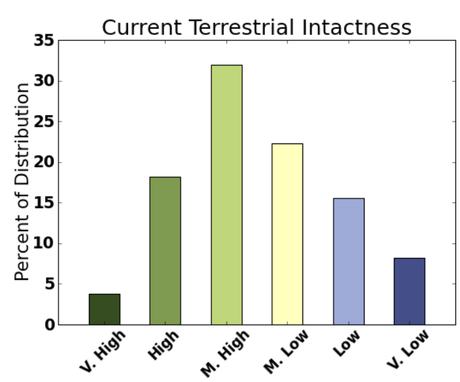


MQ D1. What are the current distribution and status of mountain lion (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?



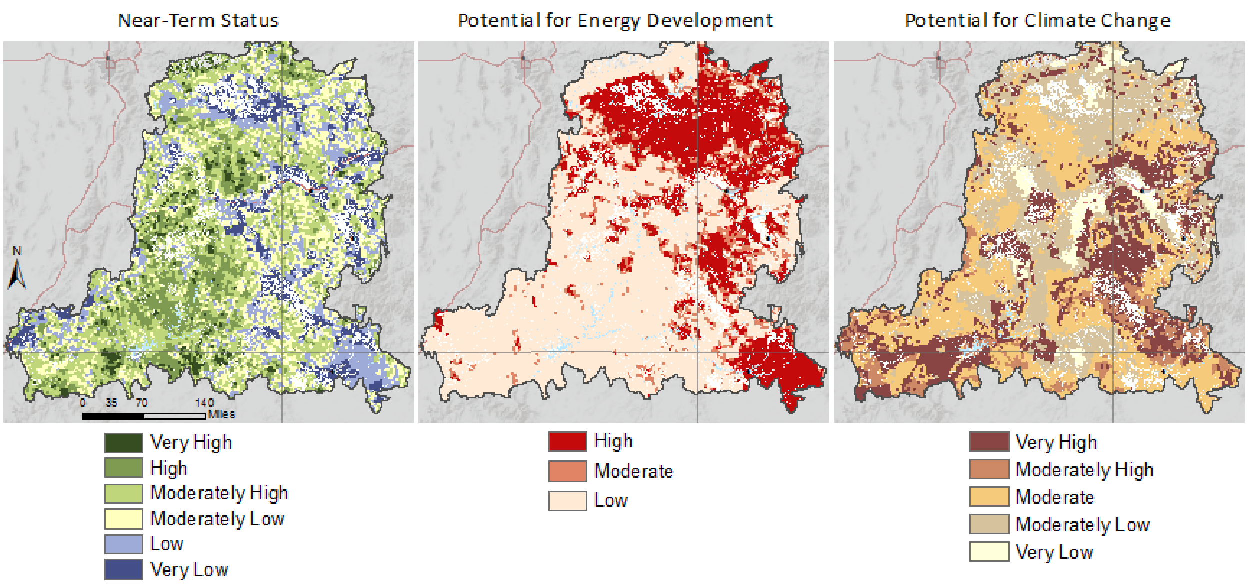
Data Source:

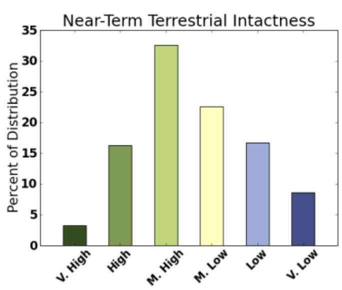
SW ReGAP (Southwest Regional GAP Analysis Project).

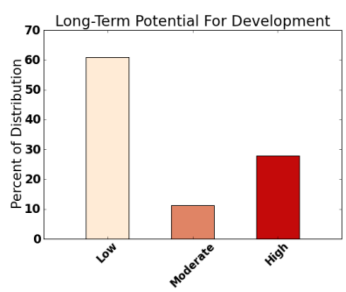


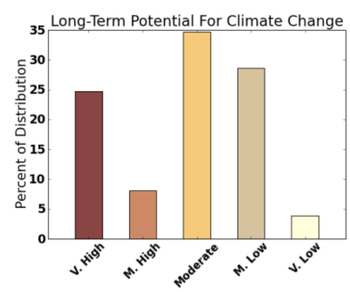
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

Mountain Lion Potential for Change

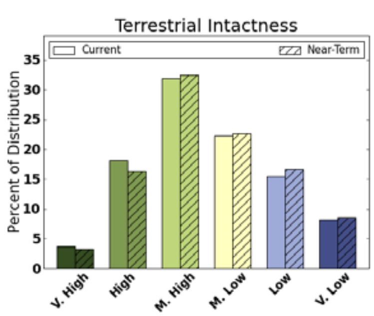








Current & Near-term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

Mule Deer – *Odocoileus hemionus*

Mule deer have the ability to occupy a diverse set of habitats but are most commonly associated with sagebrush communities (Mule Deer Working Group 2003, Theodore Roosevelt Conservation Partnership 2011). Shrub communities are important to mule deer for food and shelter, and the connectivity of such seasonal habitats is critical to the survival of mule deer populations (Theodore Roosevelt Conservation Partnership 2011). Like most deer, mule deer are browsers that rely on a diverse range of plants for their nutrition. In late spring to early fall, mule deer eat mostly forbs and grasses, while in late fall they eat the leaves and stems of brush species, and in winter to early spring they must survive on just twigs and branches (Theodore Roosevelt Conservation Partnership 2011). So, while mule deer forage on a wide variety of plant species, they also have very specific seasonal foraging requirements, and variety and high nutritional content across seasons is imperative to the survival of populations (Watkins et al. 2007). Mountain lions are the top predators in the ecoregion.

Despite their adaptability, mule deer populations have been decreasing in numbers since the latter third of the 20th century. In Utah, the 2007 post-hunting season population was estimated to be 302,000 deer, well below the long-term management objective of 426,000 individuals (Utah Division of Wildlife Resources, Statewide Management Plan for Mule Deer 2008). There are a myriad of stressors on mule deer, but the most significant threats involve habitat fragmentation and conversion (Theodore Roosevelt Conservation Partnership 2011). The vegetative species composition has been modified extensively with the invasion of non-native plants such as cheatgrass (Watkins et al. 2007). Cheatgrass out-competes most native plant species in a moisture-limited environment and changes the site-specific fire ecology, resulting in a loss of important shrub communities (Watkins et al. 2007). Plant species composition has also changed due to livestock grazing, successional changes caused by fire suppression, and the disturbance and conversion of habitat (Watkins *et* al. 2007). In addition to the change in plant species composition, active fire suppression has changed the vegetation structure to result in the accumulation of unnaturally high fuel loads that can lead to more extensive fires (Watkins et al. 2007, Mule Deer Working Group 2011). Other factors that contribute to the decline of mule deer populations include habitat fragmentation due to gas, mineral, and oil exploration and increased competition with elk when habitat is poor or limited (Mule Deer Working Group 2011).

Oil and gas development is the main change agent presently affecting mule deer populations in the Colorado Plateau. Energy development results in direct loss of habitat, disturbance and displacement from foraging areas and migration routes, resulting loss of connectivity between seasonal habitats, contamination of water supplies, spread of invasive non-native vegetation, and stress-related energy expenditures, particularly in the winter months (Tessman et al. 2004). Watkins et al. (2007) have developed management guidelines for mitigating the impacts of energy development on mule deer populations.

Attributes and Indicators

Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
Habitat degradation	Distance from oil wells	<2.7 km	-	-	>3.7 km	Sawyer et al. (2006)
Habitat degradation	Well density	>16 wells or >80 acres disturbed per mile^2 section	5–16 wells and 20–80 acres disturbed per mile^2 section	1–4 wells and ≤20 acres disturbed per mile^2 section	No wells	Tessman et al. (2004)
Habitat degradation	Distance from roads	>200m	-	-	>500 m	
Habitat	Loss, fragmentation, drought, fire, low quality					http://www.ndow.org/wild/animals/facts/mule_deer.shtm
Habitat	Vegetation/food preference as associated with fire suppression	Large, hot fires	-	-	Small, frequent fires (early successional plants)	Mule Deer Working Group - Western Assoc. of Fish & Wildlife agencies, (2003)
Habitat	Variety of vegetation	Homogen-eous	-	-	Mosaic of early successional habitat (food) & tree-dominated habitats (cover)	Mule Deer Working Group, Western Assoc. of Fish & Wildlife agencies (2003)

References Cited

Mule Deer Working Group. 2003. Western Association of Fish & Wildlife agencies.

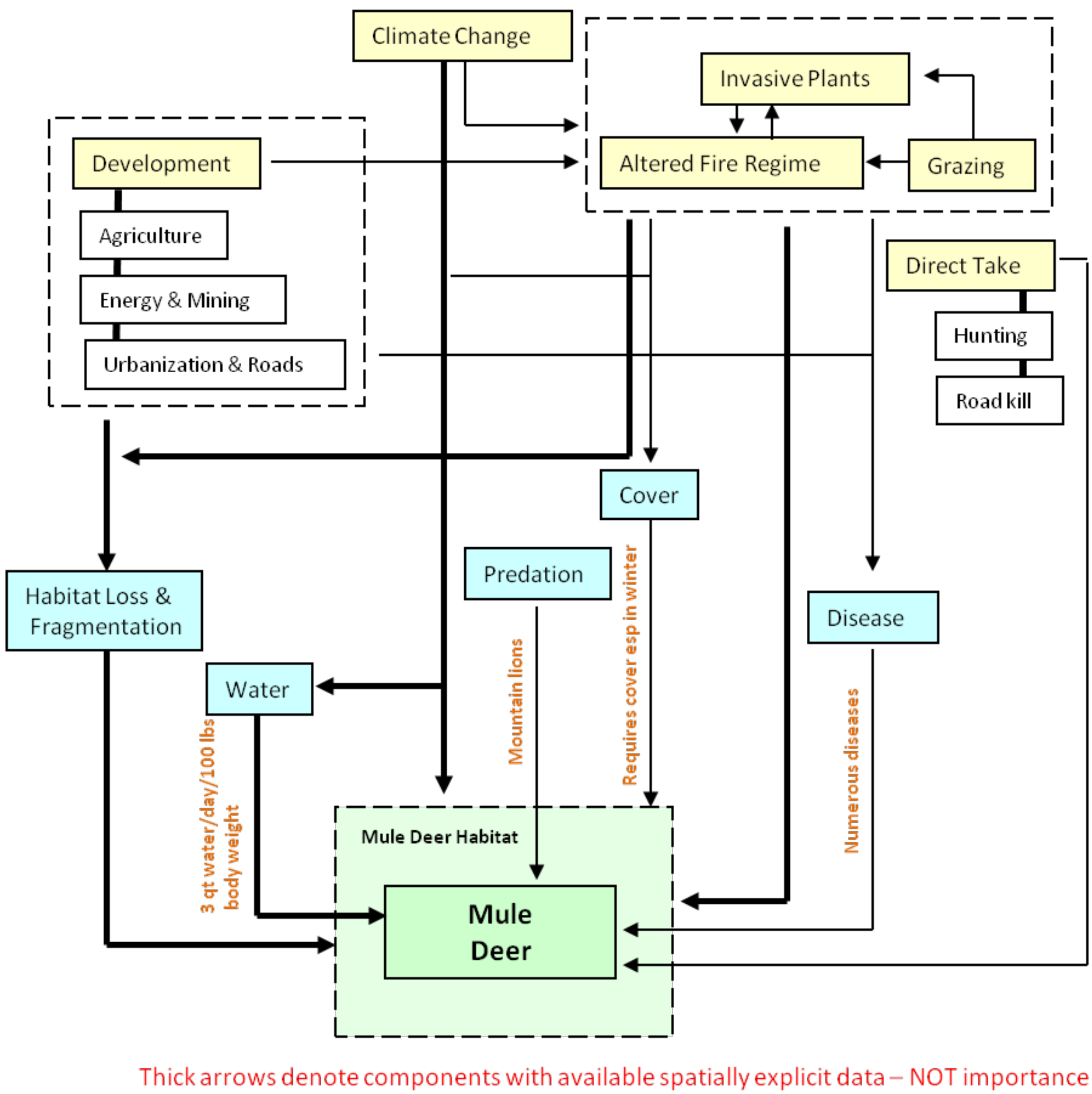
Sawyer, H.R.M. Nielson, F. Lindzey and L.L. McDonald. 2006. Winter habitat selection of mule deer before and during development of a natural gas field. *Journal of Wildlife Management* 70(2): 396–403.

Tessmann, S., J. Bohne, B. Oakleaf, B. Rudd, S. Smith, V. Stetler, D. Stroud, and S. Wolff. 2004. DRAFT: Minimum recommendations to sustain important wildlife habitats affected by oil and gas development: A strategy for managing energy development consistently with the FLPMA principles of multiple use and sustained yield. Wyoming Game and Fish Department, Cheyenne, Wyoming.

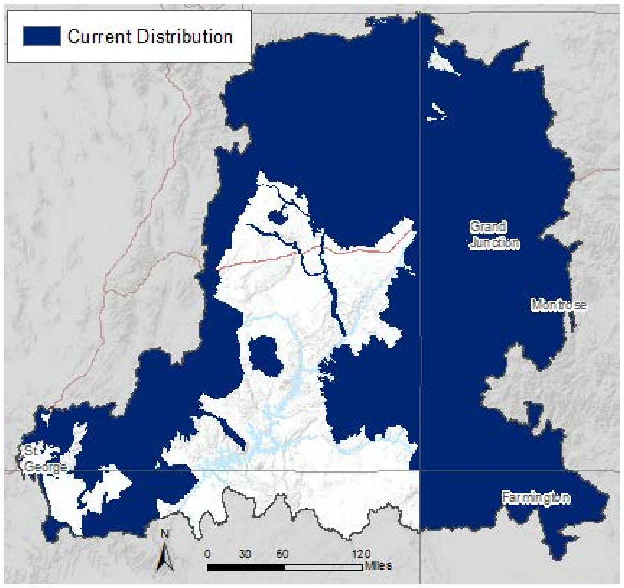
Theodore Roosevelt Conservation Partnership Mule Deer & Energy: Federal Policy and Planning in the Greater Green River Basin April 2011

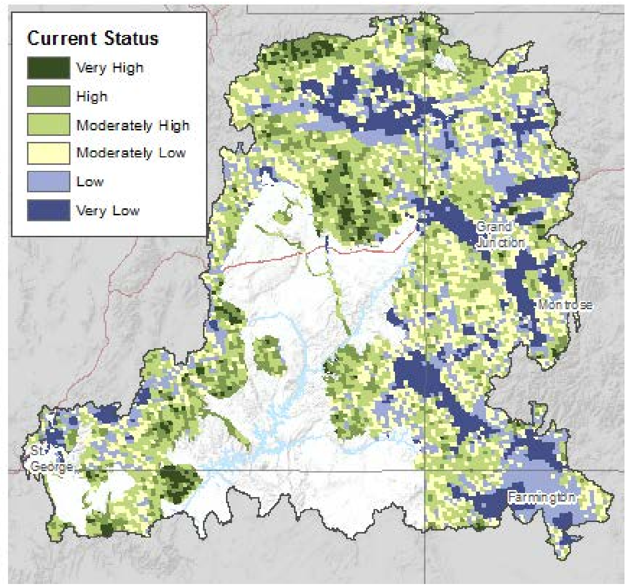
Watkins, B. E., C. J. Bishop, E. J. Bergman, A. Bronson, B. Hale, B.F. Wakeling, L.H. Carpenter, and D.W. Lutz. 2007. Habitat guidelines for mule deer: Colorado Plateau shrubland and forest ecoregion. Mule Deer Working Group, Western Association of Fish and Wildlife Agencies.

Mule Deer Conceptual Model



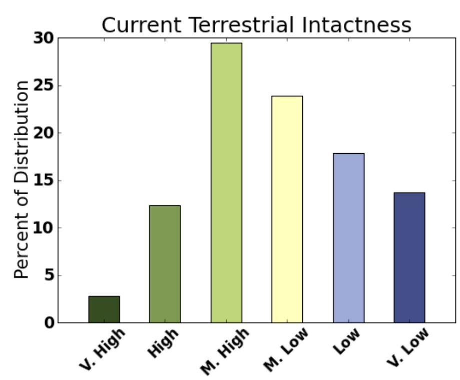
MQ D1. What are the current distribution and status of mule deer (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?





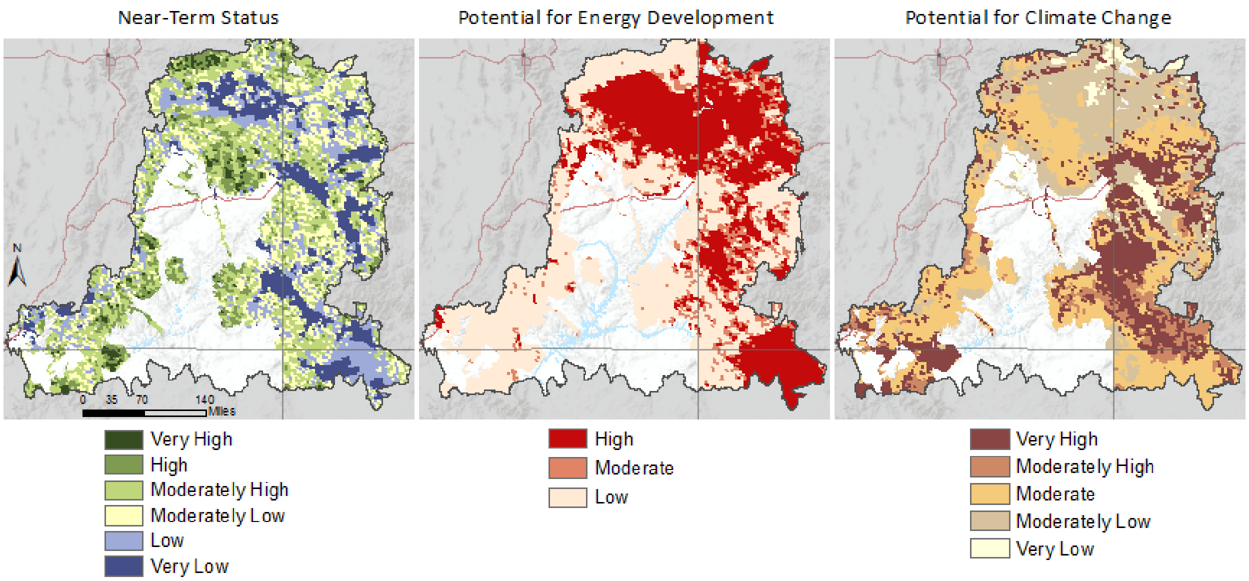
Data Sources:

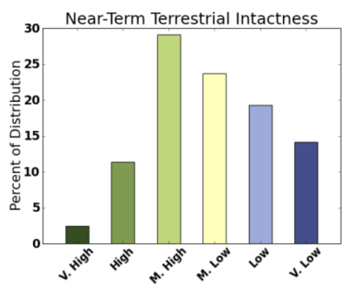
Colorado Division of Wildlife, Arizona Department of Fish & Game, Utah Division of Wildlife Resources, and "Mule Deer Habitat of North America"
Summer Habitat: Arizona Department of Fish & Game, Utah Division of Wildlife Resources, and "Mule Deer Habitat of North America"
Winter Habitat: Arizona Department of Fish & Game, Utah Division of Wildlife Resources, and "Mule Deer Habitat of North America"

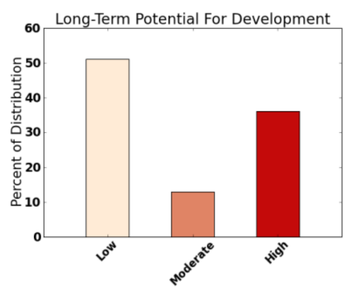


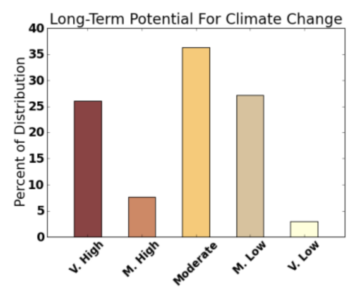
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

Mule Deer Potential for Change

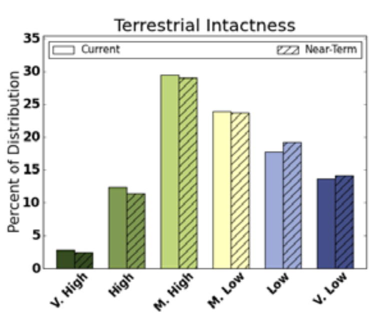








Current & Near-term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

Pronghorn Antelope – ***Antilocapra americana***

Pronghorns have specific habitat requirements necessary for the species to persist and thrive. Yoakum et al. (1996) and Jaeger and Fahrig (2004) defined the optimal habitat parameters for the North American pronghorn, the most critical of which are elevation, terrain, connectivity of habitat, distance from water, and vegetation. Peak concentrations of herds are located between 1200 and 1850 meters above sea level in open shrubland (Yoakum et al. 1996). In addition, for predator detection and escape, pronghorns require flat, open habitat, with rolling hills and slopes less than 30% to detect approaching predators (Yoakum et al. 1996). With speeds reaching 60 mph, pronghorns can easily outrun any predator once detected.

Some pronghorn populations migrate long distances between summer and winter feeding grounds. Fences form an especially significant barrier to pronghorn movement, as the species is averse to jumping fences and will typically choose to go under a fence (Yoakum et al. 1996, Jaeger and Fahrig 2004). Other barriers along the pronghorn migration include roads, railroads, urban sprawl, and gas fields (Sawyer et al. 2006). Additionally, pronghorns require ready access to water and they are usually found within 1.5-–6.5 km of a water source (Yoakum *et al*, 1996). Pronghorn also need a variety of vegetation for foraging; they select, in order of preference, forbs, shrubs, and grasses (Yoakum et al. 1996). Accessibility to a combination of both grasses and shrubs has been shown to be essential to fawn survival rate (Ellis, 1970). Throughout North America, pronghorn antelope populations have declined by as much as 95% from historic levels. In Utah, the current statewide population estimate is 12,000–14,000 (Utah Division of Wildlife Resources, Utah Pronghorn Statewide Management Plan, 2009). Oil and gas development in the Colorado Plateau is a major change agent affecting the future sustainability of pronghorn, particularly related to area needs for foraging and maintenance of seasonal migration routes. Heavy fragmentation of pronghorn habitat and migration blockages and bottlenecks from oil and gas development have been documented in western Wyoming (Sawyer et al. 2002, Berger 2003).

Attributes and Indicators

Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
Habitat	Distance to water	>6.5 km	4.5-6.5 km	4.5-1.5 km	<1.5 km	Yoakum et al. (1996)
Habitat	Fragmentation	<242 ha			large patch	Berger et al. 2006
Movement	Barriers	abundant	common	few	none	Jaeger and Fahrig (2004)
Habitat	Diet	woody vegetation	single food	somewhat mixed food	well-mixed food - forbs, grass, and shrubs	Yoakum et al. (1996), Martinka (1967)

References Cited

Berger, J. 2003. Is it acceptable to let a species go extinct in a National Park? *Conservation Biology* 17(5):1451–1454.

Berger, J., Berger, K.M and Beckmann, J.P. 2006. Wildlife and energy development: pronghorn of the Upper Green River Basin – year 1 summary. Wildlife Conservation Society, Bronx, New, York. http://www.wcs.org/yellowstone.

Ellis, J. 1970. A computer analysis of fawn survival in the pronghorn antelope. PhD Dissertation, University of California, Davis, California.

Jaeger, J. A., L. Fahrig. 2004. Effects of road fencing on population persistence. *Conservation Biology* 18(6): 1651–1657.

Martinka, C. 1967. Mortality of northern Montana pronghorns in a severe winter. *Journal of Wildlife Management* 31(1): 159–164.

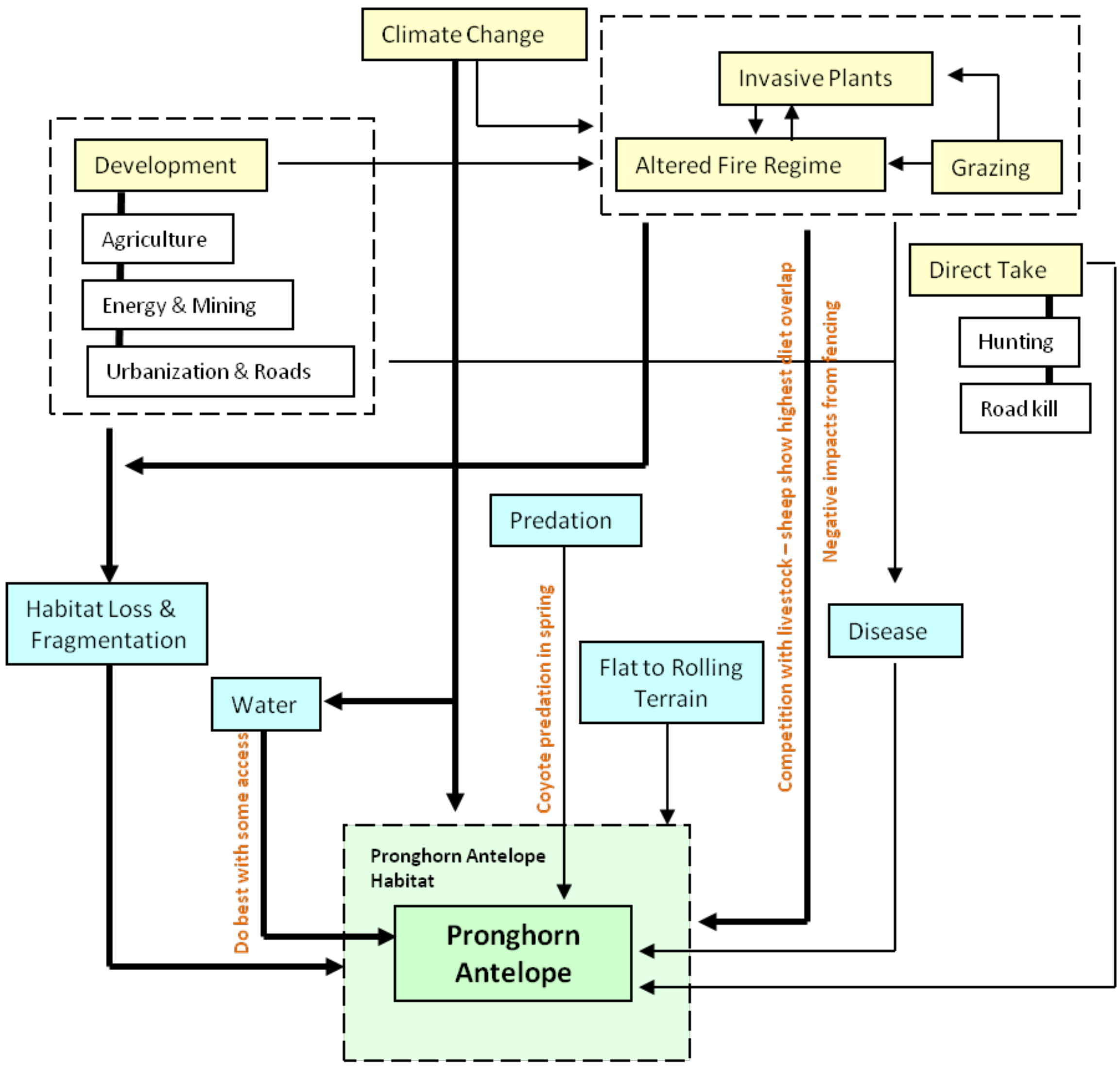
Sawyer, H.R.M., F. Lindzey, D. McWhirter, and K. Andrews. 2002. Potential effects of oil and gas development on mule deer and pronghorn populations in western Wyoming. Pages 350–365 in Rahm, J. (ed.), Transactions of the 67th North American Wildlife and Natural Resources Conference, Washington, D.C.

Sawyer, H. R.M. Nielson, F. Lindzey and L.L. McDonald. 2006. Winter habitat selection of mule deer before and during development of a natural gas field. *Journal of Wildlife Management* 70(2):396–403.

Utah division of wildlife resources, statewide management plan for pronghorn. 2009. http://wildlife.utah.gov/hunting/biggame/pdf/Statewide_prong_mgmt_2009.pdf

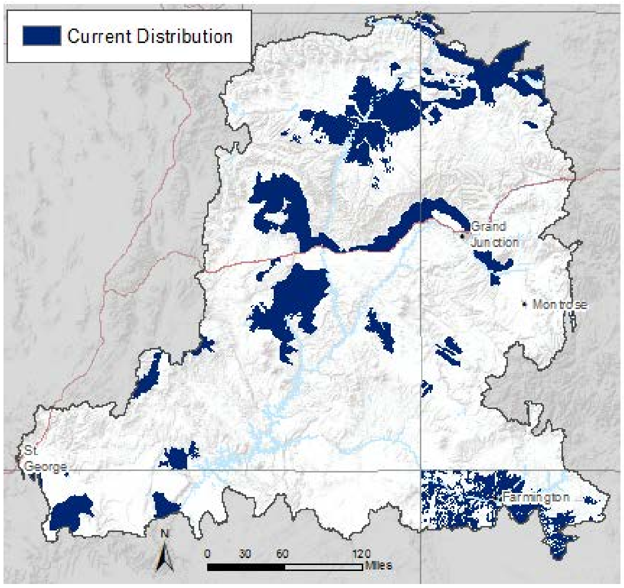
Yoakum, J.D., B.W. O'Gara, and V.W. Howard. 1996. Pronghorn on western rangelands. Pages 211–216 *in* Krausman, P.R. (ed.), Rangeland Wildlife, Society of Range Management, Denver, Colorado.

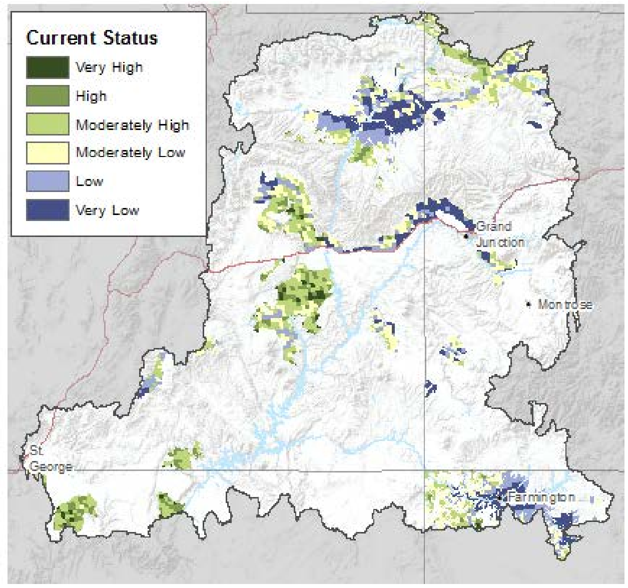
Pronghorn Antelope Conceptual Model



Thick arrows denote components with available spatially explicit data – NOT importance

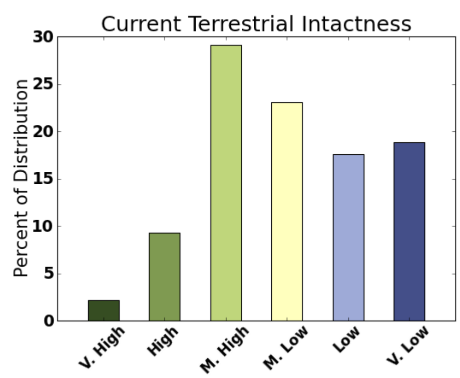
MQ D1. What are the current distribution and status of pronghorn antelope (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?





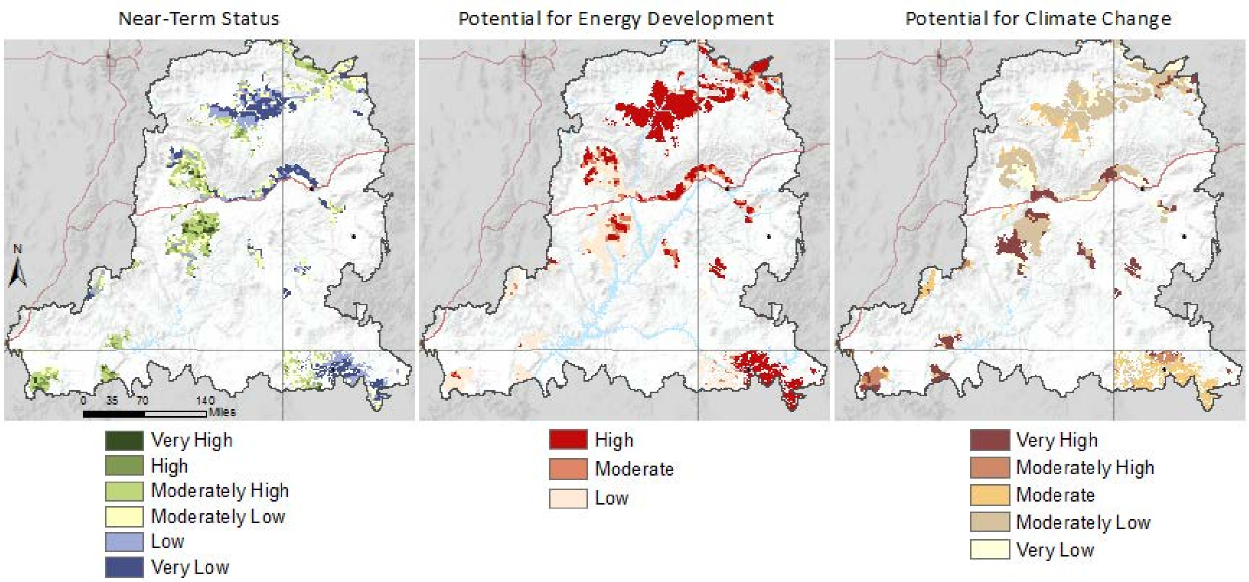
Data Source:

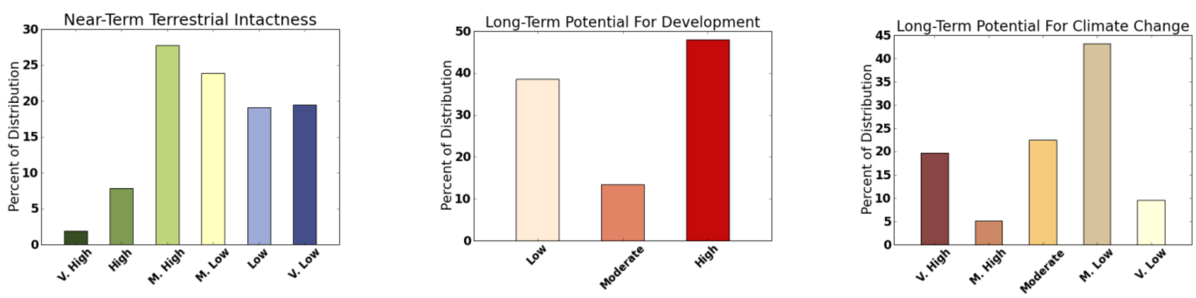
Colorado Division of Wildlife, Arizona Department of Fish & Game, Utah Division of Wildlife Resources, and NM GAP
Summer: Colorado Division of Wildlife, Arizona Department of Fish & Game, Utah Division of Wildlife Resources
Winter: Colorado Division of Wildlife, Arizona Department of Fish & Game, Utah Division of Wildlife Resources



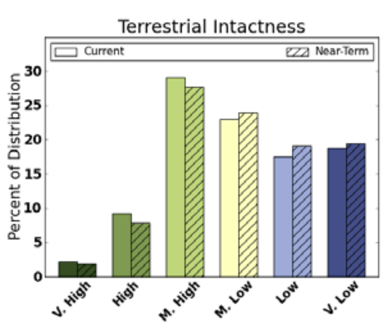
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

Pronghorn Antelope Potential for Change





Current & Near-term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

White-tailed Prairie Dog – *Cynomys leucurus*

White-tailed prairie dogs thrive in dry, high elevation prairies (1700–3000 meters, Center for Native Ecosystems 2006, Goldbroch and Frost, 2008). Of the five prairie dog species found in the U.S., the white-tailed prairie dogs are the least social (Center for Native Ecosystems 2006, Goldbroch and Frost 2008). They have fairly specific habitat and diet preferences. Sage is an especially critical form of cover and an important component of their diet (Tileston and Lechleitner, 1966). In the springtime, after emerging from dormancy, they feed on sagebrush and saltbush while other food sources are still unavailable. As the season progresses, the species switches to foraging on forbs and grasses, such as western wheatgrass (Tileston and Lechleitner, 1966). White-tailed prairie dogs will also eat the mature seed heads of grasses, forbs, and sedges when available (Tileston and Lechleitner, 1966; Goldbroch and Frost, 2008).

Despite the severe decline of white-tailed prairie dog populations in recent times, they maintain a key ecological role in grassland and sagebrush ecosystems and they are considered a keystone species (Center for Native Ecosystems, 2006; Goldbroch and Frost, 2008). The species is prey for many grassland predators, including American badgers, golden eagles, foxes, and American minks. Additionally, the highly endangered black-footed ferret relies almost exclusively on prairie dogs for prey and shelter (Center for Native Ecosystems, 2006; Goldbroch and Frost, 2008). In addition to providing food and burrows for many species, white-tailed prairie dogs aerate and mix the soil through their burrowing, which provides better grazing for herbivores, including the American pronghorn (Goldbroch and Frost, 2008). Among the top threats contributing to the range-wide decline of white-tailed prairie dog populations are poisoning campaigns, the conversion of natural grasslands to agriculture and urban development, and the spread of sylvatic plague. The plague appears to be the single most critical factor influencing the abundance and distribution of the species; it is capable of inflicting 85–100 percent mortality in affected colonies (Pauli et al. 2006). The plague not only reduces colony size and prairie dog abundance, but it reduces the viability of entire colony complexes by increasing interannual variation in population size and the distances between colonies, which affects recruitment (Pauli et al., 2006).

Attributes and Indicators

Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
Habitat	Elevation	<4,160 ft or >9,630 ft	8,525–9,630 ft	7,640–8,525 ft	4,160–7,640 ft	Utah Natural Heritage Program
Habitat	Slope	>10 degrees	5–10 degrees	0–5 degrees	0 degrees	Collins and Lichvar (1986)
Disease	Sylvatic plague	exposed			no exposure	Center for Native Ecosystems
Habitat	Oil drilling and energy development	present			not present	Center for Native Ecosystems
Habitat	Max. vegetation height	>92 cm	62–92 cm	31–62 cm	<31 cm	Collins and Lichvar (1986)

References Cited

Center for Native Ecosystems, 2006; http://nativeecosystems.org/species/white-tailed-prairie-dog

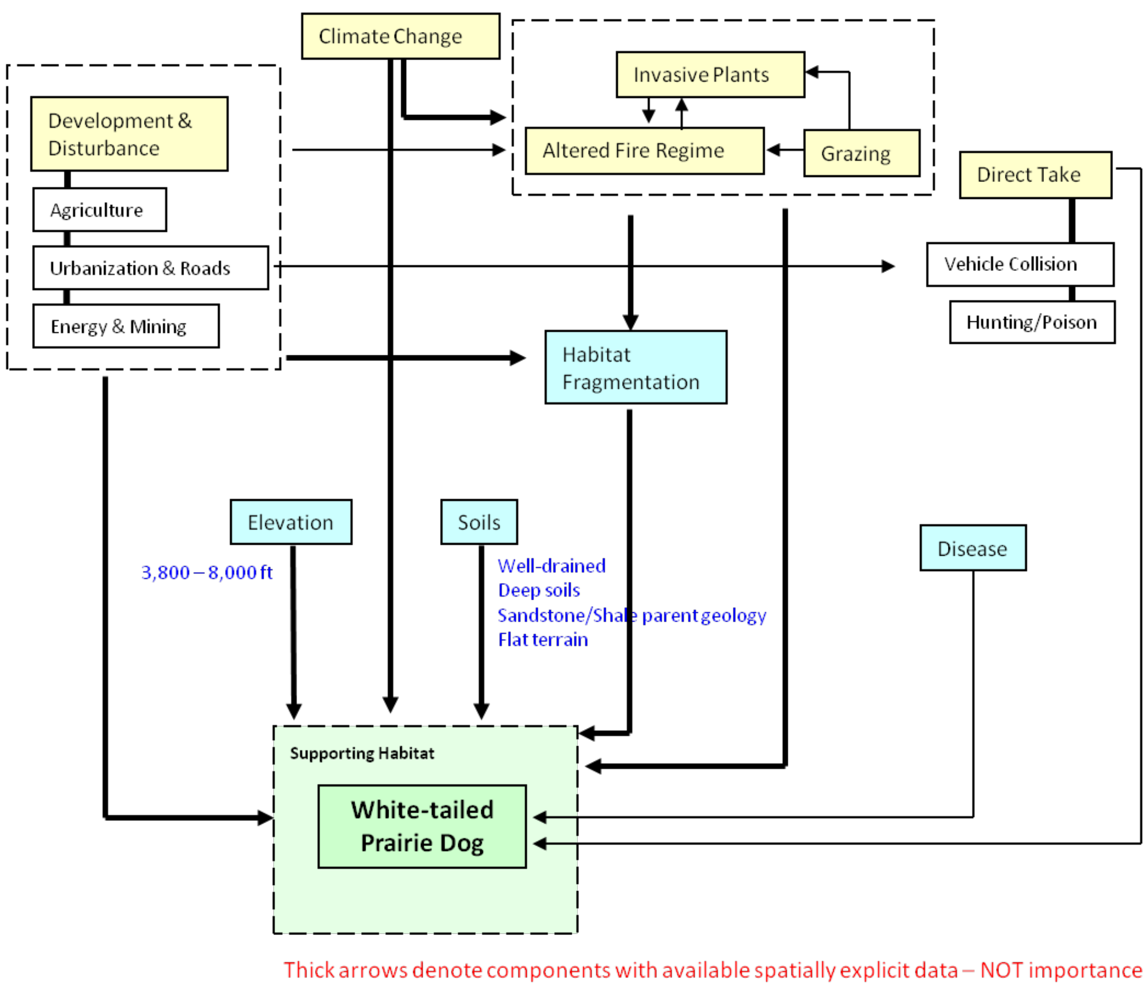
Collins, E. I., and R. W. Lichvar. 1986. Vegetation inventory of current and historic black-footed ferret habitat in Wyoming. *Great Basin Naturalist Memoirs* 8: 85–98.

Goldbroch, S. and S. Frost. 2008. "Cynomys leucurus" (On-line), Animal Diversity Web. Accessed January 14, 2012 http://animaldiversity.ummz.umich.edu/site/accounts/information/Cynomys_leucurus.html.

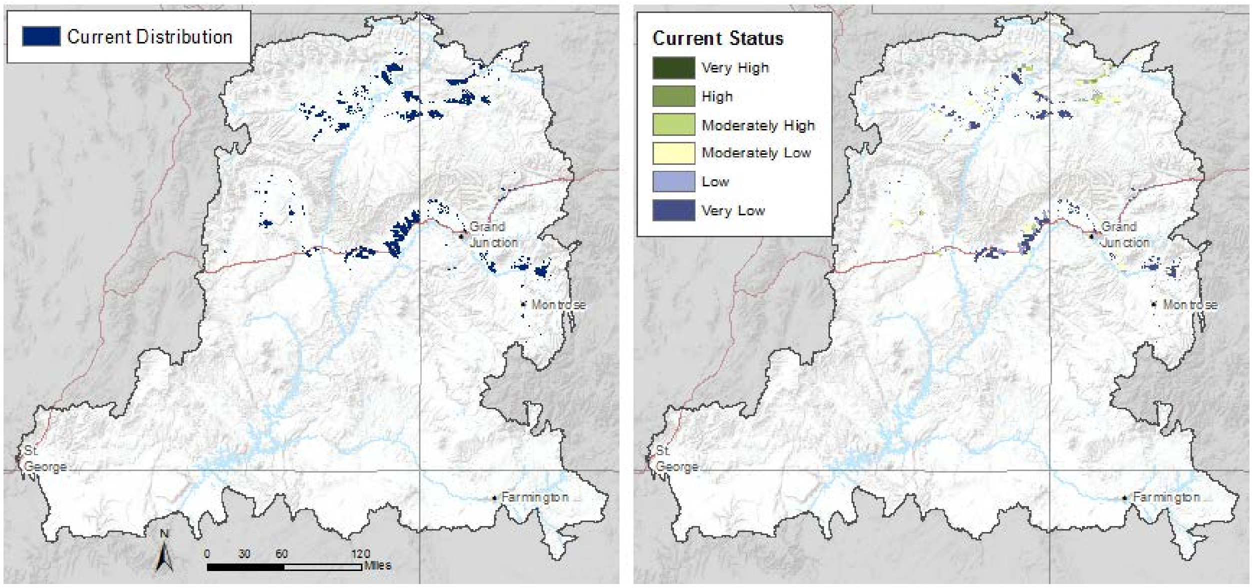
Pauli, J.N., R.M. Stephens, and S.H. Anderson. (2006, November 13). White-tailed Prairie Dog (*Cynomys leucurus*): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/whitetailedprairiedog.pdf

Tileston, J., R. Lechleitner. 1966. Some Comparisons of the black-tailed and white-tailed Prairie Dogs. *American Midland Naturalist* 75(2): 292–316.

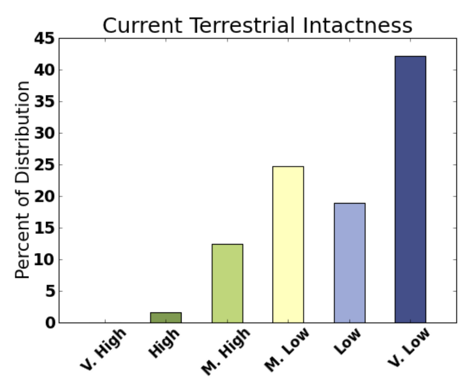
White-Tailed Prairie Dog Conceptual Model



MQ D1. What are the current distribution and status of white-tailed prairie dog (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?



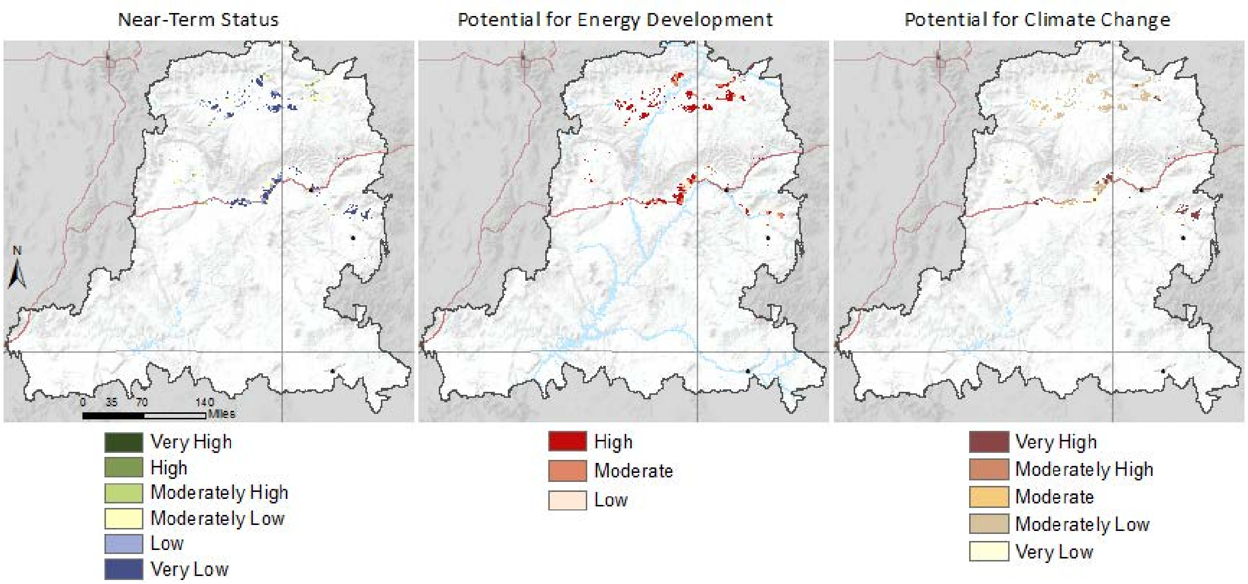
Data Source:
Digitized from Seglund et al. (2004)

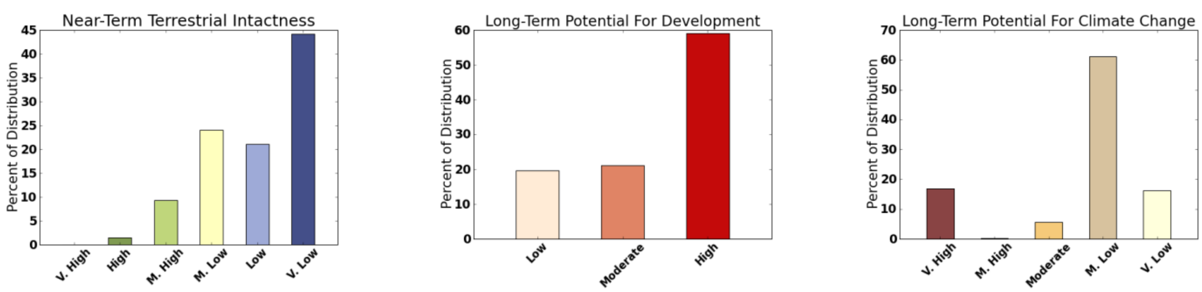


Seglund, A.E., A.E. Ernst, M. Grenier, B. Luce, A. Puchniak and P. Schnurr. 2004. White-tailed Prairie Dog Conservation Assessment.

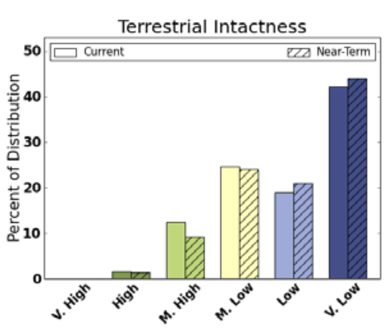
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

White-Tailed Prairie Dog Potential for Change



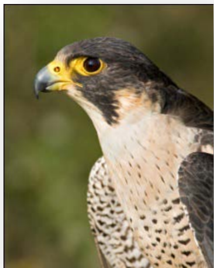


Current & Near-term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

American Peregrine Falcon – *Falco peregrinus*



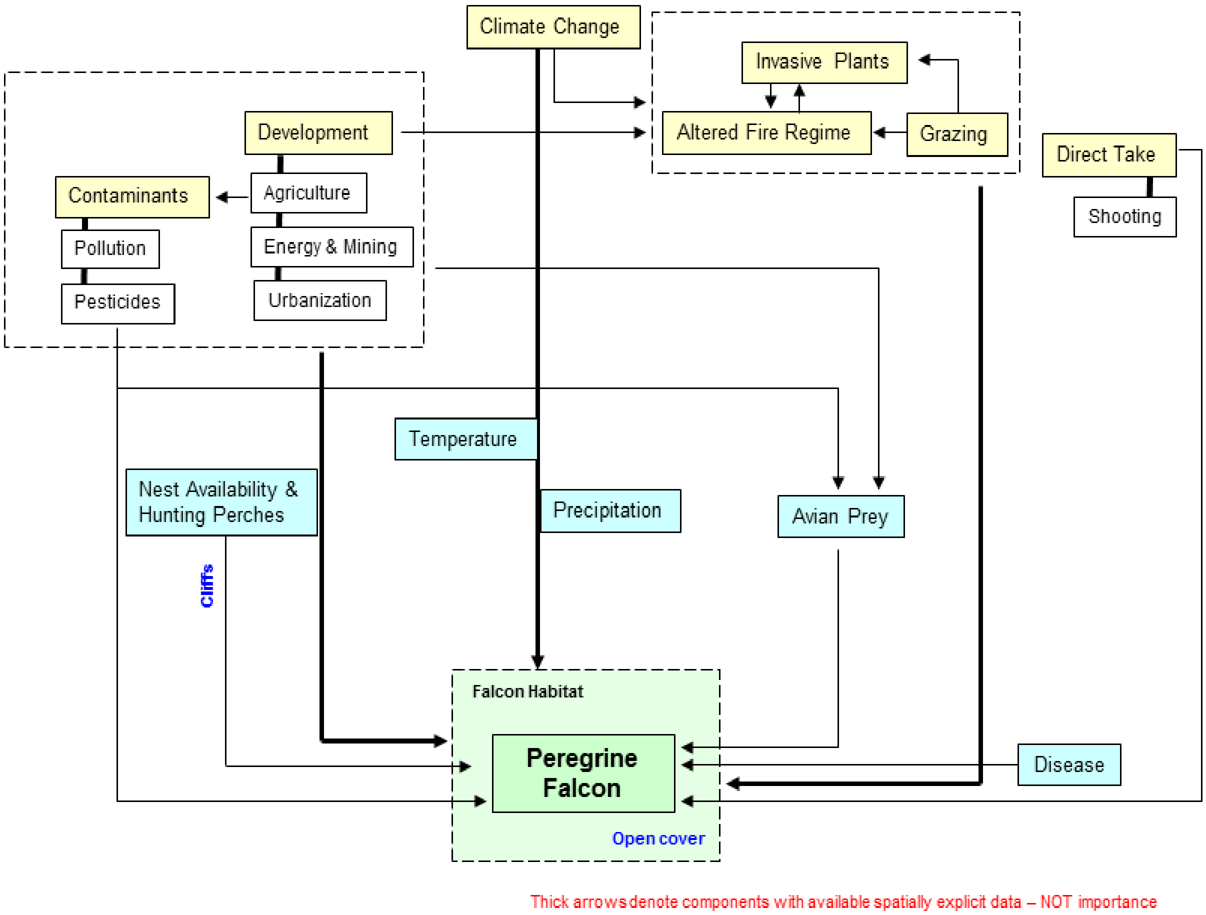
Attributes and Indicators

Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
Breeding Habitats	Distance between nest sites			minimum distance = 1 km	3.3–5.6 km	Univ. of Michigan, Museum of Zoology; White et al. 2002
Breeding Habitats	Cliff height	<12m		200 m	200+ m	GBBO; Cornell Lab of Ornithology; White et al. 2002

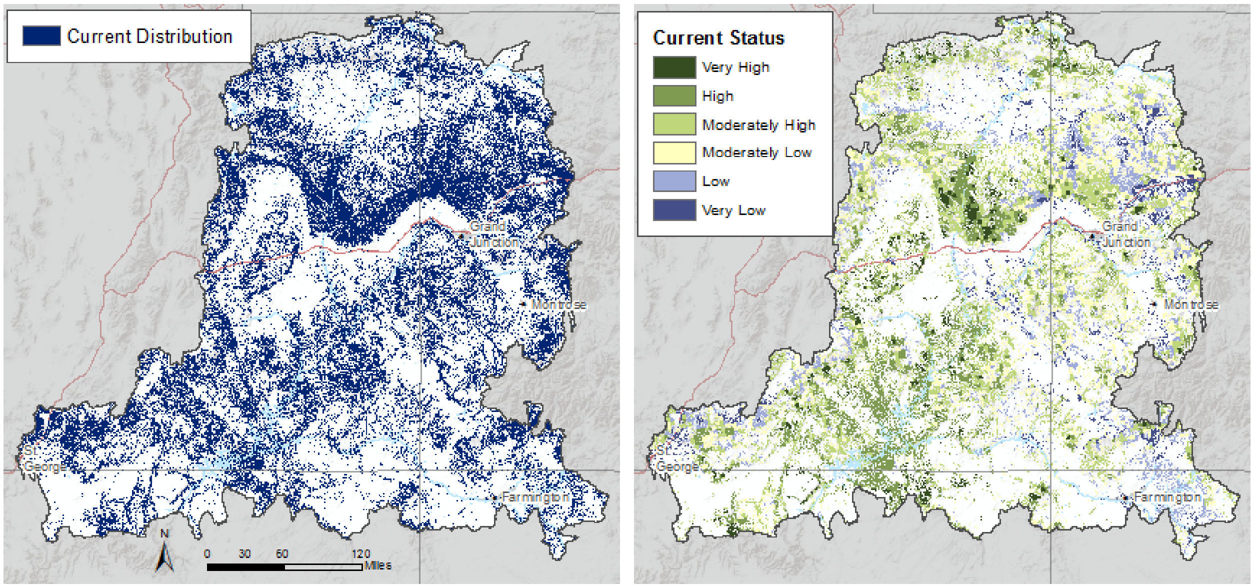
Cornell Lab of Ornithology http://www.allaboutbirds.org/guide/Peregrine_Falcon/lifehistory

White, C., N. Clum, T. Cade, W. Hunt. 2002. Peregrine Falcon (Falco peregrinus). The Birds of North America, 660. http://bna.birds.cornell.edu/BNA/account/Peregrine_Falcon

Peregrine Falcon Conceptual Model

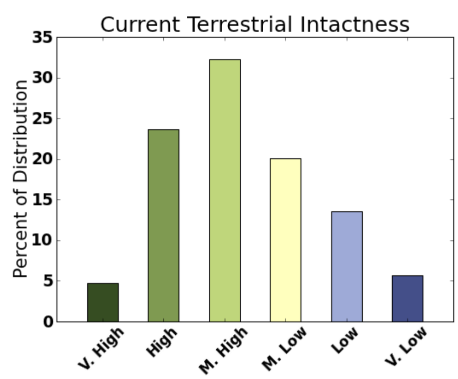


MQ D1. What are the current distribution and status of American peregrine falcon (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?



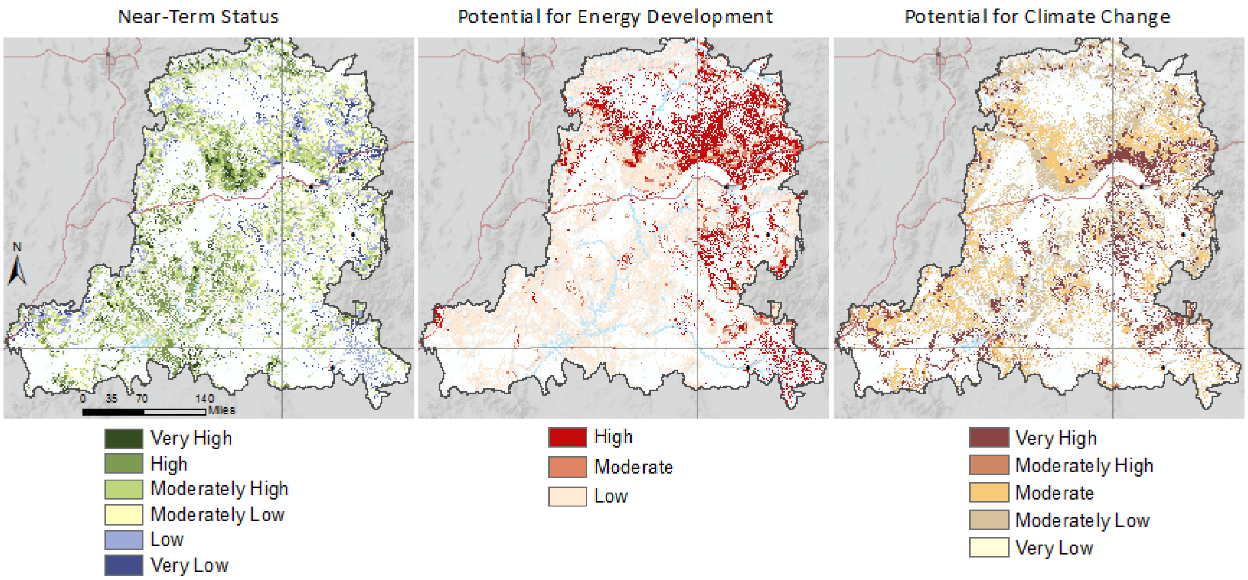
Data Source:

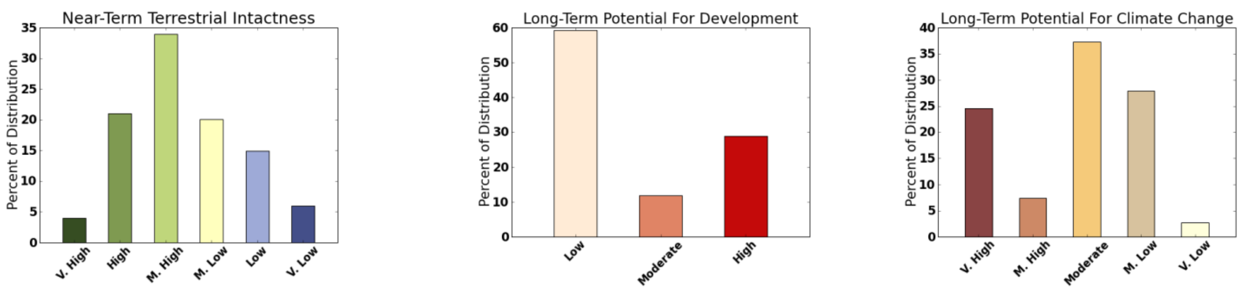
SW ReGAP (Southwest Regional GAP Analysis Project), limited to slopes >10 degrees



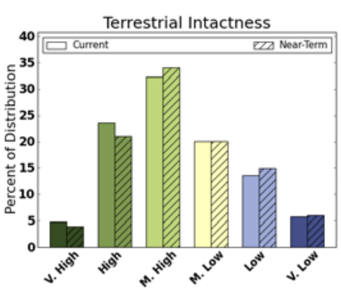
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

American Peregrine Falcon Potential for Change





Current & Near-term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

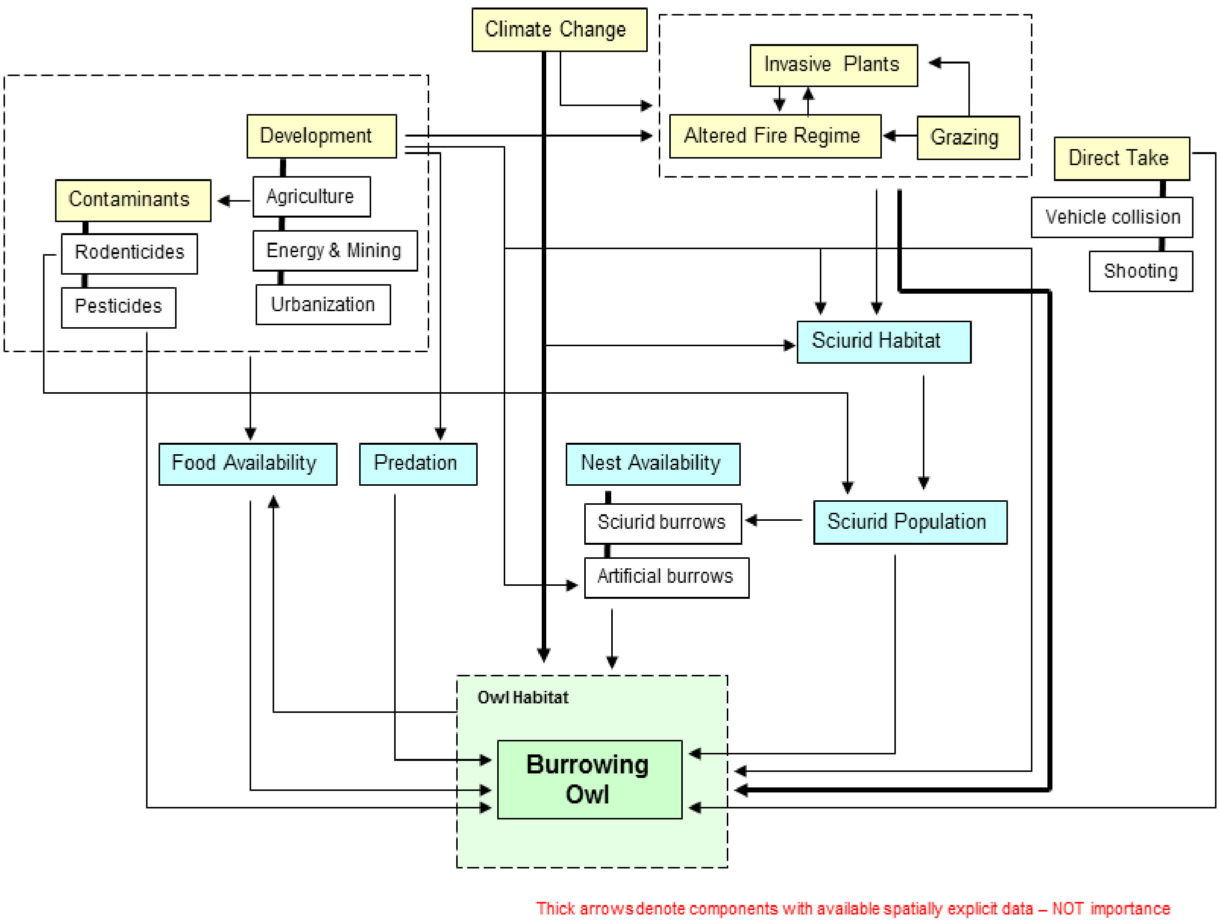
Burrowing Owl – *Athene cunicularia*

Attributes and Indicators

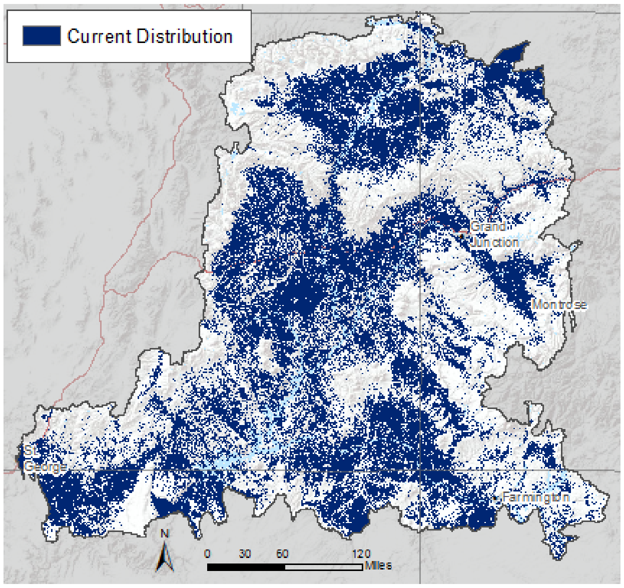
Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
Thermal biology	Elevation	>9,000 ft	7,500–9,000 ft	5,500–7,500 ft	<5,500 ft	Utah Natural Heritage Program (2007)
Mortality	Proximity to roads	<0.5 mi	0.5–1.0 mi	1.0–1.5 mi	>1.5 mi	Haug et al. (1993)
Habitat	Aridity/openness of habitat	other	golf courses, fairgrounds & some ag land		dry, open short-grass prairies and steppes	Haug et al. (1993)

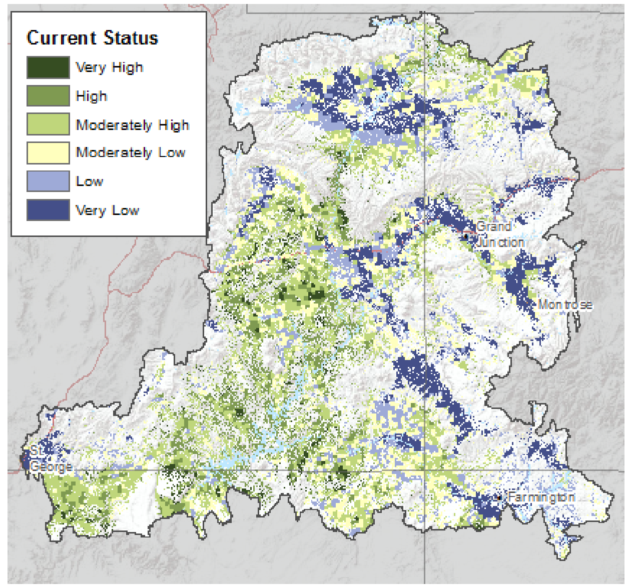
Haug, E. A., B. A. Millsap, and M. S. Martell. 1993. Burrowing owl. Birds of North America 61: 1–19.

Burrowing Owl Conceptual Model



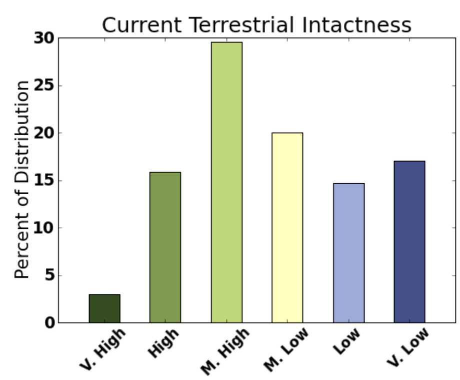
MQ D1. What are the current distribution and status of burrowing owl (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?





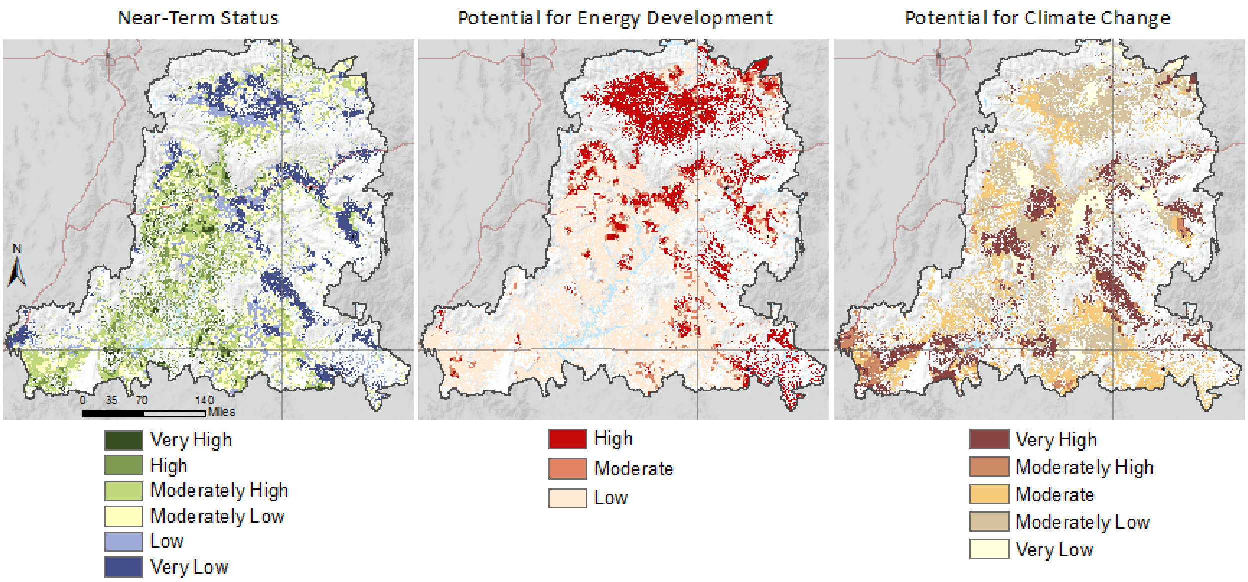
Data Source:

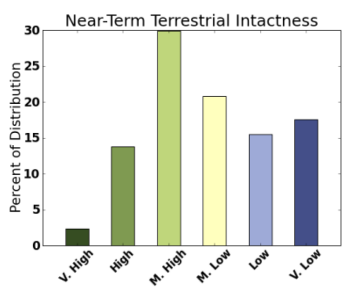
SW ReGAP (Southwest Regional GAP Analysis Project).

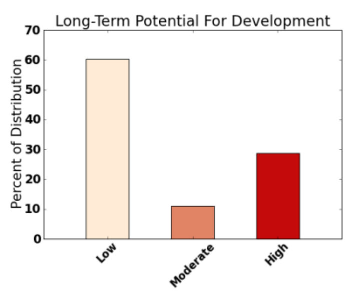


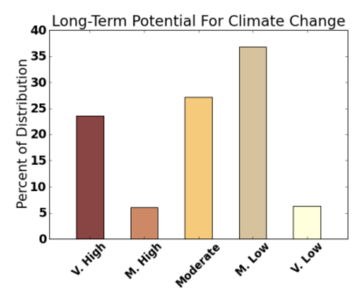
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

Burrowing Owl Potential for Change

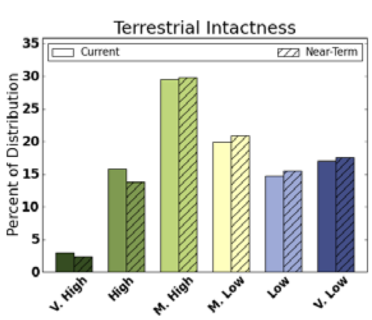








Current & Near-term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

Ferruginous Hawk – *Buteo regalis*

The ferruginous hawk was selected as a wildlife species conservation element for the REA because it is a BLM species of concern and a representative of open grasslands and sage shrublands that are undergoing development pressures. It and a group of other conservation elements (burrowing owl, black-footed ferret, Gunnison's and white-tailed prairie dog) form an assemblage of species associated with prairie dog colonies. The species occurs throughout most of the Colorado Plateau ecoregion, although it is absent or sparsely distributed in parts of southeastern Utah and western Colorado. The southern edge of its breeding range extends to northwestern New Mexico and northern Arizona. Of the four states included in the REA, it is a state Species of Concern in Utah, Arizona, and Colorado and a federal (U.S. Forest Service and BLM) species of concern in New Mexico. The U.S. Forest Service listed the ferruginous hawk as a Management Indicator Species, defined as a "species selected because its welfare is presumed to be an indicator of the welfare of other species sharing similar habitat requirements", and "a species which reflects ecological changes caused by land management activities" (Collins and Reynolds 2005). Ferruginous hawks are very sensitive to disturbance during the nesting season (White and Thurow 1985). Entry into nesting areas is not advised for 99 days from egg laying and 68 days after hatching (Olendorff 1993).

Attributes and Indicators

Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
Abundance of main prey	Jackrabbit density	<10 per sq km	10-30 per sq km	30-50 per sq km	>50 per sq km	Howard and Wolfe (1976)
Habitat suitability	Size of contiguous cropland	>16 ha	8-16 ha	1-8 ha	none	Jasikoff (1982)
Habitat loss and degradation	Livestock density	present in large number	present in moderate numbers	present in small numbers	absent	Olendorff (1993)

References Cited

Collins, C.P., and T.D. Reynolds. 2005. Ferruginous Hawk (*Buteo regalis*): A technical conservation assessment. USDA Forest Service, Rocky Mountain Region, Golden, Colorado. http://www.fs.fed.us/r2/projects/scp/assessments/ferruginoushawk.pdf. [Accessed: 3-2012].

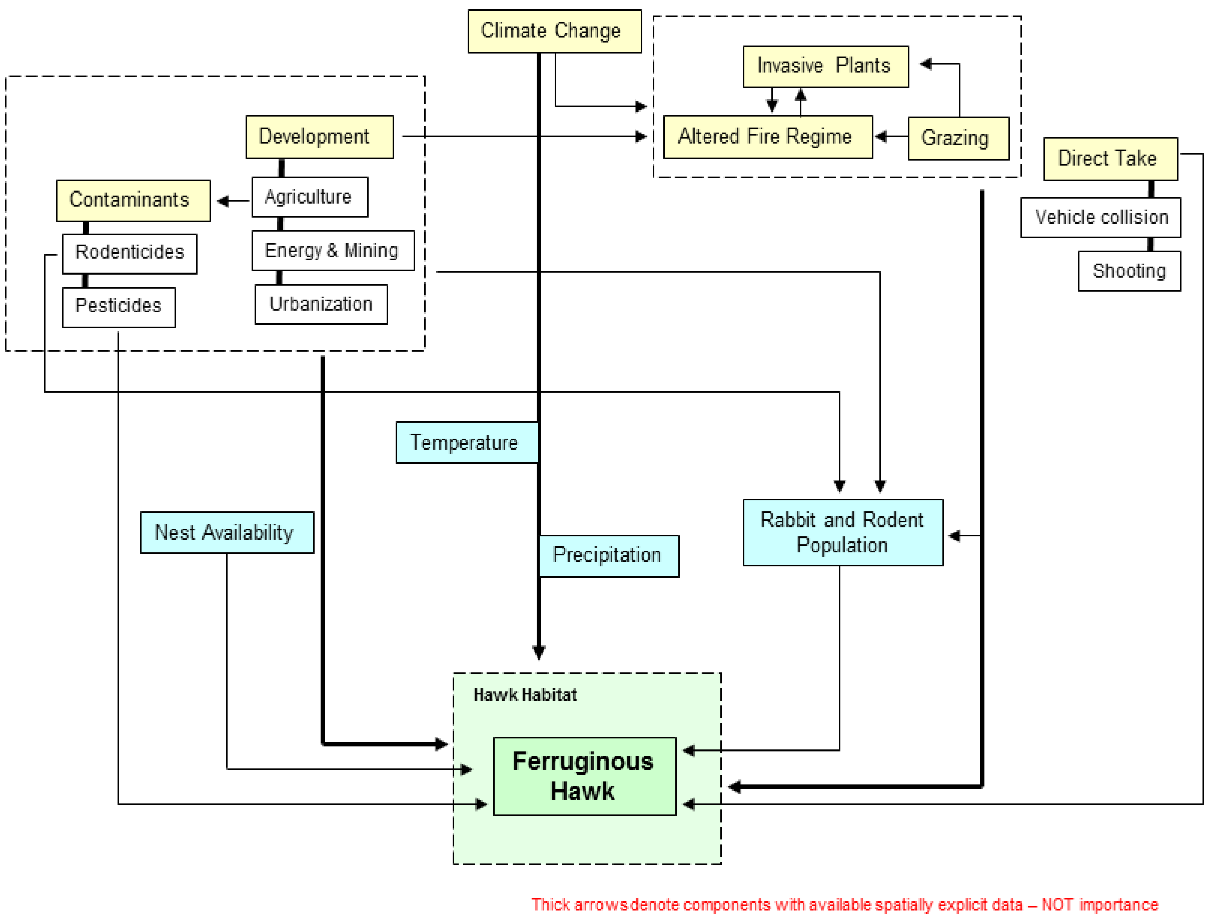
Howard, R. P., and M. L. Wolfe. 1976. Range improvement practices and ferruginous hawks. *Journal of Range Management* 29:33–37.

Jasikoff, T. M. 1982. Habitat suitability index models: Ferruginous hawk. Report FWS/OBS-82/10.10. U.S. Fish and Wildlife Service, Fort Collins, Colorado. vi + 18 pp.

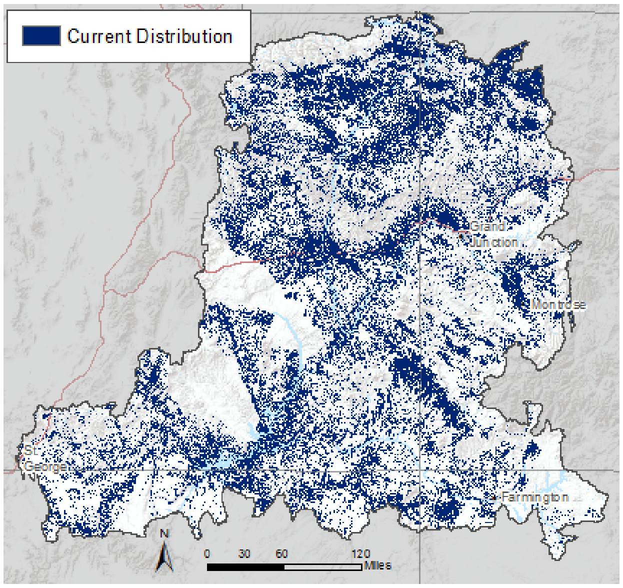
Olendorff, R.R. 1993. Status, biology, and management of ferruginous hawks: A review. Special report, Raptor Research and Technical Assistance Center, U.S. Bureau of Land Management, Boise, Idaho. 84 pp.

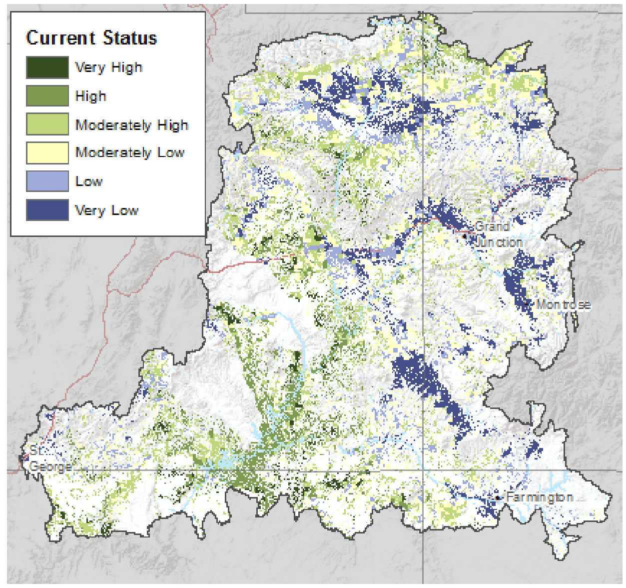
White, C. M. and T. L. Thurow. 1985. Reproduction of Ferruginous Hawks exposed to controlled disturbance. *The Condor* 87: 14–22.

Ferruginous Hawk Conceptual Model



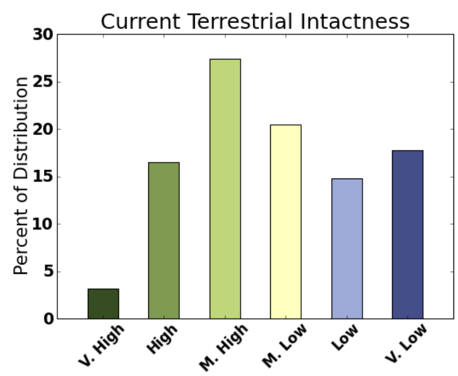
MQ D1. What are the current distribution and status of ferruginous hawk (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?





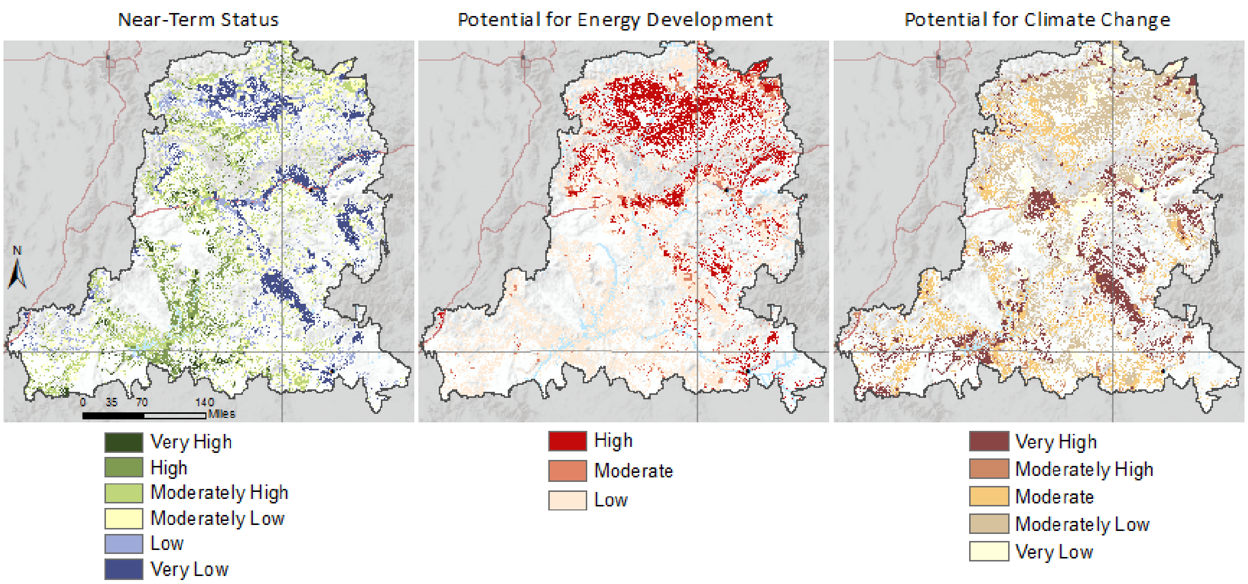
Data Source:

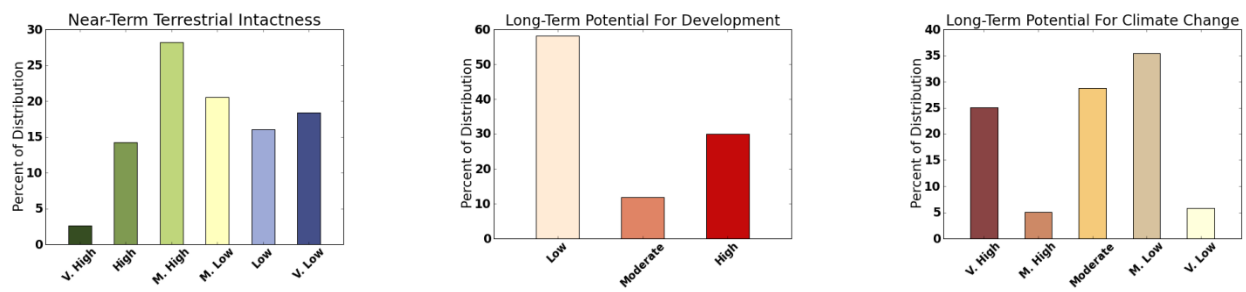
SW ReGAP (Southwest Regional GAP Analysis Project)



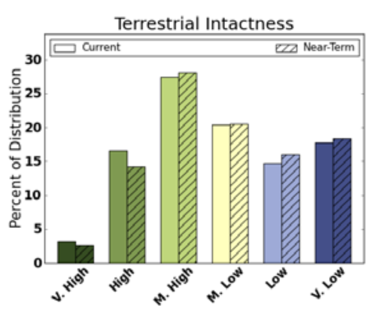
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

Ferruginous Hawk Potential for Change





Current & Near-term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

Golden Eagle – *Aquila chrysaetos*

Golden eagles hunt over open spaces in western North America, often in the vicinity of cliffs and ridges where the birds prefer to nest (Kochert et al. 2002). In two coal-mining counties in eastern Utah, Bates and Moretti (1994) found active eagle nests in four different habitats: on cliffs and escarpments in pinyon-juniper woodland and in trees on saltbush flats, in low elevation riparian areas, and in the aspen-conifer zone. The eagles feed primarily on small to medium-sized mammals, principally hares and rabbits (Olendorff 1976, Marzluff et al. 1997). Stahlecker et al. (2009), in their survey of 191 nests in the Four Corners region of the southwestern U.S., confirmed the preference for jackrabbit and noted that ravens were the most common avian prey.

Golden eagles benefit from the protection of large areas of intact desert and semi-desert habitat. Eagle home ranges are large, but they vary considerably in size depending on region, prey availability, and season from a few thousand to tens of thousands of hectares. In the Uinta Basin in the 1980s, average territory size per pair of eagles observed varied from 136 km^2 to 19 km^2 to 56 km^2 over the three years of the survey (Grant et al. 1991). Eagle management is inseparable from management of prey populations and their habitat, and shrub patch size is an important element; a management rule of thumb is to avoid fragmentation of shrub habitats below the mean patch size of 5000 ha shown to support healthy jackrabbit populations (Marzluff et al. 1997).

Although eagles and their nests have been protected since 1962 by the Bald and Golden Eagle Protection Act, long-term surveys indicate population declines in portions of the western U.S. (Kochert and Steenhof 2002). Eagles are vulnerable to environmental change, especially from human development and changes to habitat. Breeding Bird Survey trend results show a 1.3% yearly percentage decline for eagles in the Colorado Plateau-Southern Rockies for 1966–2009. However, these trend results carry substantial caveats since they reflect the detection difficulties and small sample size of a wide-ranging species with low abundance (Sauer et al. 2011). To reduce the speculation surrounding the estimates of golden eagle populations, the U.S. Fish and Wildlife Service in 2003 sponsored the first in a series of planned annual surveys of golden eagles across a broad area of the northwestern plains and the intermountain west (Good et al. 2004). The objective of the study is to use annual aerial surveys along systematic 100 km transects to detect golden eagle population changes ≥ 3% per year over a 20-year period. The survey over the Colorado Plateau-Southern Rockies Bird Conservation Region recorded 0.01 eagles/km^2 or an estimated abundance of 4998 birds across the entire region. The analysis was not stratified by habitat type, and results showed that "substantially" fewer eagles were observed in forested rugged habitats than in more open landscapes. The 0.01 eagles/km^2 estimate for the Colorado Plateau-Southern Rockies region is lower than the 0.017 eagles/km^2 estimated for the Great Basin (although the habitats covered in the Great Basin were more uniformly open).

The major reasons for the decline of golden eagles are direct take and habitat destruction through development. Humans cause over 70% of recorded deaths, either directly or indirectly, through collisions with vehicles, power lines, and wind turbines, electrocution on power poles, poisoning, and shooting (Franson et al. 1995). Although they are protected under the Bald and Golden Eagle Protection Act, golden eagles are sometimes illegally shot when suspected of killing livestock. Habitat destruction due to land development has led to large-scale population declines in some areas (Kochert and Steenhof 2002). Alteration of open shrubland habitats through development or conversion to agriculture has a negative effect on eagle populations because it reduces prey populations. Eagles will actively avoid agricultural areas when hunting (Marzluff et al. 1997). Eagles are often the victims of secondary poisoning when they consume prey that have been killed or sickened by pesticides, herbicides, or rodenticides (Franson et al. 1995). Eagles may also survive with elevated blood-lead levels from consuming prey items that are contaminated with lead or from directly ingesting lead shot (Pattee et al. 1990, Kramer and Redig 1997). Wildfires affect golden eagles in sagebrush communities in the western U.S. through the loss of shrub habitat and resident prey. Large-scale shrub loss in sagebrush communities from wildfire in southwestern Idaho reduced golden eagle reproductive success for 4-6 years post-burn (Kochert et al. 1999). The eagles avoided hunting in previously burned areas and eagle fledging success declined with an increasing extent of burned area in the vicinity of the nest. Post-burn effects on golden eagle hunting and reproductive success would likely be similar in sagebrush communities of the Colorado Plateau.

Human-made infrastructure such as power lines and wind turbines are also responsible for eagle mortality. In the Altamont Pass Wind Resource Area in west-central California, where there is an array of 5000 wind turbines on the ridgelines, Smallwood and Thelander (2008) estimated 67golden eagle fatalities per year from collisions with turbines; sub-adults and floaters appeared to be affected disproportionately (Hunt 2002). Golden eagle fatalities were correlated with turbine height, location, and topography with the majority of deaths associated with shorter turbines (e.g. Type 13), end of row and second from the end turbines, and favored aerial pathways through dips and notches in the topography (Curry and Kerlinger 1998, Hunt 2002). Although it has been reported that fatalities are much lower from newer wind farms with more recent turbine designs, there is no clear relationship between pre-construction risk assessment planning and reduced mortality (Lynn and Auberle 2009). While, on one hand, Smallwood and Karas (2009) estimated that newer turbines at Altamont could reduce mean annual fatality rates by 54% for raptors (while more than doubling annual wind-energy generation), eagle deaths tallied at a new (2 year old) wind farm north of Los Angeles, showed an annual death rate per turbine to be three times higher than at the older Altamont facility (Sahagan 2011). Potential risk assessments conducted prior to permitting wind facilities evaluate topography, weather patterns, and vegetation type, the presence of flyways and migration corridors, the numbers of birds potentially flying in the risk zones near the rotors, the possible presence of species of concern, the distance to important nesting areas and roost sites for birds and bats, and the potential for prey species such as ground squirrels to inhabit the site (Lynn and Auberle 2009). With the advent of renewable energy development in the Colorado Plateau ecoregion, planning for golden eagles should include protecting nest sites and minimizing activity in eagle nesting areas, eagle-sensitive turbine selection and placing (Curry and Kerlinger 1998, Hunt 2002, Smallwood and Thelander 2007), and raptor-safe electrical transmission lines and poles with widely spaced conductors, perch guards, or perches installed above the conductors (BLM 2005).

The potential consequences of climate change are related to how climate change may directly affect shrub and grassland habitats or indirectly affect them through altered fire regimes and distribution of invasive plants, both of which may affect prey populations. For example, if climate change leads to more widespread fire, this could lead to the loss of shrubs and a decline in small mammal populations which could negatively affect eagle populations in burned areas (Kochert et al. 1999). However, the golden eagle’s broad latitudinal range in North America (from Mexico to the Arctic) and generalist habits make it a poor candidate to model the effects of climate change.

Attributes and Indicators

Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
Habitat loss or degradation	Urban development	present	--	minimal	absent	Kochert and Steenhof (2002)
Habitat degradation	Livestock grazing and agriculture	existing or planned	--	--	absent	Beecham and Kochert (1975)
Habitat degradation	Fire	>40,000 ha of shrublands burned	--	burned territory; adjacent vacant unburned	unburned territories	Kochert et al. (1999)
Habitat degradation	Mining and energy development	present	--	--	absent	Phillips and Beske (1990)
Habitat	Vegetation	disturbed areas, grasslands, agriculture			shrubland/open grassland	Marzluff et al. (1997), Peterson (1988)
Habitat/nest sites	Topography	--	--	--	cliffs within 7 km of shruband	Menkens and Anderson (1987), McGrady et al. (2002), Cooperrider et al. (1986)
Mortality	Infrastructure (roads, power lines, wind turbines	--	--	--	infrastructure absent	Franson et al. (1995)
Illness mortality	Poisoning from pesticides and other toxins	high levels of contaminants	--	--	low/no contaminants	Franson et al. (1995), Harmata and Restani (1995), Kramer and Redig (1997), Pattee et al. (1990)
Habitat loss or degradation	Urban development	present	--	minimal	absent	Kochert and Steenhoff (2002)

References Cited

Beecham, J. J., and M. N. Kochert. 1975. Breeding biology of the golden eagle in southwestern Idaho. Wilson Bulletin 87:506–513.

BLM (Bureau of Land Management). 2005. Final environmental impact report and statement for the West Mojave plan: A habitat conservation plan and California desert conservation area plan amendment, volume1. U.S. Bureau of Land Management, Moreno Valley, California.

Bates, J.W., and M.O. Moretti. 1994. Golden Eagle (*Aquila chrysaetos*) population ecology in eastern Utah. *Great Basin Naturalist* 54:248–255.

Brodeur, S., R.D. Carie, D.M. Bird, and M. Fuller. 1996. Complete migration cycle of golden eagles breeding in northern Quebec. *The Condor* 98:293–299.

Cooperrider, A.Y., R.J. Boyd, and H.R. Stuart (eds.). 1986. Inventory and monitoring of wildlife habitat. U.S. Bureau of Land Management, Service Center, Denver, CO. 858 p.

Curry, R. C., and P. Kerlinger. 1998. Avian mitigation plan: Kenetech model wind turbines, Altamont Pass Wind Resource Area, California. Prepared for Kenetech Windpower, San Francisco, California.

Franson, J.C., L. Sileo, and N.J. Thomas. 1995. Causes of eagle deaths. Page 68 *in* Our living resources, LaRoe, E. T., G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac (eds.). U.S. Department of the Interior, National Biological Service, Washington, D. C.

Good, R.E., R.M. Nielson, H.H. Sawyer, and L.L. McDonald. 2004. Population-level survey of golden eagles (*Aquila chrysaetos*) in the western United States. Report prepared by Western EcoSystems Technology, Inc. for the U.S. Fish and Wildlife Service, Arlington, Virginia.

Grant, C.V., B.B. Steele, and R.L. Bayn, Jr. 1991. Raptor population dynamics in Utah's Uinta Basin: The importance of food resource. *The Southwestern Naturalist* 36(3):265–280.

Harmata, A. R., and M. Restani. 1995. Environmental contaminants and cholinesterase in blood of vernal migrant Bald and Golden Eagles in Montana. Intermountain Journal of Sciences 1:1–15.

Hunt, G. 2002. Golden eagles in a perilous landscape: Predicting the effects of mitigation for wind turbine blade-strike mortality. Public Interest Energy Research P500-02-043F, California Energy Commission, Sacramento, California. 72 p.

Kochert, M.N., and K. Steenhof. 2002. Golden Eagles in the U.S. and Canada: Status, trends, and conservation challenges. *Journal of Raptor Research* 36 (supplement):33–41.

Kochert, M.N., K. Steenhof, L.B. Carpenter, and J.M. Marzluff. 1999. Effects of fire on Golden Eagle territory occupancy and reproductive success. *Journal of Wildlife Management* 63:773–780.

Kochert, M.N., K. Steenhof, C.L. McIntyre, and E.H. Craig. 2002. Golden Eagle (*Aquila chrysaetos*), The Birds of North American Online, A. Poole (ed.), Cornell Laboratory of Ornithology, Ithaca, New York. http://bna.birds.cornell.edu.proxy.library.oregonstate.edu/bna/species/684 .

Kramer, J.L., and P. T. Redig. 1997. Sixteen years of lead poisoning in eagles, 1980–95: An epizootologic view. *Journal of Raptor Research* 31:327–332.

Lynn, J., and W. Auberle. 2009. Guidelines for assessing potential impacts to birds and bats from wind energy development in northern Arizona and the southern Colorado Plateau. Ecological Monitoring and Assessment Program, Northern Arizona University, Flagstaff, Arizona. http://www.landsward.nau.edu/document_forms/NAU_Avian_and_Bat_Regional_Guidelines_Final_10Feb%2009.pdf

Marzluff, J.M., S.T. Knick, M.S. Vekasy, L.S. Schueck, and T.J. Zarriello. 1997. Spatial use and habitat selection of golden eagles in southwestern Idaho. *Auk* 114:673–687.

McGrady, M.J., Maechtle, T.L., Vargas, J.J., Seegar, W.S. & Porras Peña, C. 2002. Movements of peregrine falcons *Falco peregrinus,* wintering on the Gulf Coast of Mexico 1996–1998. *The Condor* 104: 39–48.

Menkens, Jr., G. E. and S. H. Anderson. 1987. Nest site characteristics of a predominantly tree-nesting population of golden eagles. *Journal of Field Ornithology* 58:22–25.

Olendorff, R.R. 1976. The food habits of North American golden eagles. *American Midland Naturalist* 95:231–236.

Pattee, O.H., P.H. Bloom, J.M. Scott, and M.R. Smith. 1990. Lead hazards within the range of the California condor. *The Condor* 92:931–937.

Peterson, D. L. 1988. Nesting and habitat parameters for selected raptors in the desert of northern Utah Master's Thesis, Utah State University, Logan, Utah.

Phillips, R. L. and A. E. Beske. 1990. Distribution and abundance of Golden Eagles and other raptors in Campbell and Converse Counties, Wyoming. Fish and Wildlife Technical Report 27. Unites States Fish and Wildlife Service.

Sahagan, L. "Officials investigate eagle deaths at wind farm," Los Angeles Times, August 3, 2011.

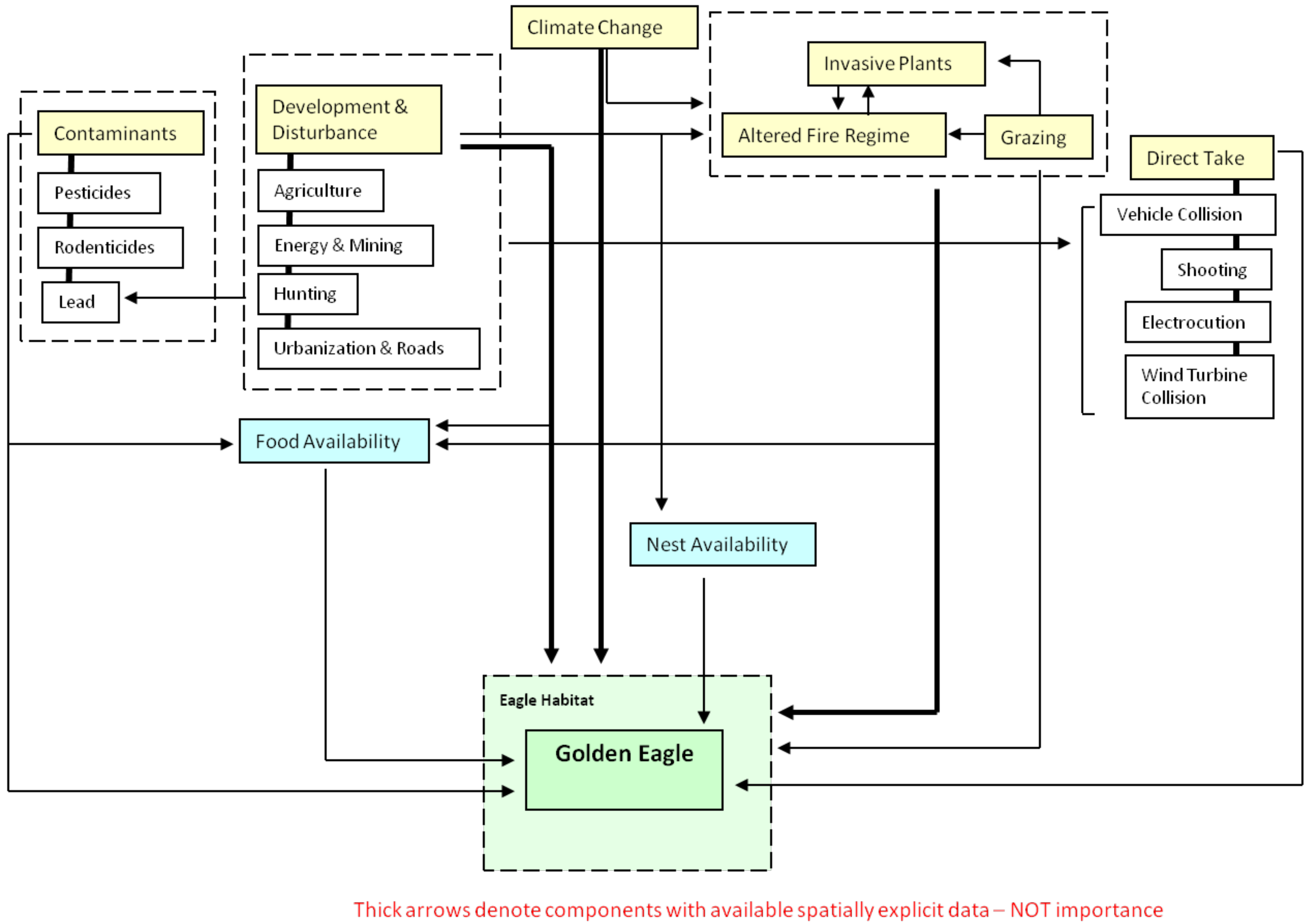
Sauer, J.R., J.E. Hines, J.E. Fallon, K.L. Pardieck, D.J. Ziolkowski, Jr., and W.A. Link. 2011. The North American Breeding Bird Survey, results and analysis 1966–2009. Version 3.23.2011, U. S. Geological Survey Patuxent Wildlife Research Center, Laurel, Maryland. http://www.mbr-pwrc.usgs.gov/bbs/bbs.html .

Smallwood, K.S., and B. Karas. 2009. Avian and bat fatality rates at old-generation and repowered wind turbines in California. *Journal of Wildlife Management* 73(7):1062–1071.

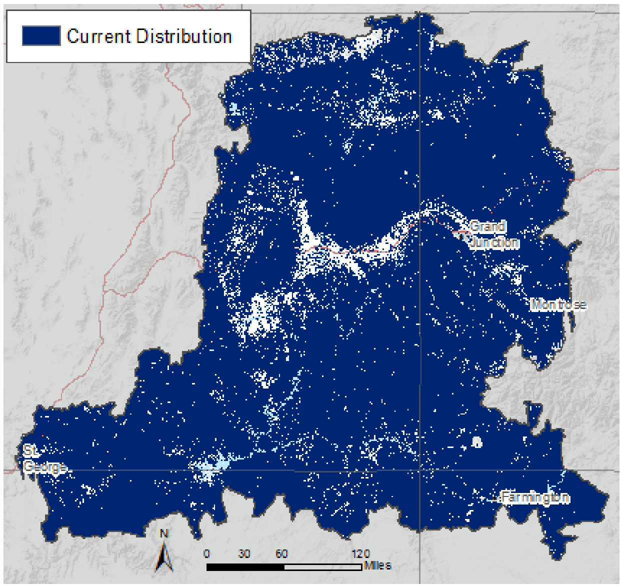
Smallwood, K.S., and C. Thelander. 2008. Bird mortality in the Altamont Pass Wind Resource Area, California. *Journal of Wildlife Management* 72(1):215–223.

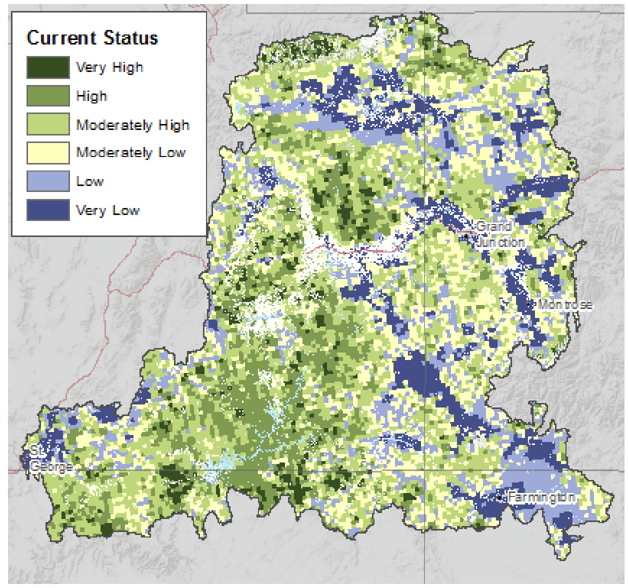
Stahlecker, D.W., D.G. Mikesic, J.N. White, S. Shaffer, J.P. Delong, M.R. Blakemore, and C.E. Blakemore. Prey remains in nests of Four Corners golden eagles, 1998–2008. *Western Birds* 40:301–306.

Golden Eagle Conceptual Model



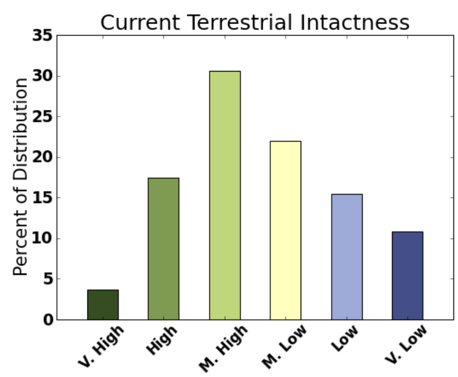
MQ D1. What are the current distribution and status of golden eagle (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?





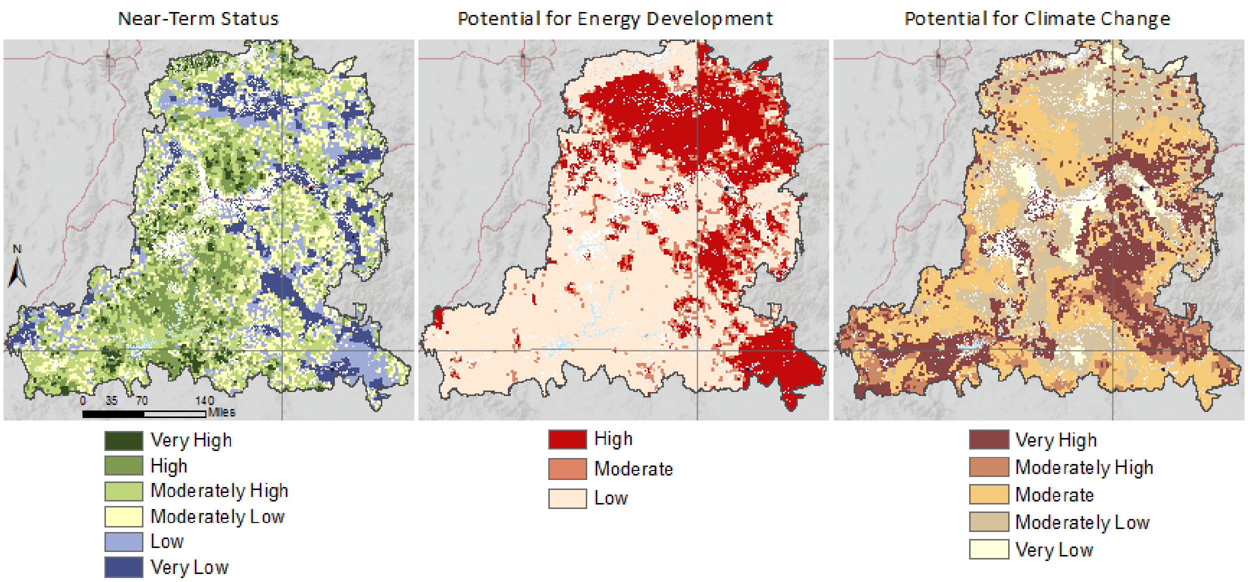
Data Source:

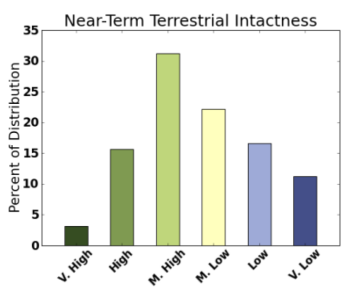
SW ReGAP (Southwest Regional GAP Analysis Project)

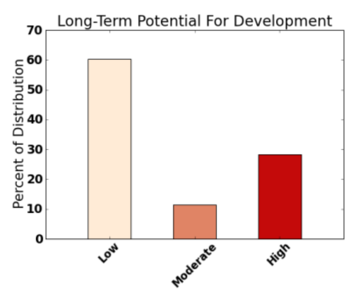


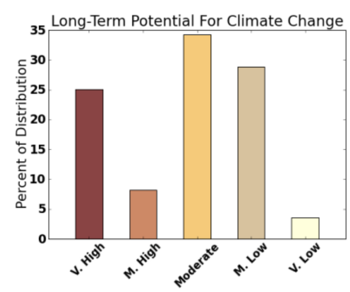
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

Golden Eagle Potential for Change

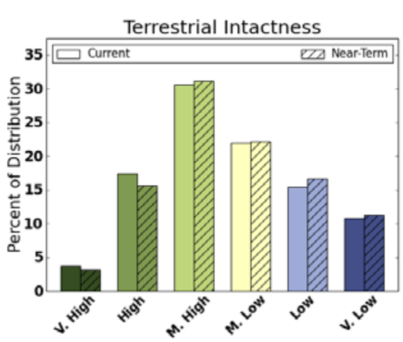








Current & Near-term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

Greater Sage-Grouse – *Centrocercus urophasianus*

For full detailed account of Greater sage-grouse, see Sage Grouse Case Study Insert.

The sustainability of the greater sage-grouse (*Centrocercus urophasianus*) is entirely dependent on intact expanses of sagebrush. The sage-grouse is one of over 350 plant and animal species that are sagebrush obligates; a high proportion of these are endemic, threatened, or endangered, because the sagebrush community is one of the most-altered vegetation classes in the western states (Connelly et al. 2004). Over the last century, the sage-grouse has been reduced to 56% of its former range westwide. The U.S. Fish and Wildlife Service (USFWS) recently gave the greater sage-grouse candidate status rather than listing it as threatened or endangered—stating that it warrants protection, but that other species, facing greater and more immediate threats, take precedence (USFWS 2010). A court ruling in 2011 followed a number of law suits filed against the USFWS for delaying full Endangered Species Act protection for the grouse; it gave the USFWS until 2015 to decide the bird's status. In the interim, the BLM will review Resource Management Plans throughout the range of the greater sage-grouse and revise or amend them if necessary to incorporate sage-grouse conservation measures (BLM 2011a).

Across the species' range, trend results from research and monitoring of sage-grouse populations indicate general declines, but results vary depending on the region and the scale of the investigation. Breeding Bird Survey trend estimate data for the Southern Rockies-Colorado Plateau ecoregion showed a 7.1% per year decline for the period 1966–2009 and a 5.2% per year decline for the period 1999–2009 (Sauer et al. 2011). However, these trend results carry a caveat, since they reflect detection difficulties on existing Breeding Bird Survey routes and a small sample size (<14). Local trends differ when examined at a regional level. Utah and northwestern Colorado represent the southeastern-most extent of the species' current distribution, which has contracted to the north, based on evidence of historic distributions. Greater sage-grouse populations in northwestern Colorado still maintain some connectivity with sage-grouse strongholds in Wyoming and Montana. Colorado populations are relatively stable and have been increasing (about 1% per year) over the last 17 years (Connelly et al. 2004). Sage-grouse habitat in Utah connects to these northern populations through the Uinta Basin where sage habitats are heavily fragmented. Sage-grouse populations are small and scattered along the western border of the Colorado Plateau ecoregion, and several small populations have been recently extirpated from former leks in southern Utah (Connelly et al. 2004). Annual rates of change in Utah populations indicate a long-term decline from levels of the late 1960s and early 1970s, when populations were approximately 2-3 times higher than current numbers (Connelly et al. 2004). The number of males per lek has decreased significantly and lek size has also decreased since the late 1960s, although there was a gradual increase in number of males per lek between 1997 and 2005 (UDWR 2009). In an examination of available data, Connelly at al. (2004) determined that sage-grouse populations declined at an overall rate of 0.35% per year in Utah from 1965 to 2003.

Thousands of pages have been written about sage-grouse functional requirements and threats to their future productivity; for a detailed review of greater sage-grouse related population ecology, data, study results, and literature, see Connelly et al. (2004) and Knick and Connelly (2011). Sage-grouse need large contiguous patches of sagebrush habitat because their functional habitat requirements differ by season and are quite specific, based on percent sagebrush cover and height, percent herbaceous cover and height, distance to other seasonal habitat types, and topographic position (Connelly et al. 2000). Access to several types of seasonal habitats for lekking, nesting, brood-rearing, and wintering is important for reproductive success, chick survival, and recruitment. Sagebrush patches used for nesting and brooding may be under 100 ha and located within a few kilometers of leks, but distances traveled by male grouse from lek to summer habitat and for all grouse between summer and winter ranges may be as much as 35–50 km (Connelly et al. 2004).

The species is sensitive and easily disturbed by land use activities that subdivide the landscape, disrupt the birds' site fidelity to traditional lekking and nesting areas, and ultimately isolate remnants of the population. Widespread degradation and conversion of sagebrush communities has occurred over the last century with broad scale agricultural conversion in irrigable areas, sagebrush treatments to increase forage for livestock on rangelands, the introduction of invasive annual species, and subsequent changes in fire regimes. In somewhat higher and more mesic areas, a cycle of grazing, leading to a decrease in fire frequency, has resulted in pinyon and juniper encroachment into sage grouse habitat and a reduction in ground cover perennials and forbs. Elsewhere, the invasion of cheatgrass (*Bromus tectorum*) and an associated increase in fire frequency has resulted in extensive loss of sagebrush stands that may take several decades to recover (Connelly et al. 2004, Crawford et al. 2004). Agricultural fields and irrigation canals affect 32% of sagebrush habitat in 9 western states (Connelly et al. 2004). In recent decades, exurban growth, expressed as rural small parcel development, has increased the fragmentation of sage habitat in former rangelands. The subsequent expansion of road networks, even low-volume secondary roads, negatively affects sage grouse. Recent studies have indicated that minimal road traffic (1–12 vehicles/day) reduces female grouse nest initiation (Lyon and Anderson 2003) and the number of breeding males displaying at leks (Holloran 2005). Powerlines and communications towers increase the pressure from predators and provide perches for raptors as do fences, which also cause direct mortality of sage grouse through collision and entanglement. Fences within 1.25 miles of active leks and fence densities > 1.6 miles/mile^2 of fence have been shown to increase risks for sage-grouse (thresholds listed in BLM [2011b], adopted from a study by Stevens [2011]).

Oil and gas drilling is the most pressing current and future threat to the sustainability of the sage-grouse in the Colorado Plateau. Increasing demand, a desire for energy security, favorable pricing, and recent extraction methods (e.g., fracking, see Section 4.1.4, Aquatic Resources of Concern) that retrieve oil and gas once thought too difficult and expensive to extract have created intense pressure to drill on public land in sagebrush habitats. Westwide, seven million hectares (~17,300,000 acres) of public lands—or 44% of the lands that the federal government controls for oil and gas development—have been authorized for drilling within distribution of the greater sage-grouse (Naugle et al. 2011).

Attributes and Indicators

Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
General habitat	Cover type	cultivated fields	scrub-willow; sagebrush savannas	small sagebrush-forb mosaics	tall sagebrush	Schroeder et al. (1999) Connelly et al. (2004)
Disturbance	Oil and gas	>12 per 4 sq km x4sq km			none	Harju et al. 2010
Habitat	Invasive conifers (e.g. junipers)	abundant and encroaching	present but not encroaching	few and not encroaching	absent	Connelly et al. (2000)
Nest sites	Mean sagebrush canopy cover	<15% or >38%	15-23%	23-30%	30-38%	Connelly et al. (2000)

References Cited

BLM (Bureau of Land Management). 2011a. National greater sage-grouse planning strategy charter. http://www.blm.gov/pgdata/etc/medialib/blm/wo/Communications_Directorate/public_affairs/sage-grouse_planning/documents.Par.2415.File.dat. Accessed 1/12.

BLM (Bureau of Land Management). 2011b. Greater sage-grouse interim management policies and procedures, Instruction Memorandum No. 2012-043. http://www.blm.gov/wo/st/en/info/regulations/Instruction_Memos_and_Bulletins/national_instruction/2012/IM_2012-043.html. Accessed 1/12.

Connelly, J.W., S.T. Knick, M.A. Schroeder, and S.J. Stiver. 2004. Conservation assessment of greater sage-grouse and sagebrush habitats. Western Association of Fish and Wildlife Agencies. Unpublished Report. Cheyenne, Wyoming.

Connelly, J.W., M.A. Schroeder, A.R. Sands, and C.E. Braun. 2000. Guidelines to manage sage grouse populations and their habitats. *Wildlife Society Bulletin* 28:967–985.

Crawford, J.A., R.A. Olson, N.E. West, J.C. Mosley, M.A. Schroeder, T.D. Whitson, R.F. Miller, M.A. Gregg, and C.S. Boyd. 2004. Ecology and management of sage-grouse and sage-grouse habitat. *Journal of Range Management* 57:2–19.

Harju, S.M., M.R. Dzialak, R.C. Taylor, L.D. Hayden-Wing, and J.B. Winstead. 2010. Thresholds and time lags in effects of energy development on greater sage-grouse populations. *Journal of Wildlife Management* 74(3): 437–448.

Holloran, M.J. 2005. Greater sage-grouse (*Centrocercus urophasianus*) population response to natural gas field development in western Wyoming. PhD dissertation. University of Wyoming, Laramie. 211 pp.

Lyon, A.G., and S.H. Anderson. 2003. Potential gas development impacts on sage grouse nest initiation and movement. *Wildlife Society Bulletin* 31: 486–491.

Knick, S.T., and J.W. Connelly (eds.). 2011. Greater sage-grouse: Ecology and conservation of a landscape species and its habitat. Studies in Avian Biology, Volume 38, University of California Press, Berkeley, California.

Naugle, D.E., K.E. Doherty, B.L. Walker, M.J. Holloran, and H.E. Copland. 2011. Energy development and greater sage-grouse. Number 21 *in* Knick, S.T., and J.W. Connelly (eds.). Greater sage-grouse: Ecology and conservation of a landscape species and its habitats. Studies in Avian Biology, Volume 38, University of California Press, Berkeley, California.

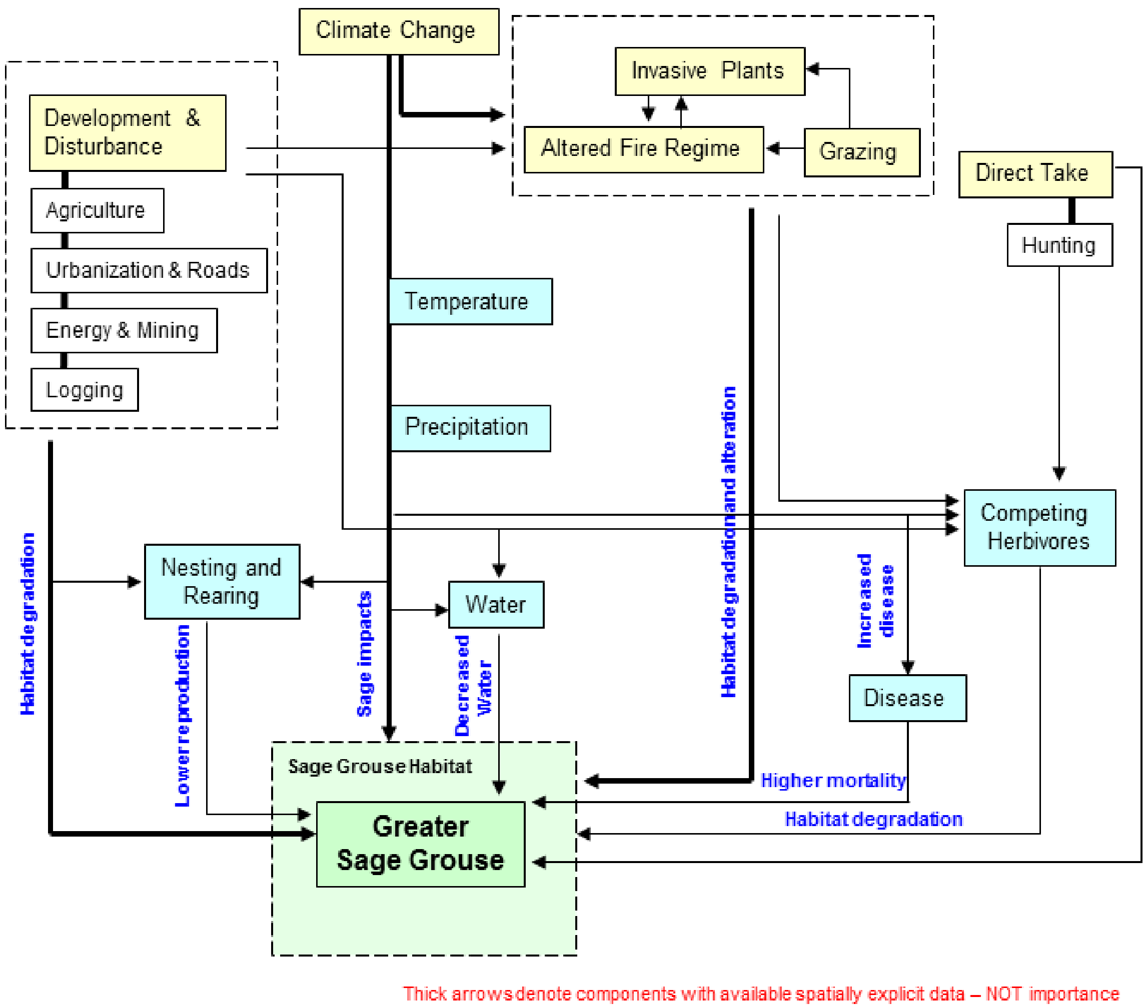
Sauer, J.R., J.E. Hines, J.E. Fallon, K.L. Pardieck, D.J. Ziolkowski, Jr., and W.A. Link. 2011. The North American Breeding Bird Survey, results and analysis 1966–2009. Version 3.23.2011, U.S. Geological Survey Patuxent Wildlife Research Center, Laurel, Maryland. http://www.mbr-pwrc.usgs.gov/bbs/bbs.html.

Schroeder, M.A., J.R. Young, and C.E. Braun. 1999. Sage Grouse. Birds of North America 425:1-27.

Stevens, B.S. 2011. Impacts of fences on greater sage-grouse in Idaho: Collision, mitigation, and spatial ecology. Master's Thesis, University of Idaho, Moscow, Idaho.

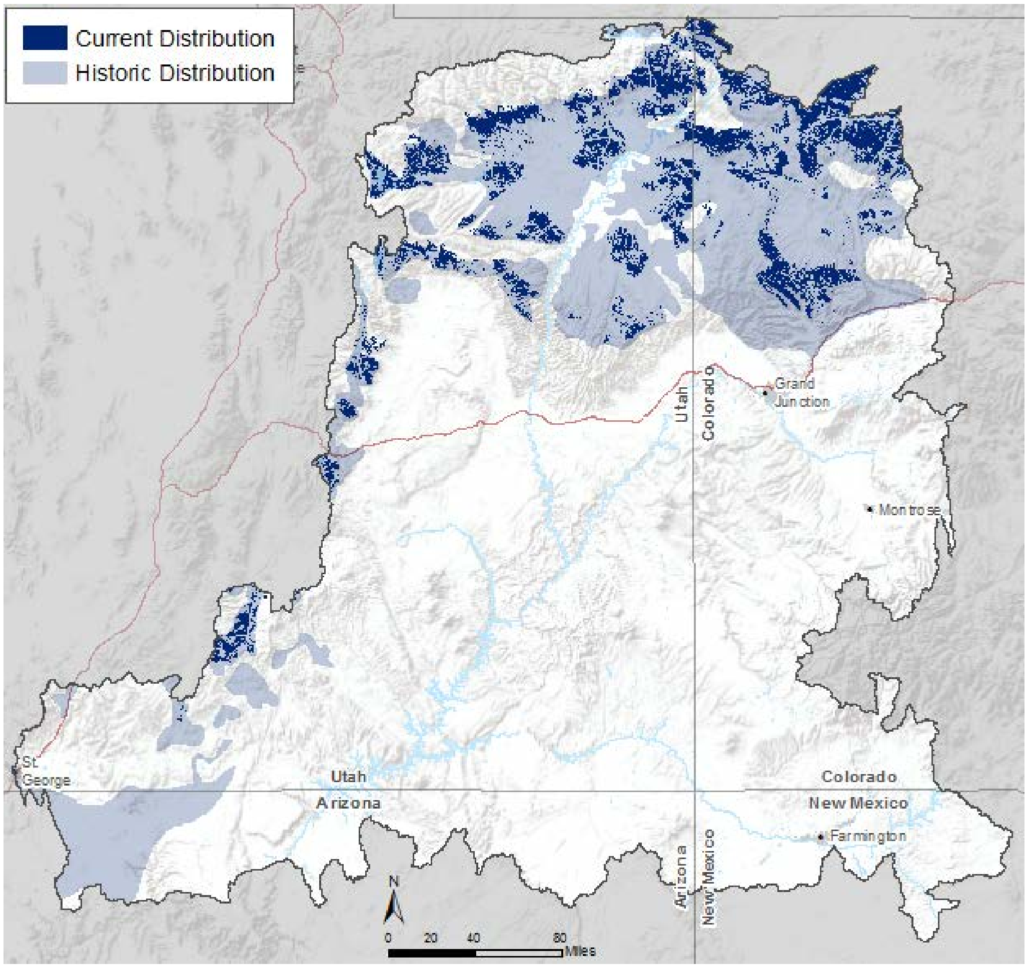
UDWR (Utah Division of Wildlife Resources). 2009. Utah greater sage-grouse management plan. Utah Department of Natural Resources, Division of Wildlife Resources, Publication 09-17, Salt Lake City.

USFWS (U.S. Fish and Wildlife Service). 2010. 12-month findings for petitions to list the greater sage-grouse (*Centrocercus urophasianus*) as threatened or endangered. Proposed rules, March 4, 2010. *Federal Register* 1–107.

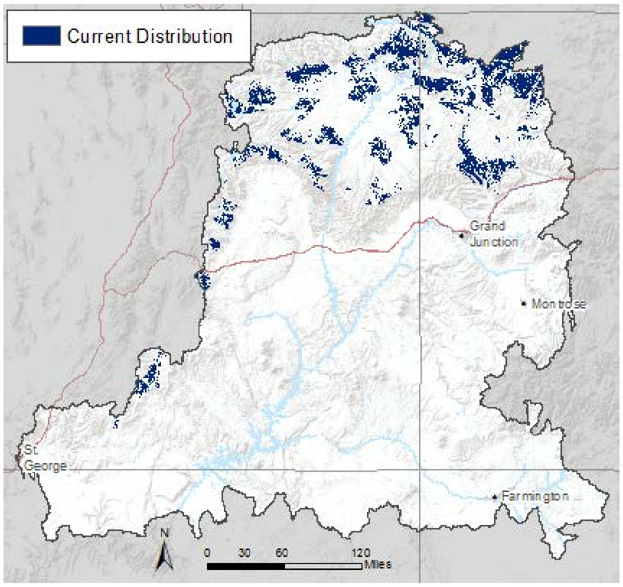


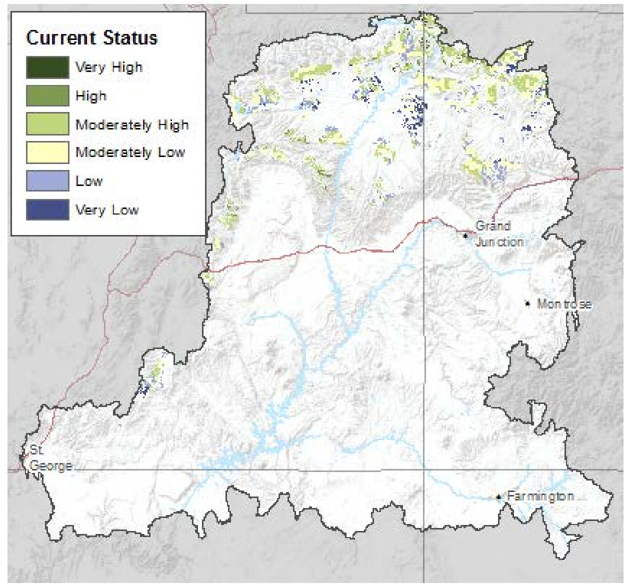
Greater Sage-Grouse Conceptual Model

MQ D1. What are the current distribution and status of greater sage-grouse (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?



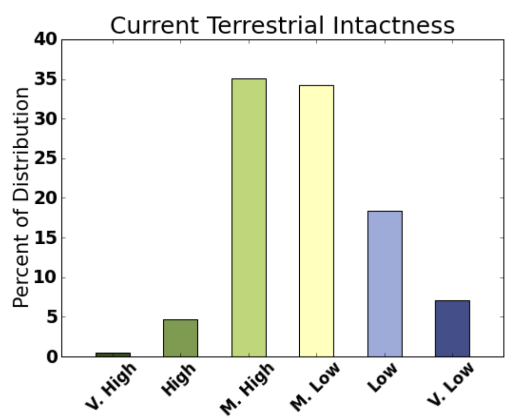
MQ D1. What are the current distribution and status of greater sage-grouse (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?





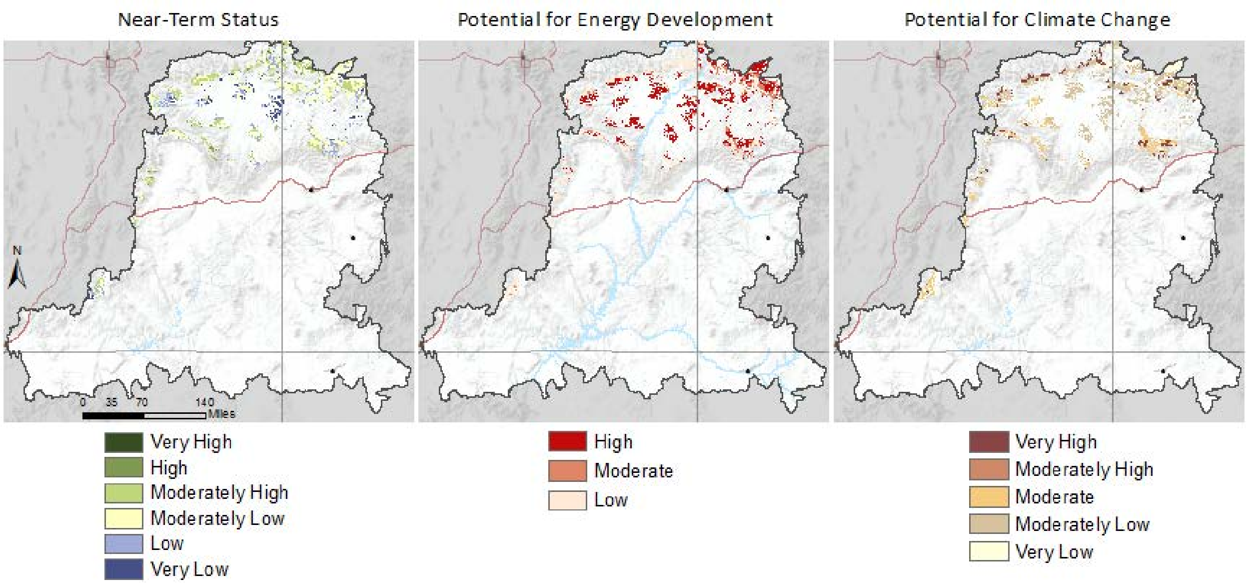
Data Sources:

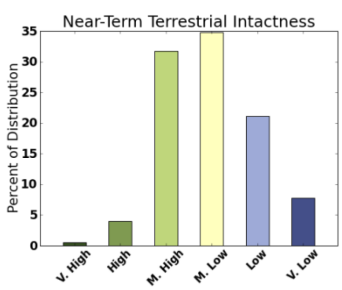
Greater Sage Grouse Occupied Habitat (BLM)
Nesting Habitat: Colorado Division of Wildlife and Utah Division of Wildlife Resources
Winter Habitat: Colorado Division of Wildlife and Utah Division of Wildlife Resources

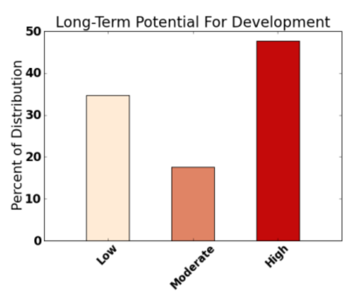


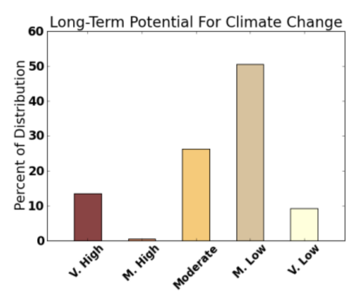
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

Greater Sage-Grouse Potential for Change

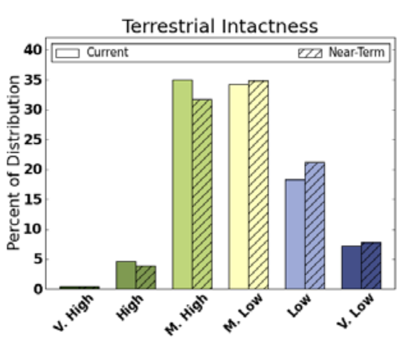








Current & Near-term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

Gunnison Sage-Grouse – *Centrocercus minimus*

Attributes and Indicators

Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
Habitat	Plant communities (sagebrush obligate)	developed	agricultural fields	grasslands	sagebrush, riparian, wet meadows	Lupis (2005)
Habitat degradation	Sagebrush loss from leks	<0.6 mi of active lek	0.6-4.0 mi from active lek	4.0-6.0 mi from active lek	none in vicinity	GSRSC (2005)
Disturbance	Development footprint	<0.6 mi of active lek	0.6-4.0 mi from active lek	>4.0 mi from active lek	none in vicinity	GSRSC (2005)

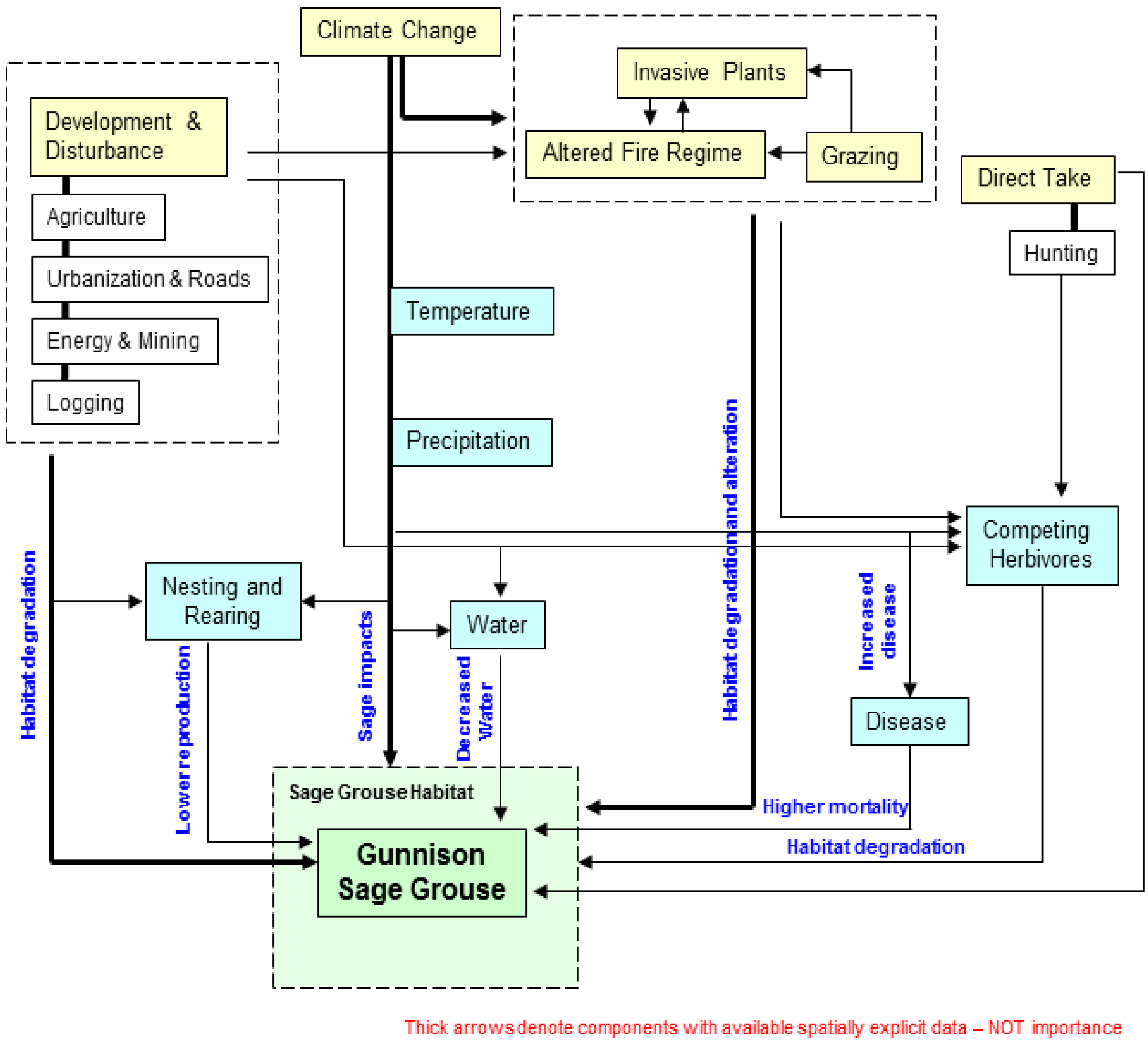
References Cited

GSRSC (Gunnison Sage-grouse Rangewide Steering Committee). 2005. Gunnison sage-grouse rangewide conservation plan. Colorado Division of Wildlife, Denver, Colorado.

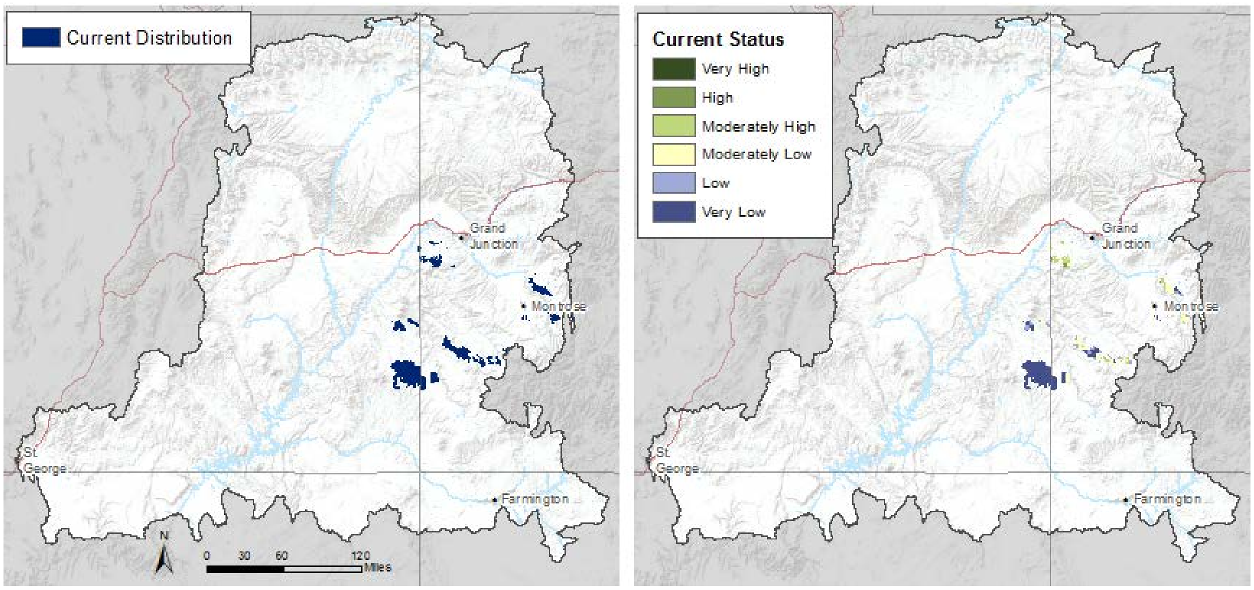
Lupis, S. G. 2005. Summer ecology of Gunnison sage-grouse (Centrocercus minimus) in San Juan County, Utah. M. S. thesis, Utah State University, Logan, Utah. xi + 81 pp.

Neely, B., P. McCarthy, M. Cross, C. Enquist, G. Garfin, D. Gori, G. Hayward, and T. Schulz. 2010. Climate change adaptation workshop for natural resource managers in the Gunnison Basin: Summary, December 2–3, 2009, Gunnison, Colorado.

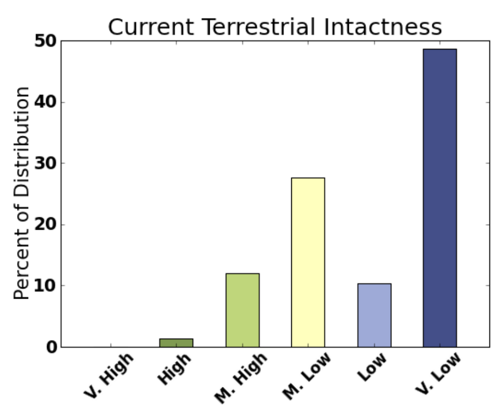
Gunnison Sage-Grouse Conceptual Model



MQ D1. What are the current distribution and status of Gunnison sage grouse (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?

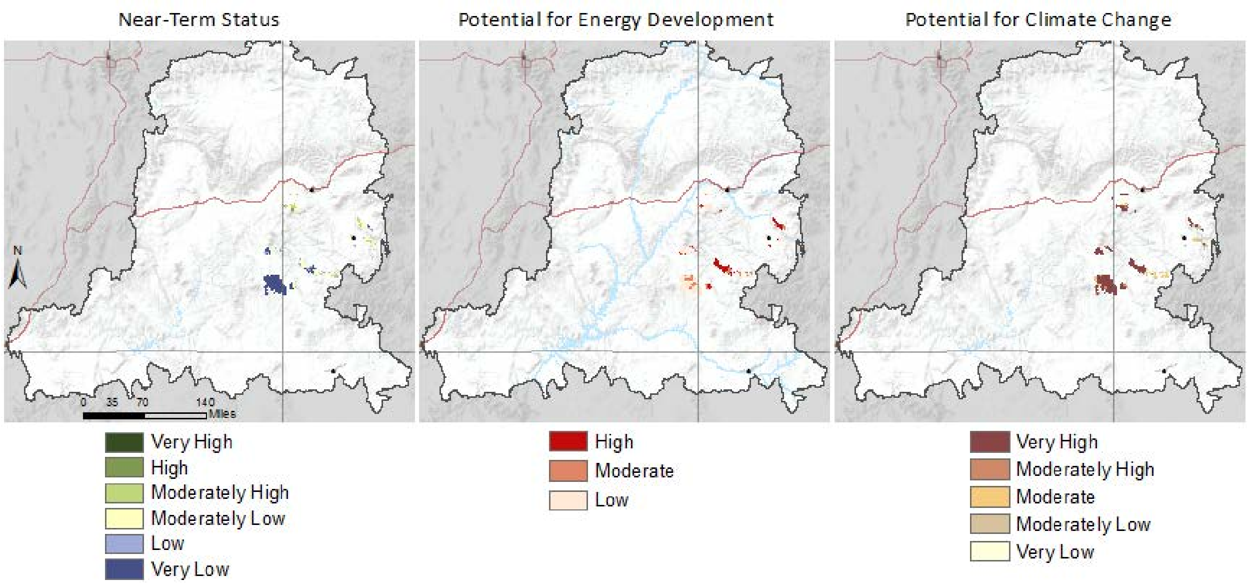


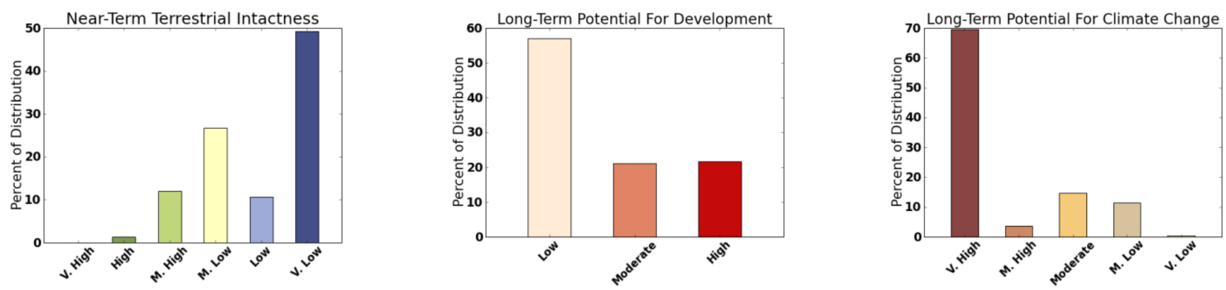
Data Sources:
Colorado Division of Wildlife, Utah Division of Wildlife Resources Nesting: Colorado Division of Wildlife, Utah Division of Wildlife Resources Winter: Colorado Division of Wildlife, Utah Division of Wildlife Resources



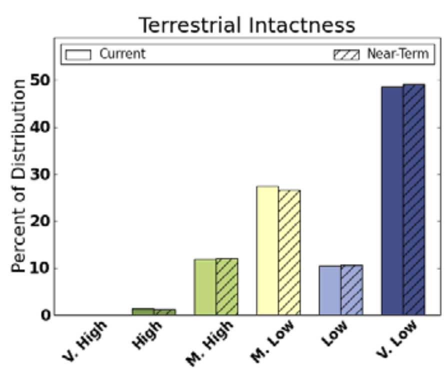
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

Gunnison Sage Grouse Potential for Change





Current & Near-term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

Mexican Spotted Owl – *Strix occidentalis lucida*

The Mexican spotted owl (*Strix occidentalis lucida*) was listed as threatened in 1993; the US Fish and Wildlife Service wrote the initial recovery plan in 1995 (USFWS 1995), designated areas of critical habitat in 2004 (USFWS 2004), and completed a revised recovery plan in 2011 (USFWS 2011). The characteristics of suitable habitat for Mexican spotted owl in the Colorado Plateau (specifically in southeastern Utah and the southwestern corner of Colorado) differ from occupied habitats encountered elsewhere in the owl's overall range; Mexican Spotted owls in this ecoregion use ledges and crevices in sheer sandstone canyons for nesting and roosting rather than larger trees within a forested matrix (Rinkevich and Gutiérrez 1996, Willey and van Riper 2007a). Prior to listing, extensive surveys were conducted in forested areas in southern Utah, but no breeding owls were detected outside of the canyonlands (LaRoe et al. 1995, USFWS 1995). Narrow, steep-walled tributary canyons offer the owl isolation, shade, water sources, and patches of riparian trees for alternate roost sites (USFWS 2011). The species' current distribution is naturally fragmented because owl habitat in the region depends on specific structural elements of canyon architecture.

The map of current distribution identifies known concentrations of Mexican spotted owls. Deeply incised canyon networks provide natural dispersal corridors joining occupied habitat islands and potentially suitable habitat (LaRoe et al. 1995). Identifying areas of potentially suitable habitat is critical to the expansion and recovery of the species. Willey et al. (2007b) developed a spatial model that predicts the potential distribution of Mexican spotted owl nesting and roosting habitat in the canyonlands of Utah using variables derived from optimal canyon morphology, relief, and rock type: for example, canyon widths < 1 km rim to rim extending for at least 1 km with cliff faces ≥ 90° and at least 15 m in height. Ledges and caves are also required, providing cool and shaded refugia. Their map of predicted habitat has a broader extent than the owl's current distribution map and can serve as a source to plan future owl surveys and protection areas. The National Park Service (using an earlier version of the Willey et al. [2007b] model) has been successful in locating Mexican spotted owls at over 90% of the areas surveyed that predicted owl occurrence (USFWS 2007).

Mexican spotted owls were listed as threatened in part because of concerns over even-age timber management and the threat of stand-replacing wildfire. Although canyon-dwelling spotted owls are not directly affected by either of these forest-related disturbances, they are sensitive and vulnerable to a number of other common regional disturbances such as road development, off-road vehicle use, oil and gas leasing, mineral exploration, canyon helicopter tours (Delaney et al. 1999b, USFWS 2007), grazing (USFWS 2011), and even low impact activities such as hiking, birding, and field research (Swarthout and Steidl 2001, Schelz et al. 2004). The structure of narrow, incised canyons magnifies noises and increases stress and startle responses when escape and avoidance routes are limited by confined roost and nesting areas within the canyon (USFWS 1995). In Canyonlands National Park, surveyors have observed that owls have abandoned canyons with higher recreation visitation (Schelz et al. 2004). Short of abandonment, owls will modify their behavior by flushing, perching in high locations on the canyon walls, being less attentive to their young, and altering the rate at which prey is delivered to the nest (Swarthout and Steidl 2001, Delaney et al. 1999a).

It goes without saying that if the Mexican spotted owl is sensitive enough to abandon an area too often frequented by hikers it will be more easily displaced from areas undergoing mineral development or exurban rural home expansion. Even if there is no direct loss of habitat, development near owl habitat increases the risk of disturbances from the expansion of road networks, incursions by offroad vehicles, changes in water table, increases in predator abundances, influx of invasive herbaceous species, and increases in human-caused wildfire. Development peripheral to owl concentrations on federal land may also affect juvenile owl dispersal and adult winter range use outside of deep canyon habitats (USFWS 2011). Possible management actions to protect nesting owls include placing buffer zones (61m to 0.4 km) around known roosting and nesting sites (Swarthout and Steidl 2001, USFWS 2007) and limiting access or closing known nest areas to recreation during the nesting season (April–July, Schelz et al. 2004).

Grazing, if not carefully managed, affects owl habitat by altering stream channel morphology, depth to groundwater, and riparian plant species composition, density, and productivity. Changes in plant type, density, or height affect the availability and abundance of the owl's prey: woodrats (*Neotoma* sp.), deer mice (*Peromyscus maniculatus*), and voles (*Microtus* sp.). Grazers, domestic, feral, or wild, may also selectively browse riparian aspen, willow, or cottonwood seedlings and saplings, affecting long-term replacement of large roosting trees (USFWS 2011).

Drought also affects vegetation density and productivity, particularly the herbaceous plants that sustain the owl's preferred small mammal prey base. The species' reproductive success and recruitment are affected by drought because of drought-related reductions in the abundance of prey. The numbers of owls detected in surveys in Canyonlands National Park in the drought year of 2002 were alarmingly low; that year also saw the lowest vegetation production in 17 years of monitoring (Schelz et al. 2004). Most climate change scenarios predict increased drought in the region. Peery et al. (2012) modeled population dynamics and extinction risk for three Mexican spotted owl populations in Arizona and New Mexico over the next century under three climate change emissions scenarios. Their predicted changes in population growth rates indicated weather-induced changes in reproductive success; their results also indicated that owl populations were more sensitive to changes in temperature than reductions in precipitation amount. All three scenarios predicted a rapid decline in Mexican spotted owl abundances over the next century.

One could argue that the canyon-dwelling spotted owl has an advantage over members of the same species inhabiting late-seral stage forest because its preferred habitat includes the dramatic canyonlands that are revered as parklands by the American public. Owl strongholds exist in protected areas such as Canyonlands (Schelz et al. 2004), Capitol Reef, Grand Canyon, Mesa Verde, and Zion National Parks (Rinkevich and Gutiérrez 1996). Portions of these parks have been incorporated into the protected activity centers (PACs) developed for Mexican spotted owls; each PAC contains at least 600 acres of the best nesting and roosting habitat and includes 75% of the owls' foraging area (USFWS 2004). Management restrictions may be applied in PACs to protect Mexican spotted owls from disturbances, particularly during nesting season (April–July). Some find the concept of PACs for spotted owl management too limiting considering what is known (and not known) about the species' seasonal movements and home range size. Willey and van Riper (2007a) found that for 12 southeastern Utah owls tracked during breeding and non-breeding seasons, the non-breeding home range size was 49% larger than the breeding home range size. Winter ranges showed increased use of peripheral ranges (rolling mesas outside of narrow canyons) and more travel to distant use areas. Schelz et al. (2004) recommended that the PAC concept be more broadly defined to represent available habitat (as depicted in models of potential habitat) and to reflect more closely Mexican spotted owl movement patterns.

Attributes and Indicators

Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
Habitat	Canyon morphology	Closed canopy forest	-	-	Canyon width < 1 km rim to rim	Willey et al. (2007b)
Habitat	Canyon morphology	Closed canopy forest	-	-	Cliff faces ≥ 90° and at least 15 m in height	Willey et al. (2007b)
Habitat	Canyon morphology	Sheer walls, lack of perches and temperature refugia	-	-	Ledges and caves for perching and temperature refugia	Willey et al. (2007b)
Habitat	(Winter) physiography	-	-	Woodland mesas and benches	Narrow, steep-walled canyons	Schelz et al. (2004), Willey and van Riper (2007a)
Habitat	Riparian vegetation				Patches of riparian trees	USFWS (2011), Willey and van Riper (2007a)

References

Delaney, D.K., T.G. Grubb, and P. Beier. 1999a. Activity patterns of nesting Mexican spotted owls. *The Condor* 10:42–49.

Delaney, D.K., T.G. Grubb, P. Beier, L.L. Pater, and M.H. Reiser. 1999b. Effects of helicopter noise on Mexican spotted owls. *Journal of Wildlife Management* 63(1):60–76.

LaRoe, E.T., G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac (eds.). 1995. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, DC. 530 pp.

Peery, M.Z., R.J. Gutierrez, R.J. Kirby, O.E. LeDee, and W. LaHaye. 2012. Climate change and spotted owls: Potentially contrasting responses in the southwestern United States *Global Change Biology* 18(3): 865–880.

Rinkevich, S.E., and R.J. Gutiérrez. 1996. Mexican spotted owl habitat characteristics in Zion National Park. *Journal of Raptor Research* 30: 74–78.

Schelz, C.D., and D. Svendson. 2002. Mexican spotted owl inventory at Canyonlands National Park, National Park Service Report, Southeast Utah Group, Biologist Files, Southeast Utah Group National Park Service Headquarters, Moab, Utah.

Schelz, C.D., D. Kent, D. Chalmers, and D. Svendson. 2004. Mexican spotted owl inventory in Canyonlands National Park, 2002–2003. General Technical Report SEUG-002-2003, National Park Service, Moab, Utah.

Swarthout, E.C.H. and R.J. Steidl. 2001. Flush responses of Mexican spotted owls to recreationists. *Journal of Wildlife Management* 65(2):312–317.

USFWS (U.S. Fish and Wildlife Service). 1995. Draft Recovery Plan for the Mexican Spotted Owl (*Strix occidentalis lucida*). U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

USFWS (U.S. Fish and Wildlife Service). 2004. Environmental assessment for designation of critical habitat for the Mexican spotted owl. U.S. Fish and Wildlife Service, Region 2, Albuquerque, New Mexico. 67 p.

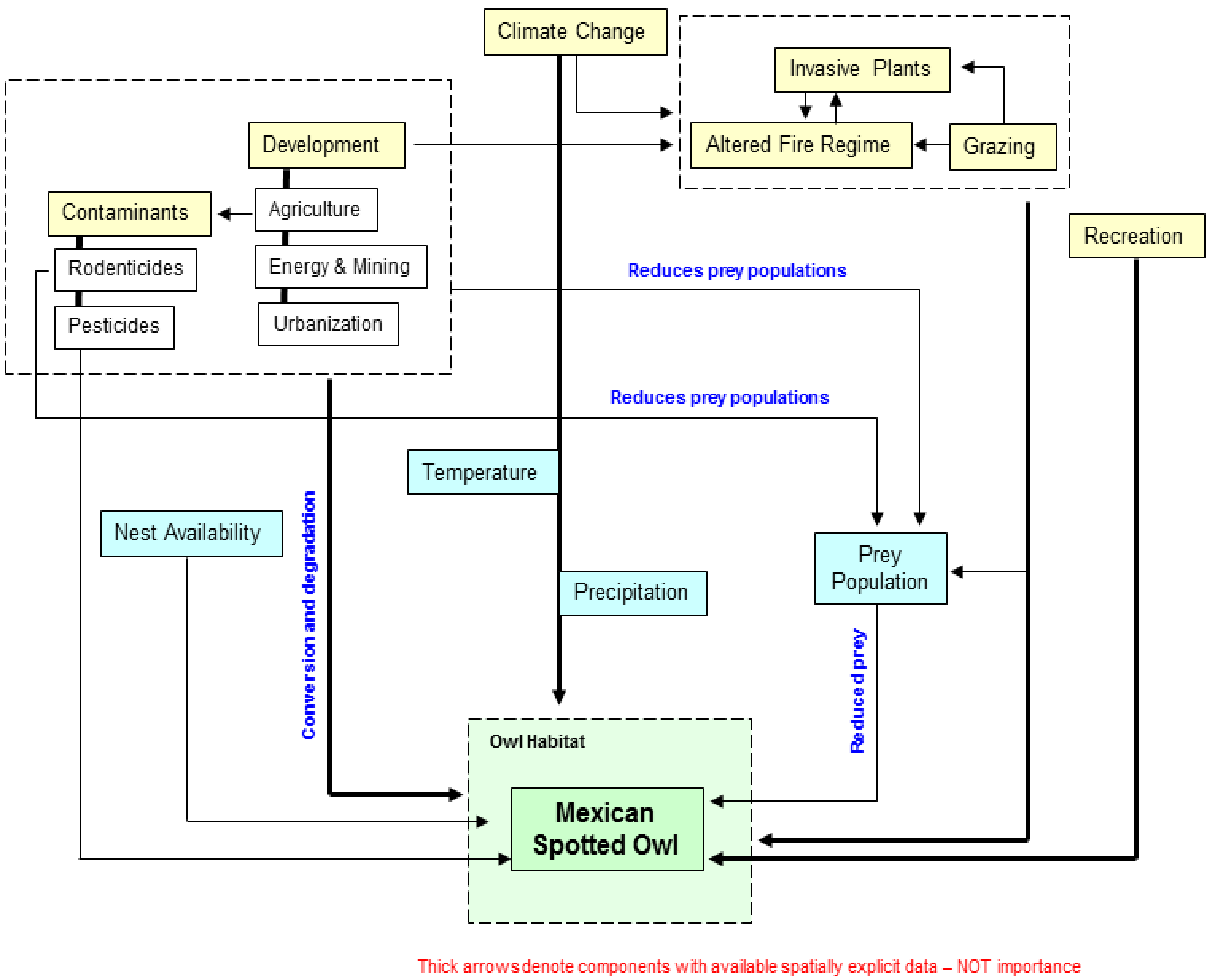
USFWS (U.S. Fish and Wildlife Service). 2007. Biological opinion for Maverick Airstar landing site in the Little Colorado River Gorge. U.S. Fish and Wildlife Service, Phoenix, Arizona.

USFWS (U.S. Fish and Wildlife Service). 2011. Draft Recovery Plan for the Mexican Spotted Owl (*Strix occidentalis lucida*), First Revision. U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 399 p.

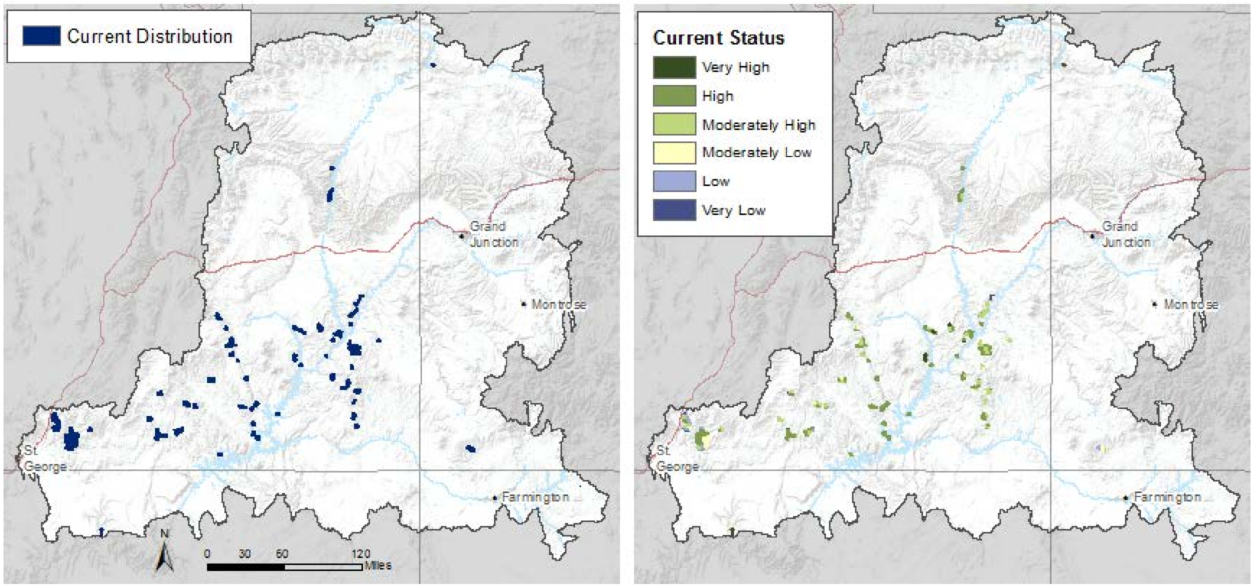
Willey, D.W., and C. van Riper, III. 2007a. Home range characteristics of Mexican spotted owls in the canyonlands of Utah. *Journal of Raptor Research* 41:10–15. http://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1071&context=crc_research.

Willey, D. W., M. Zambon, and F. Howe. 2007b. Predicting Mexican spotted owl habitat using a geographic information system and AIC-based habitat models in canyonlands of Utah. Final Technical Report. Utah Division of Wildlife Resources, Salt Lake City, Utah.

Mexican Spotted Owl Conceptual Model

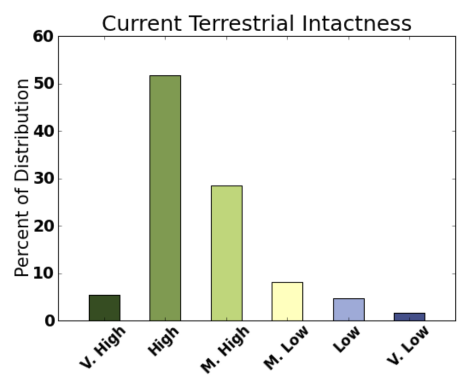


MQ D1. What are the current distribution and status of Mexican spotted owl (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?



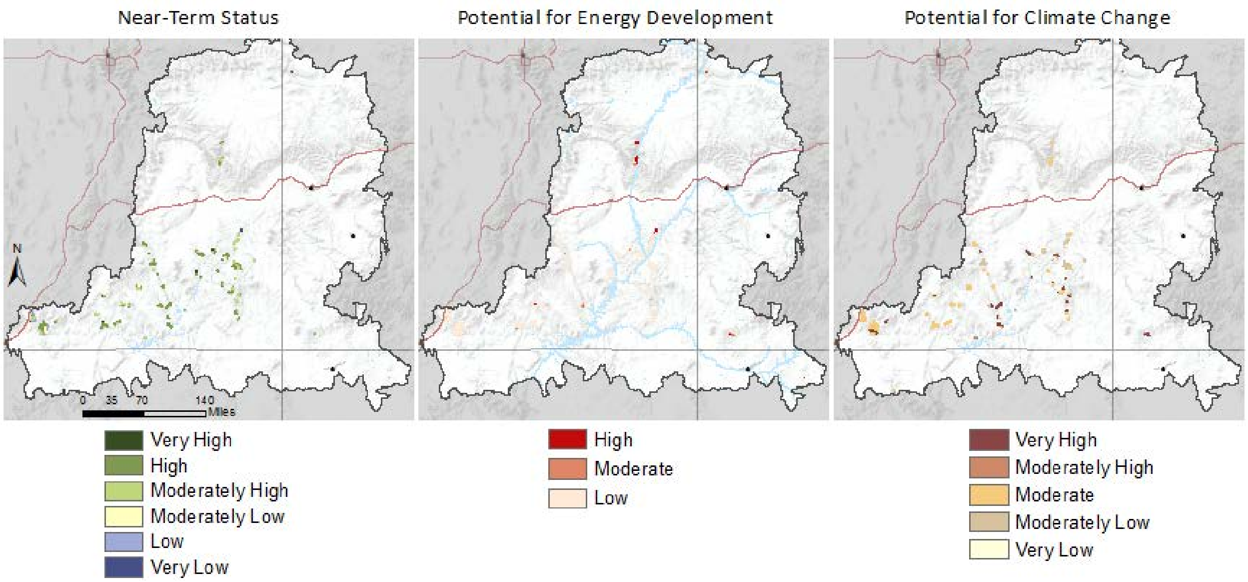
Data Sources:

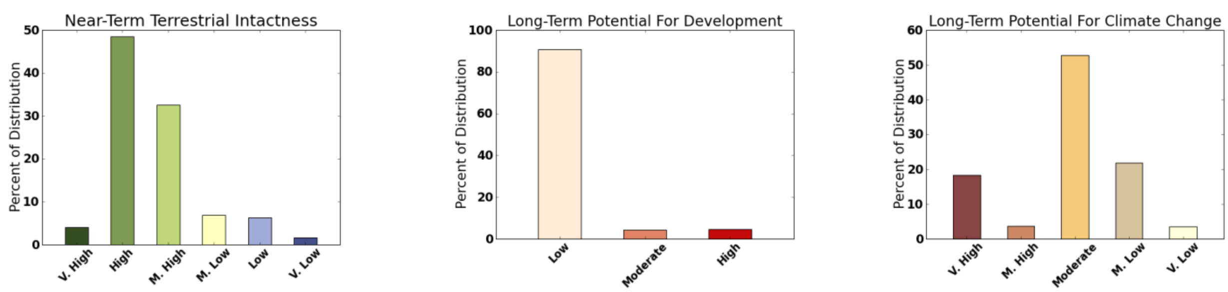
Carson National Forest Mexican Spotted Owl Management Areas, and Mexican Spotted Owl Areas identified in Draft Recovery Plan



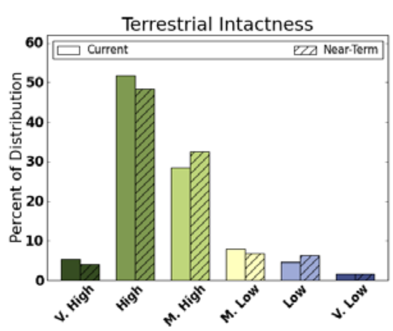
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

Mexican Spotted Owl Potential for Change





Current & Near-term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

Yellow-breasted Chat – *Icteria virens*

Attributes and Indicators

Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
Habitat	Foliage/shrub density - Riparian shrub; Himalayan blackberry = especially preferred	low			high (1-3 m.)	Connor et al, 1983; Garrett and Dunn, 1981; Ricketts and Kus, 2000
habitat	Elevation			<1600 m		Gaines, 1992
Habitat	tree/shrub height (perching)			0.9-1.8 m	> 1.8 m (i.e. cottonwoods & alders)	Dunn and Garrett, 1997

References Cited

Conner, R.N.; Dickson, J.G.; Locke, B.A.; Segelquist, C.A. 1983. Vegetation characteristics important to common songbirds in east Texas. Wilson Bulletin 95(3):349-361.

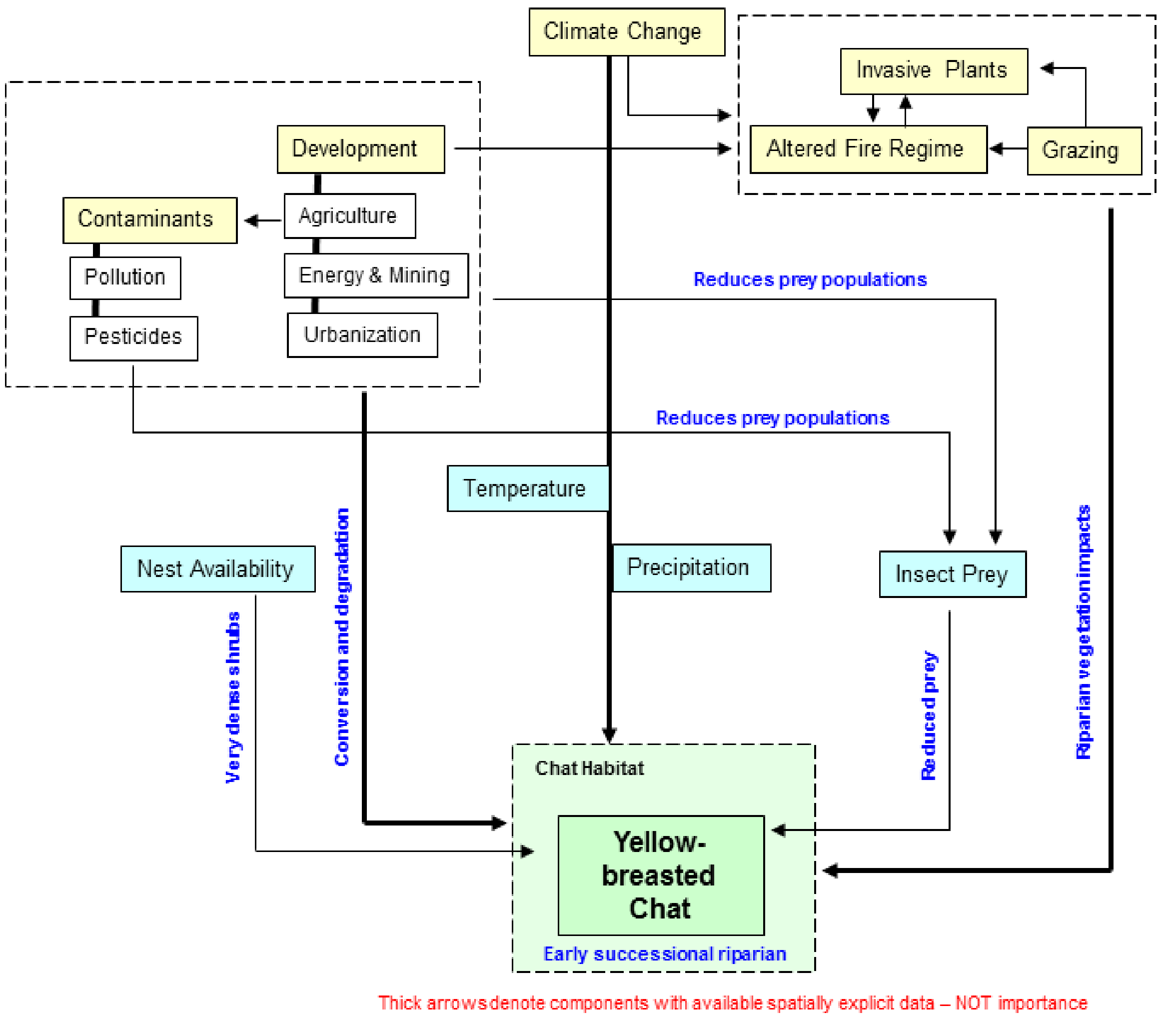
Dunn, J. L. and K. L. Garrett. 1997. A field guide to warblers of North America. Houghton Mifflin Co., New York

Gaines, D. 1992. Birds of Yosemite and the East Slope.Artemesia Press, Lee Vining, CA

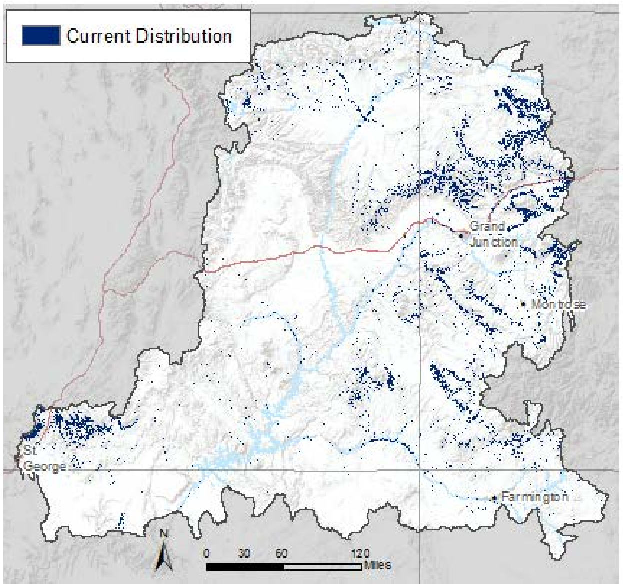
Garrett, K., and J. Dunn. 1981. Birds of southern California. Los Angeles Audubon Soc.

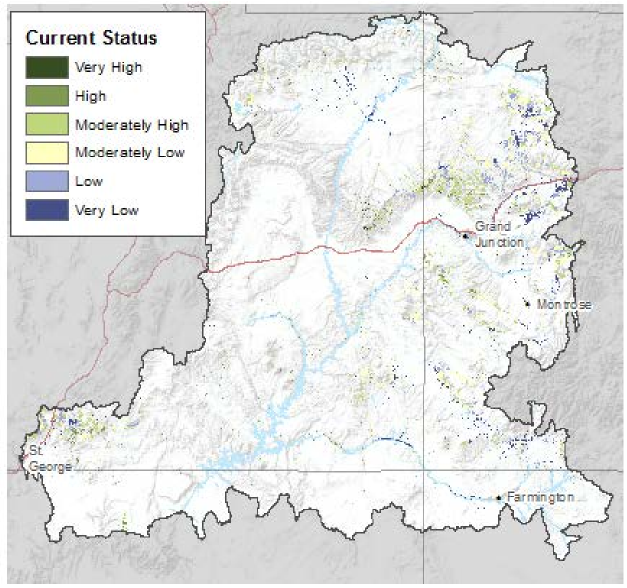
Ricketts, M. and B. Kus. 2000. Yellow-breasted Chat (*Icteria virens*). *In* The Riparian Bird Conservation Plan:a strategy for reversing the decline of riparian-associated birds in California. California Partners in Flight. http://www.prbo.org/calpif/htmldocs/riparian_v-2.html

Yellow-Breasted Chat Conceptual Model



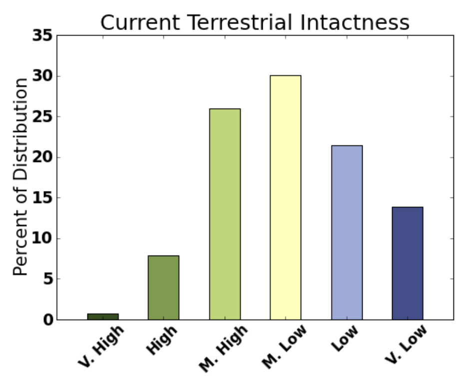
MQ D1. What are the current distribution and status of yellow-breasted chat (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?





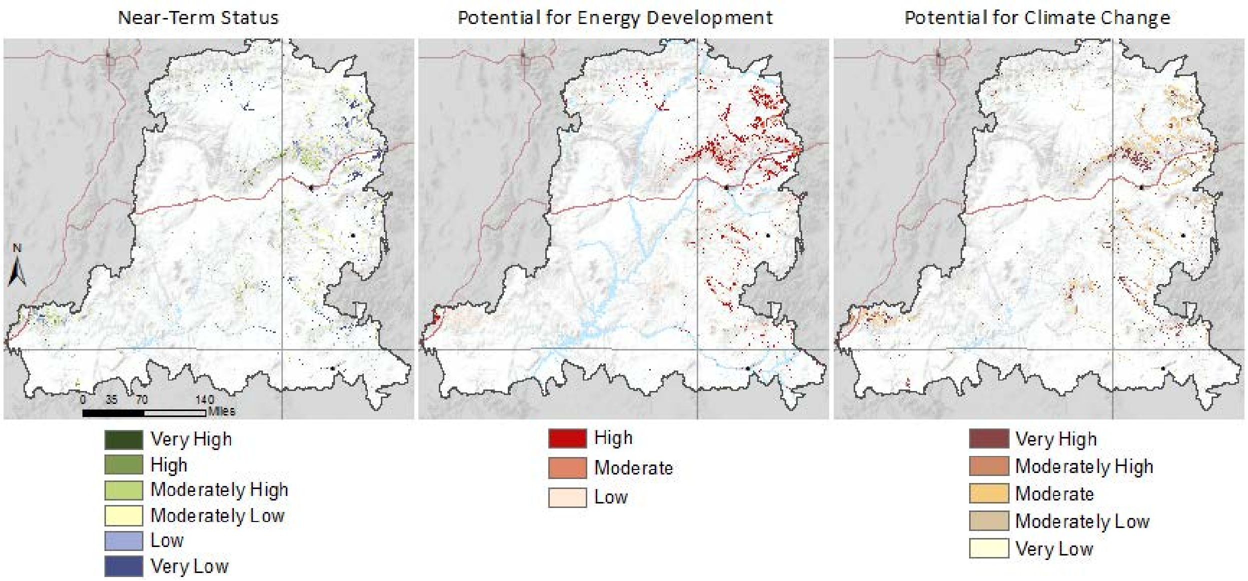
Data Sources:

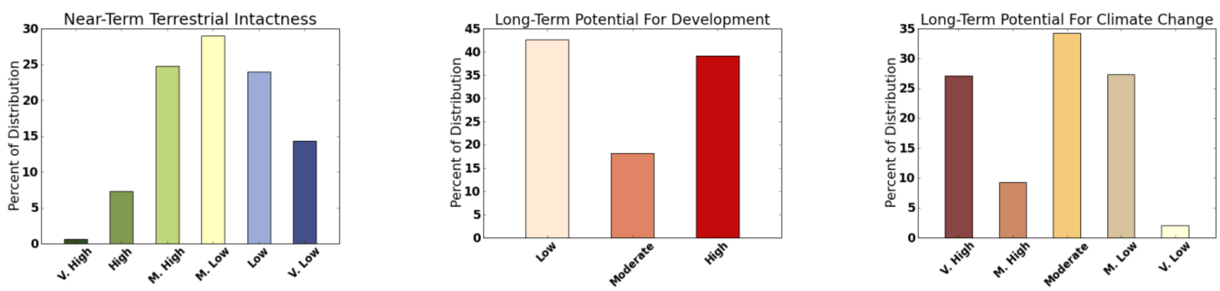
SW ReGAP (Southwest Regional GAP Analysis Project)



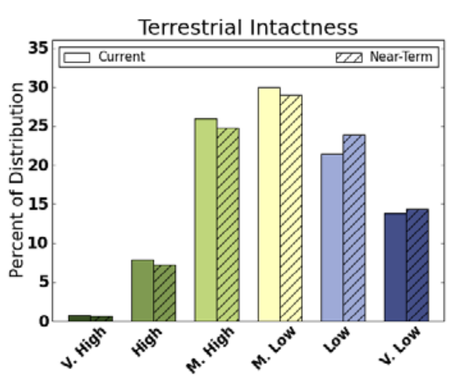
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

Yellow-Breasted Chat Potential to Change





Current & Near-term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

Colorado River Cutthroat Trout – *Oncorhynchus clarki*

Attributes and Indicators

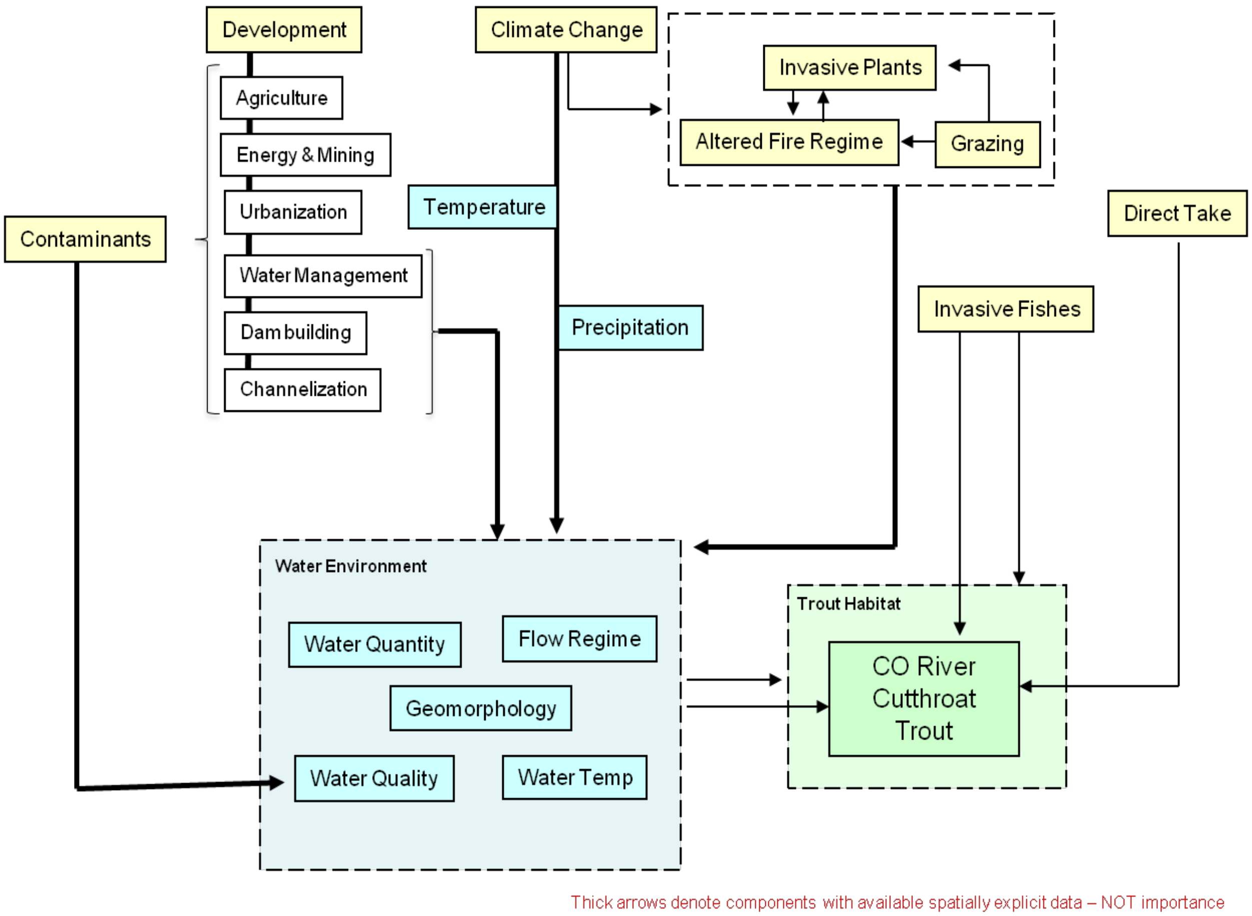
Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
Habitat	Avg max water temperature	<4 degrees C or >20 degrees C	4-6.5 degrees C or 19-20 degrees C	6.5-12 degrees C or 14-19 degrees C	12-14 degrees C	Binns and Eiserman (1979), Hickman and Raleigh (1982)
Habitat	Avg min dissolved oxygen	<6.3 mg/L	6.3-7.2 mg/L	7.2-9 mg/L	>9 mg/L	Hickman and Raleigh (1982)
Flow regime	Avg daily base flow	<25%	25-37.5%	37.5-50%	>50%	Binns and Eiserman (1979), Hickman and Raleigh (1982)

References Cited

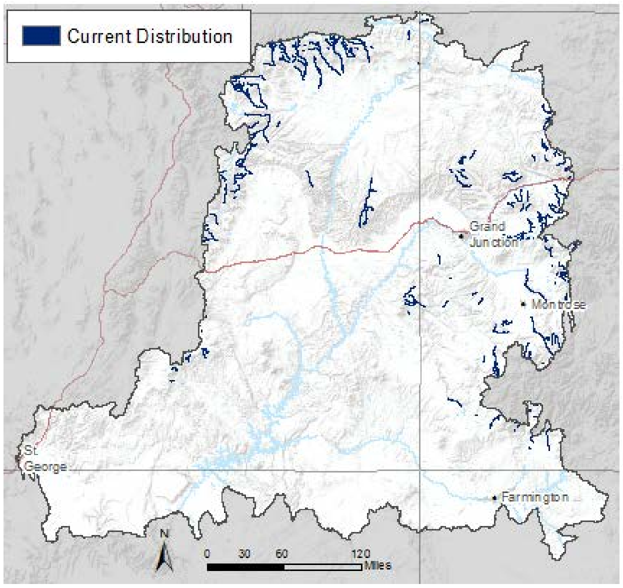
Binns, N. A., and F. M. Eiserman. 1979. Quantification of fluvial trout habitat in Wyoming. Transactions of the American Fisheries Society 108: 215–228.

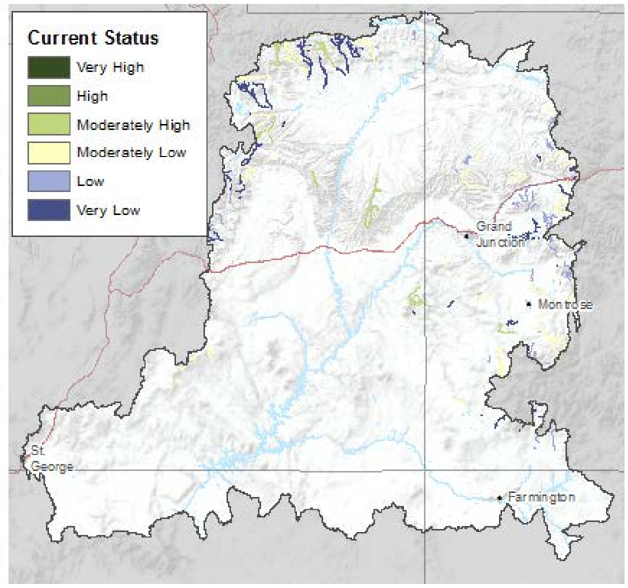
Hickman, T., and R. F. Raleigh. 1982. Habitat suitability models: cutthroat trout. U. S. D. I. Fish and Wildlife Service, Washington, D.C. FWS/OBS-82/10.5. vi + 38 pp.

Colorado River Cutthroat Trout Conceptual Model



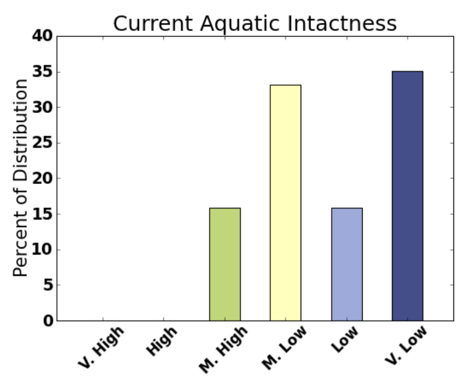
MQ D1. What are the current distribution and status of Colorado River cutthroat trout (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?





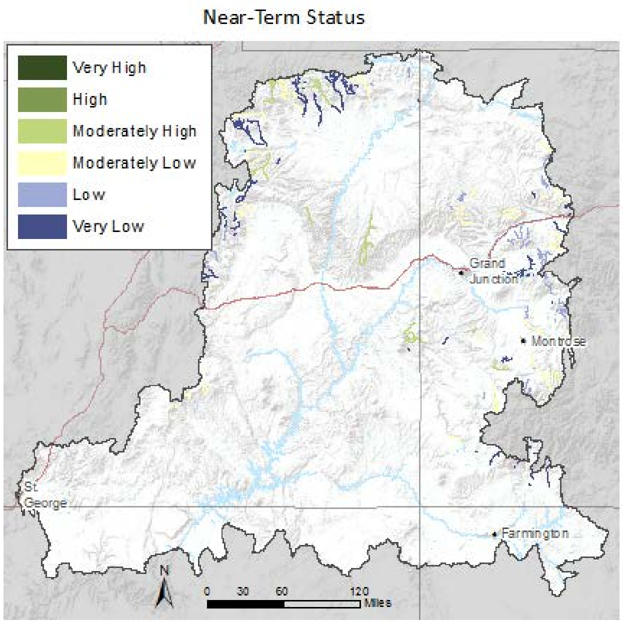
Data Source:

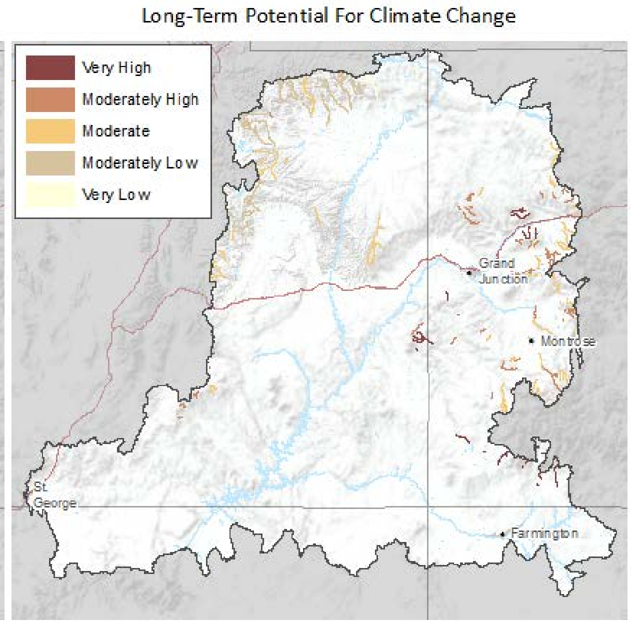
"Range-Wide Status of Colorado River Cutthroat Trout." (Hirsch, C.L., S.E. Albeke, T.P. Nesler 2006)

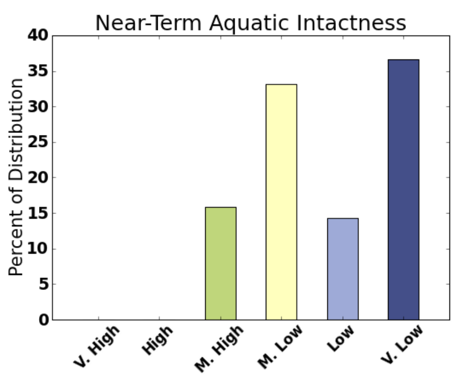


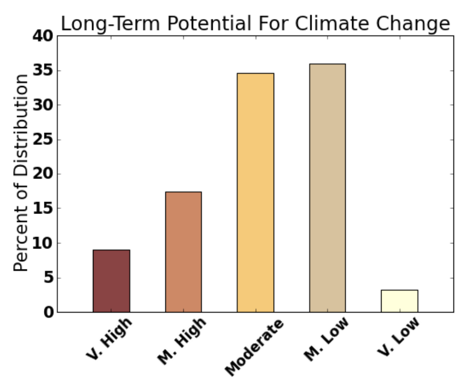
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

Colorado River Cutthroat Trout Potential for Change

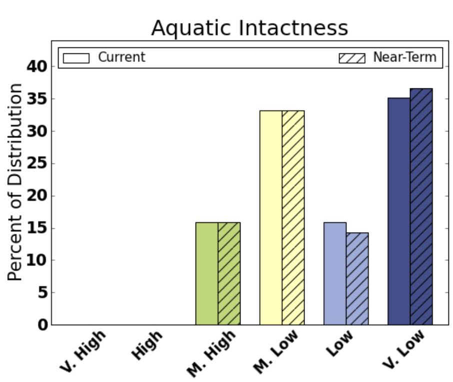








Current & Near-term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

Flannelmouth Sucker – *Catostomus latipinnis*

Attributes and Indicators

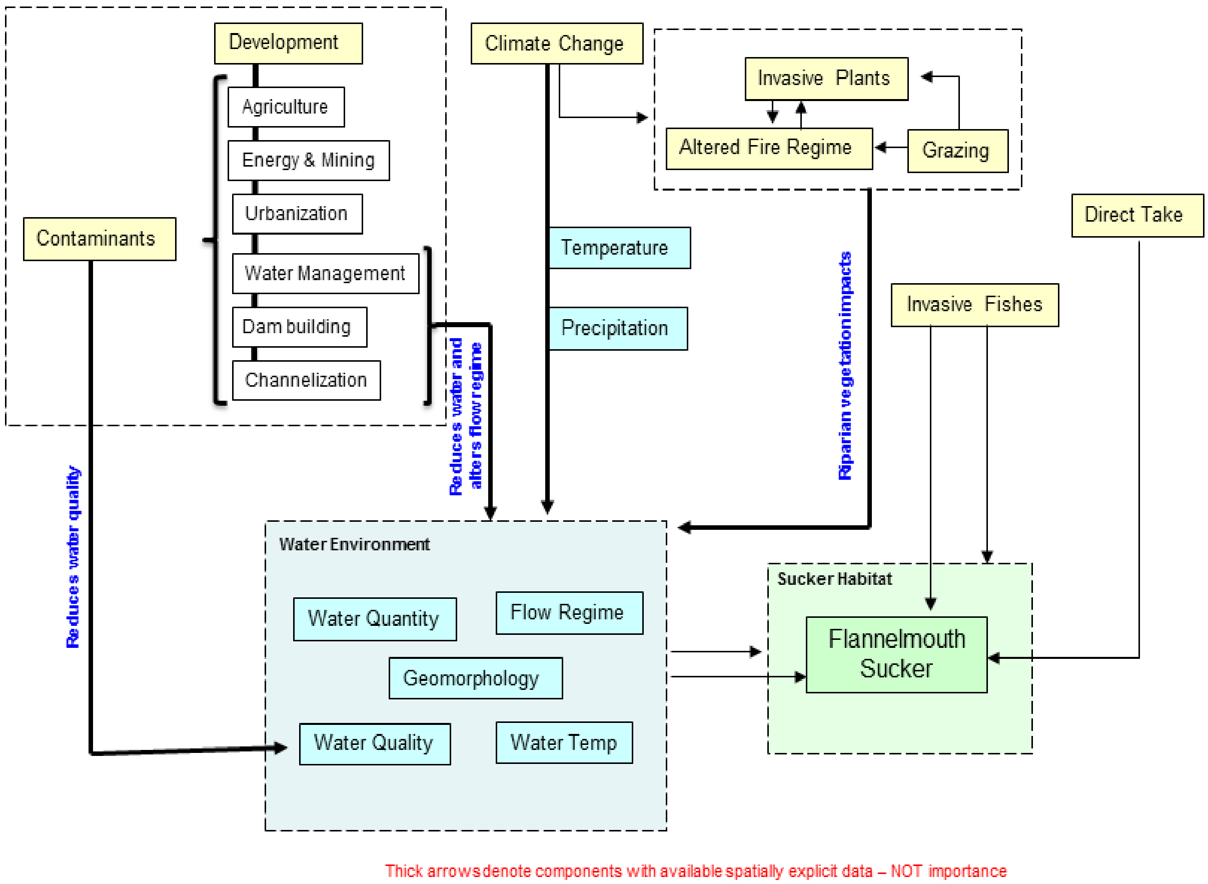
Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
Habitat	Summer water temperature	<10 degrees C or >30 degrees C	10-17.5 degrees C or 29–30 degrees C	17.5–25 degrees C or 27-29 degrees C	25–27 degrees C	Bezzerides and Bestgen (2002)
Habitat	Water depth	<0.5 m or >2.5m	0.5–1.0 m or 2.0-–2.5 m	1.5–2.0 m	1.0–1.5 m	Beyers et al. (2001)
Dispersal	Unblocked linear extent	<1.6 km	1.6–10 km	10–20 km	>20 km	Bezzerides and Bestgen (2002)

References Cited

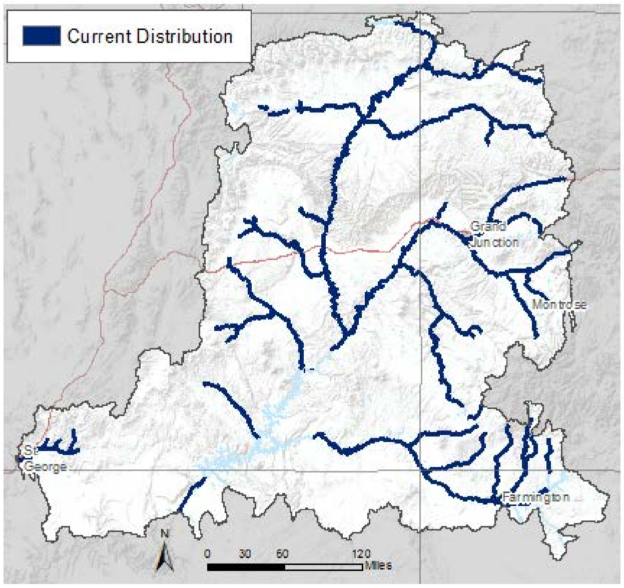
Beyers, D. W., C. Sodergren, J. M. Bundy, and K. R. Bestgen. 2001. Habitat use and movement of bluehead sucker, flannelmouth sucker, and roundtail chub in the Colorado River. Contribution 121, Larval Fish Laboratory, Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, Colorado. vi + 32 pp.

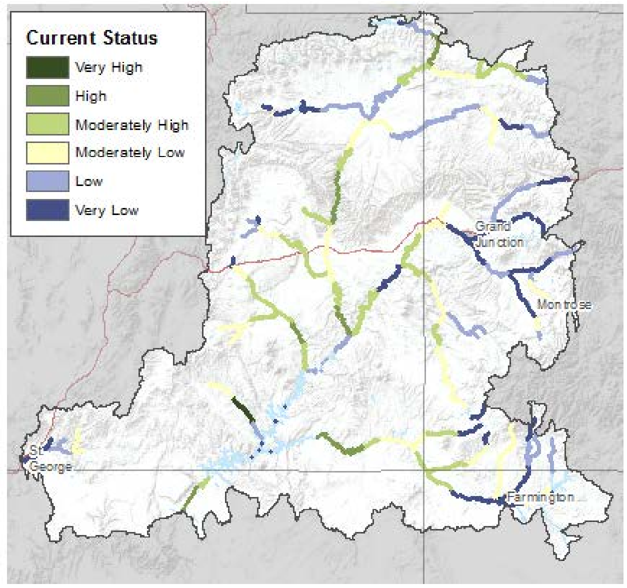
Bezzerides, N., and K. Bestgen. 2002. Status review of roundtail chub Gila robusta, flannelmouth sucker Catostomus latipinnis, and bluehead sucker Catostomus discobolus in the Colorado River basin. Contribution 118, Larval Fish Laboratory, Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, Colorado. x + 139 pp.

Flannelmouth Sucker Conceptual Model



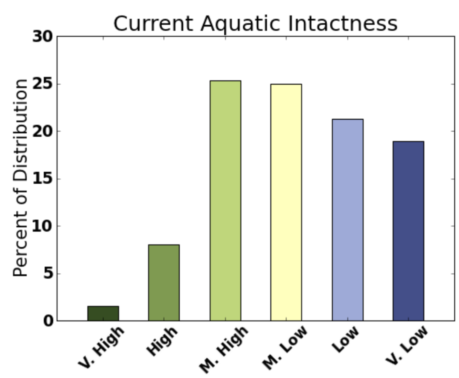
MQ D1. What are the current distribution and status of flannelmouth sucker (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?



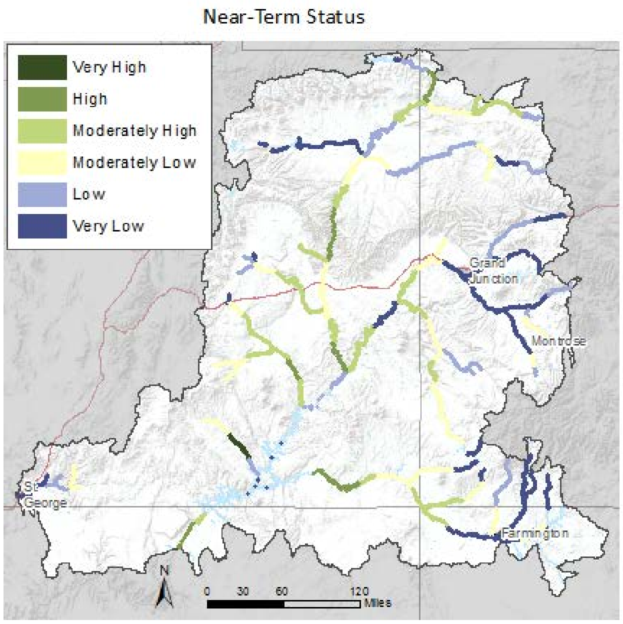


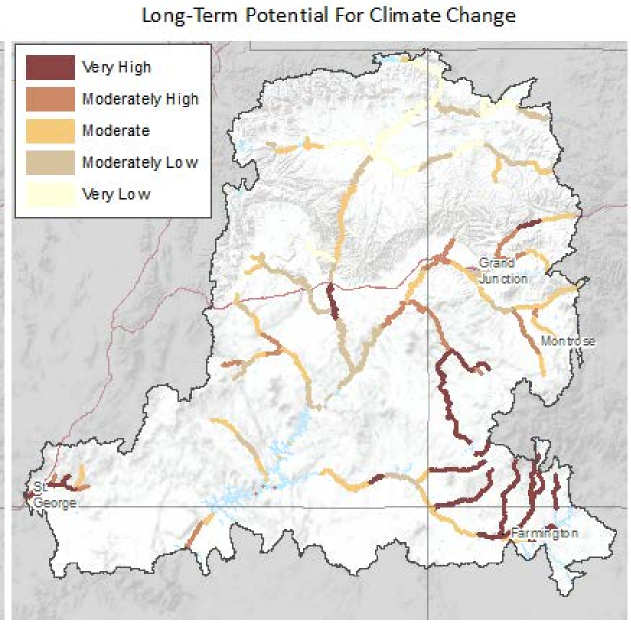
Data Sources:

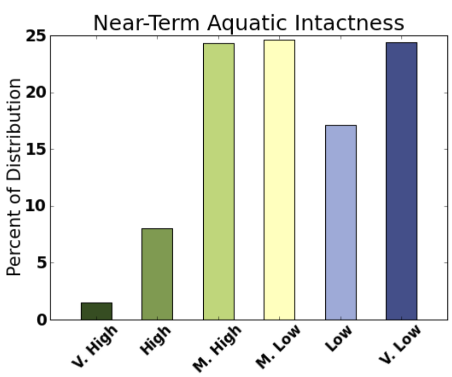
Selected features from NHD based on heritage occurrence data and survey points

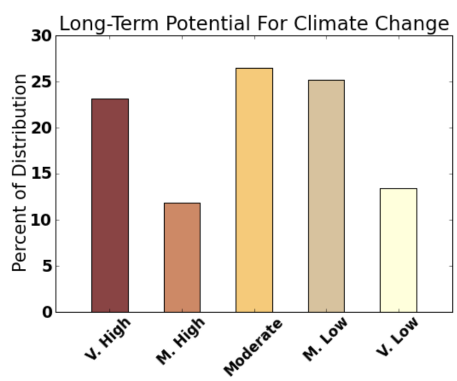


MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

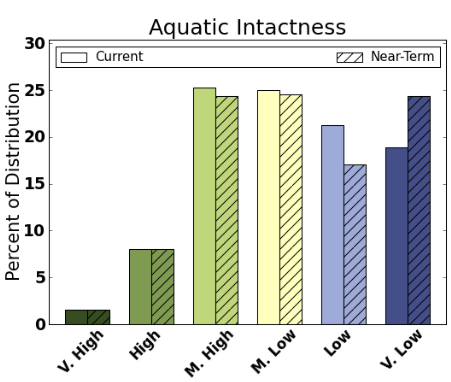








Current & Near-term Intactness



Current (solid color) and Near-term (cross-hatched) Intactness

Razorback Sucker – *Xyrauchen texanus*

The razorback sucker (also known as the humpback sucker or buffalo fish) was federally listed in 1991 as an endangered species (USFWS 1991, also IUCN Red-listed as Endangered, IUCN 2010). Endemic to and historically distributed throughout the Colorado and Gila River basins (Minckley et al. 1991, NatureServe 2010, Schooley and Marsh 2007), the species has been nearly extirpated from Arizona and now occurs naturally only in lakes Mohave and Mead (impoundments) and in small populations in the Yampa and Green rivers of Utah and Colorado (Lanigan and Tyus 1989, Minckley et al. 1991, Mueller et al. 2000, Tyus and Karp 1989). Hatchery-reared fish have been reintroduced into Lake Havasu, the Colorado River below Parker Dam, and the Verde River (Douglas and Marsh 1998, Modde et al. 1996, Minckley et al. 1991, Tyus and Karp 1989). Critical habitat was designated by the USFWS in 1994 and a Recovery Plan finalized by the USFWS in 1998. General habitat types currently utilized by razorback suckers include wetlands, permanent rivers, streams, creeks and lakes, artificial impoundments, and irrigation channels.

Given the relative interest in razorback sucker restoration in recent decades, there is a surprising paucity of quantitative razorback sucker models found in primary literature. However, numerous relationships between razorback suckers and various biological and physical parameters have been established in the literature. Some of these relationships have been incorporated into the conceptual and application/method models used in this REA.

Primary threats to the razorback sucker include interactions with non-native fishes and human alteration of riverine habitats. Dam operations continue to limit razorback sucker sustainability by restricting the amount of suitable habitat available for the species during multiple life stages. Alterations caused by dam-building and subsequent flow management trigger detrimental changes in timing, magnitude and duration of winter and spring flows, altered river temperatures (Clarkson and Childs 2000), reduced flooding (USFWS 1990, Hedrick et al. 2009), and abatement of sedimentation (Johnson and Hines 1999) and gravel bar accretion. Channelization for agricultural or highway projects further reduces the amount of gravel bar and slow backwater areas necessary for nesting and fry nurseries. Detailed changes to razorback sucker habitats are described in the USFWS proposal to federally list the species (1990) and in the recovery plan (USFWS 1998).

Recruitment of larvae and young has been very low (or absent), despite protracted hatchery intervention practices and costly habitat restoration projects (Hedrick et al. 2009). Besides a lack of recruitment from loss of backwater habitat, recruitment is also limited by the pervasiveness of predatory non-native fishes (Clarkson et al 2005, Jelks et al. 2008, Johnson et al. 1993, Marsh et al. 2003; see Table 1 in USFWS 1998 for a more detailed list). The presence of nonnative, invasive fish species can directly and indirectly influence razorback suckers by limiting the space available for razorback sucker to occupy (indirect), competing for razorback sucker food sources (prey; indirect), preying on eggs, larvae, and juvenile razorback suckers (direct), or exhibiting aggressive behavior toward razorback suckers (direct). Lenon et al. (2002) also noted that competition with and predation by non-native crayfishes may be a problem in some areas. Hybridization with other sucker species also occurs (Tyus and Karp 1989, Minckley et al. 1991).

In addition to human development and pressures from invasive species, climate change may have an additional impact on flow regimes that are so important to the razorback sucker. Climate change will have a direct impact on the type, amount, and timing of precipitation and spring runoff. Because stream flows are closely related to precipitation patterns in the region (e.g., Christensen and Lettenmaier 2007, Hoerling et al. 2009), climate change will affect the aquatic environment through influencing the flow regimes, water quality, and water quantity, all of which are important drivers of razorback sucker populations.

Attributes and Indicators

Attribute	Indicator	Indicator Rating				
		Poor	Fair	Good	Very Good	Citation
Habitat	Water body	irrigation canals	small rivers, reservoirs	medium rivers	large rivers	Valdez et al. (2002)
Breeding habitat	River feature	rapids, riffles	slow runs, eddies	pools, off-channel flooded pits	backwaters	Osmundson et al. (1995)
Habitat	Summer water temperature	>29 degrees C or <12 degrees C	26.9–29 degrees C or 12-17.5 degrees C	24.8–26.9 degrees C or 17.5-22.9 degrees C	22.9–24.8 degrees C	Buckley and Pimentel (1983)

References Cited

Bulkley, R. V., and R. Pimentel. 1983. Temperature preference and avoidance by adult razorback suckers. *Transactions of the American Fisheries Society* 112:601–607.

Christensen, N.S., and D.P. Lettenmaier. 2007. A multi-model ensemble approach to assessment of climate change impacts on the hydrology and water resources of the Colorado River Basin. *Hydrology and Earth Systems Science* 11(4): 1417–1434.

Clarkson, R.W., and M.R. Childs. 2000. Temperature effects of hypolimnion-release dams on early life history stages of Colorado River Basin big-river fishes. *Copeia* 2000: 402–412.

Clarkson, R.W., Marsh, P.C., Stefferud, S.E., and J.A. Stefferud. 2005. Conflicts between native fish and nonnative sport fish management in the Southwestern United States. *Fisheries* 30(9): 20–27.

Crowl, T.A., and N.W. Bouwes. 1997. Modeling population dynamics of Colorado squawfish, razorback sucker, and humpback chub: for management objective development. Aquatic Ecology Center, Department of Fisheries and Wildlife, Utah State University, Logan, Utah.

Douglas, M.E., and P.C. Marsh. 1998. Population and survival estimates of *Catostomus latipinnis* in northern Grand Canyon, with distribution and abundance of hybrids with *Xyrauchen texanus*. *Copeia* 1998: 915–925.

Dowling, T.E., and W.L. Minckley. 1993. Genetic diversity of razorback sucker as determined by restriction endonuclease analysis of mitochondrial DNA. Final Report to the U.S. Bureau of Reclamation (Contract 0-FC-40-O-9530-004). Department of Zoology, Arizona State University, Tempe. 56 pp.

Dowling, T.E., W.L. Minckley, D.C. Marsh, and E.S. Goldstone. 1996. Mitochondrial DNA variability in the endangered razorback sucker (Xyrauchen texanus): Analysis of hatchery stacks and implications for captive propagation. *Conservation Biology* 10(1): 120–127.

Gurtin, S.D., Slaughter, J.E., Sampson, S.J., and R.H. Bradford. 2003. Use of existing and reconnected backwater habitats by hatchery-reared adult razorback suckers: a predictive model for the Imperial Division, Lower Colorado River. *Transactions of the American Fisheries Society* 132:1125–1137.

Hedrick, T.N., K.R. Bestgen, and K.D. Christopherson. 2009. Entrainment of semi-buoyant beads and razorback sucker (*Xyrauchen texanus*) larvae into floodplain wetlands of the middle Green River, Utah. Publication 09-05, Utah Division of Wildlife Resources, Salt Lake City, Utah.

Hoerling, M., Lettenmaier, D., Cayan, D., and B. Udall. 2009. Reconciling projections of Colorado River streamflow. *Southwest Hydrology* May/June 2009, pp. 20–21, 31.

IUCN (International Union for Conservation of Nature). 2010. The IUCN Red List of Threatened Species. http://www.iucnredlist.org/apps/redlist/details/23162/0. Accessed online December 28, 2010.

Jelks, H.L., Walsh, S.J., Burkhead, N.M., Contreras-Balderas, S., Díaz-Pardo, E., Hendrickson, D.A., Lyons, J., Mandrak, N.E., McCormick, F., Nelson, J.S., Platania, S.P, Porter, B.A., Renaud, C.B., Schmitter-Soto, J.J., Taylor, E.B. and M.L. Warren, Jr. 2008. Conservation status of imperiled North American freshwater and diadromous fishes. *Fisheries* 33(8):372–407.

Johnson, J.E., and R.T. Hines. 1999. Effect of suspended sediment on vulnerability of young razorback suckers to predation. *Transactions of the American Fisheries Society* 128(4):648–655.

Johnson, J.E., Pardew, M.G., and M.M. Lyttle. 1993. Notes: Predator recognition and avoidance by larval razorback sucker and northern hog sucker. *Transactions of the American Fisheries Society* 122(6):1139–1145.

Lanigan, S. H., and H. M Tyus. 1989. Population size and status of the razorback sucker in the Green River basin, Utah and Colorado. *North American Journal of Fisheries Management* 9:68–73.

Lenon, N., Stave, K., Burke, T., and J. E. Deacon. 2002. Bonytail (*Gila elegans*) may enhance survival of razorback suckers (*Xyrauchen texanus*) in rearing ponds by preying on exotic crayfish. *Journal of the Arizona-Nevada Academy of Sciences* 34(1):46–52.

Marsh, P. C., Pacey, C. A., and B. R. Kesner. 2003. Decline of the razorback sucker in Lake Mohave, Colorado River, Arizona and Nevada. *Transactions of the American Fisheries Society* 132:1251–1256.

Minckley, W.L., Marsh, P.C., Brooks, J.E., Johnson, J.E., and B.L. Jensen. 1991. Management toward recovery of the razorback sucker. Pages 283–357 *in* W.L. Minckley and J.E. Deacon (eds.). Battle against extinction: Native fish management in the American West. University of Arizona Press, Tucson, AZ.

Modde, T., K.P. Burnham, and E.J. Wick. 1996. Population status of the razorback sucker in the middle Green River (USA). *Conservation Biology* 10(1):110–119.

Mueller, G., Marsh, P. C., Knowles, G., and T. Wolters. 2000. Distribution, movements, and habitat use of razorback suckers (*Xyrauchen texanus*) in a lower Colorado River reservoir, Arizona-Nevada. *Western North American Naturalist* 60:180–187.

NatureServe. 2010. Razorback sucker distribution. http://www.natureserve.org/explorer/servlet/NatureServe?searchName=Xyrauchen+texanus. Accessed online December 22, 2010.

Osmundson, D. B., P. Nelson, K. Fenton, and D. W. Ryden. 1995. Relationships between flow and rare fish habitat in the '15-mile reach' of the upper Colorado River. U. S. Fish and Wildlife Service, Grand Junction, Colorado. xiii + 82 pp.

Schooley, J.D., and P.C. Marsh. 2007. Stocking of endangered razorback suckers in the Lower Colorado River Basin over three decades: 1974–2004. *North American Journal of Fisheries Management:* 27:43–51.

Tyus, H. M., and C. A. Karp. 1989. Habitat use and streamflow needs of rare and endangered fishes, Yampa River, Colorado. U.S. Fish Wildlife Service, Biological Report 89(14). 27 pp.

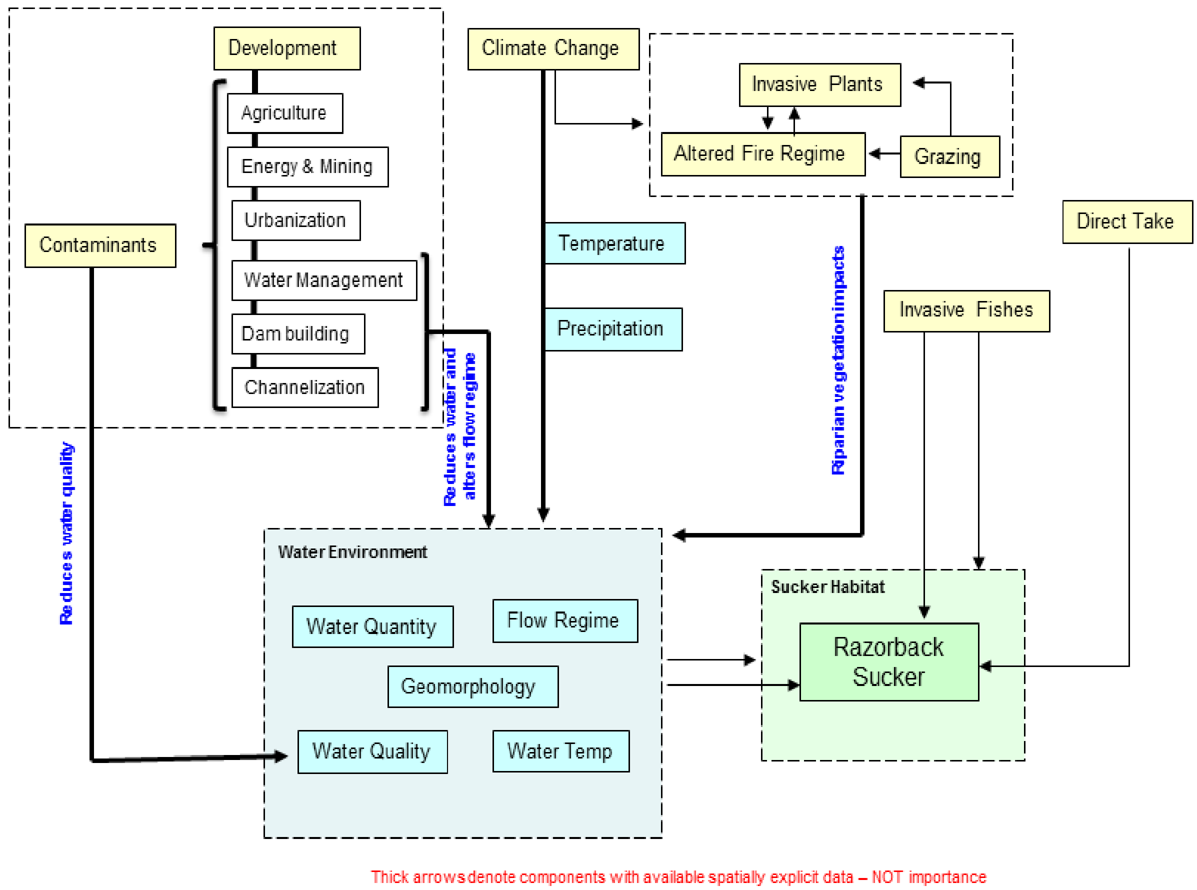
USFWS (U.S. Fish and Wildlife Service). 1990. Proposal to determine the razorback sucker (Xyrauchen texanus) to be an endangered species. Federal Register.

USFWS (U.S. Fish and Wildlife Service). 1991. The razorback sucker (*Xyrauchen texanus*) determined to be an endangered species. *Federal Register* 56(205):10842–10850.

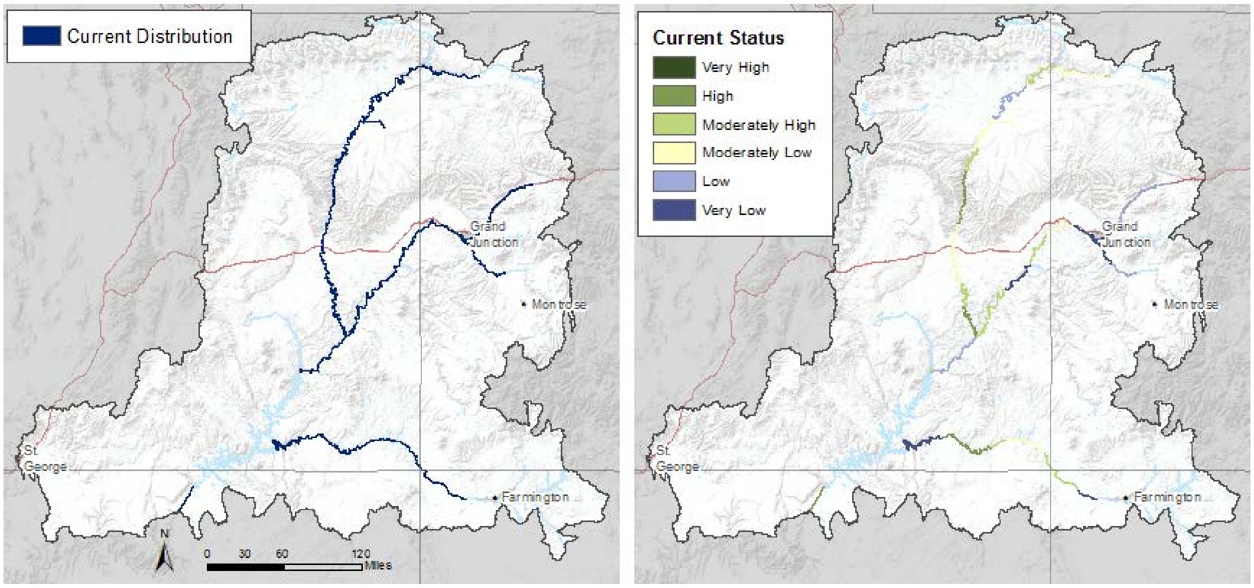
USFWS (U.S. Fish and Wildlife Service). 1998. Razorback sucker (*Xyrauchen texanus*) recovery plan. Denver, Colorado. 81 pp.

Valdez, R., R. Ryel, and S. Carothers. 2002. Razorback sucker (*Xyrauchen texanus*) recovery goals: Amendment and supplement to the razorback sucker recovery plan. U.S. Fish and Wildlife Service, Denver, Colorado. xvi + 78 pp + appendix.

Razorback Sucker Conceptual Model

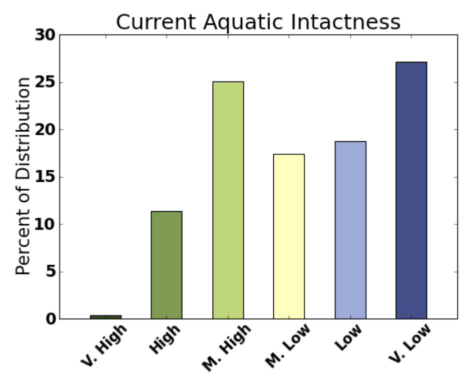


MQ D1. What are the current distribution and status of razorback sucker (and historic occupied habitat if available), seasonal and breeding habitat, and movement corridors (as applicable)?



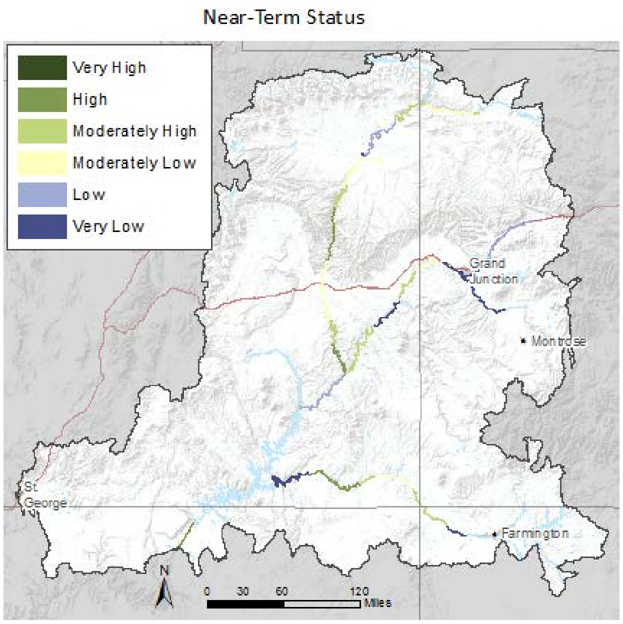
Data Sources:

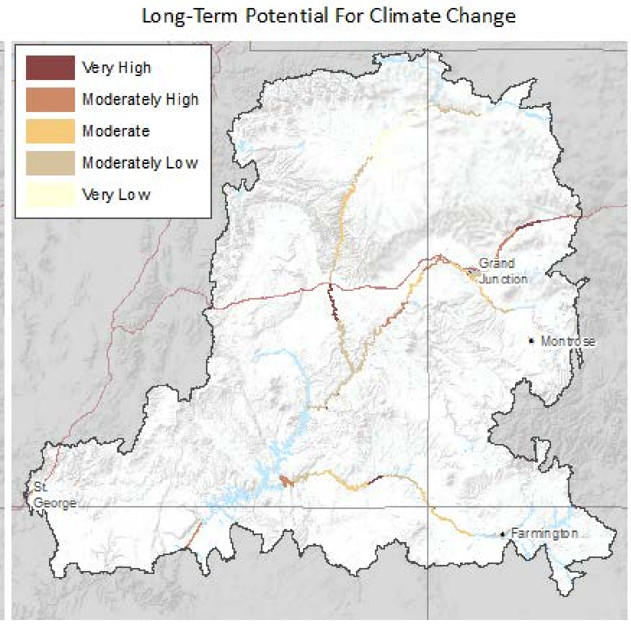
USFWS critical habitat

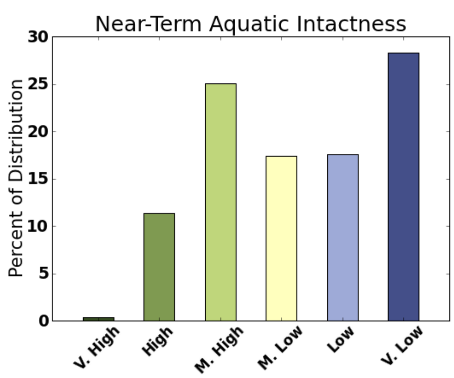


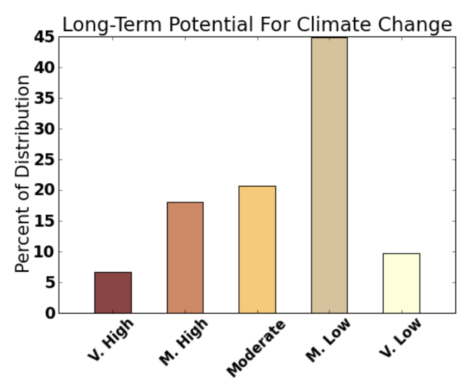
MQ D6. What sites and movement corridors are vulnerable to change agents in the near-term horizon, 2025 (development, fire, invasive species) and long-term change horizon, 2060 (climate change)?

Razorback Sucker Potential for Change

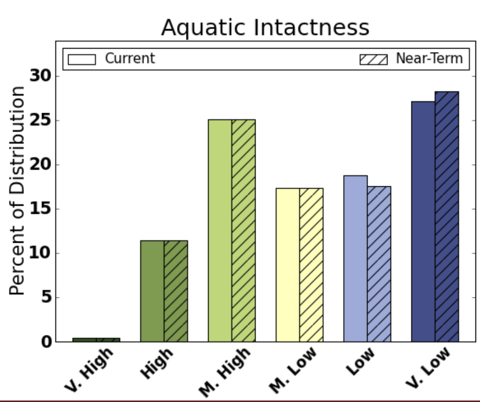








Current & Near-term Intactness

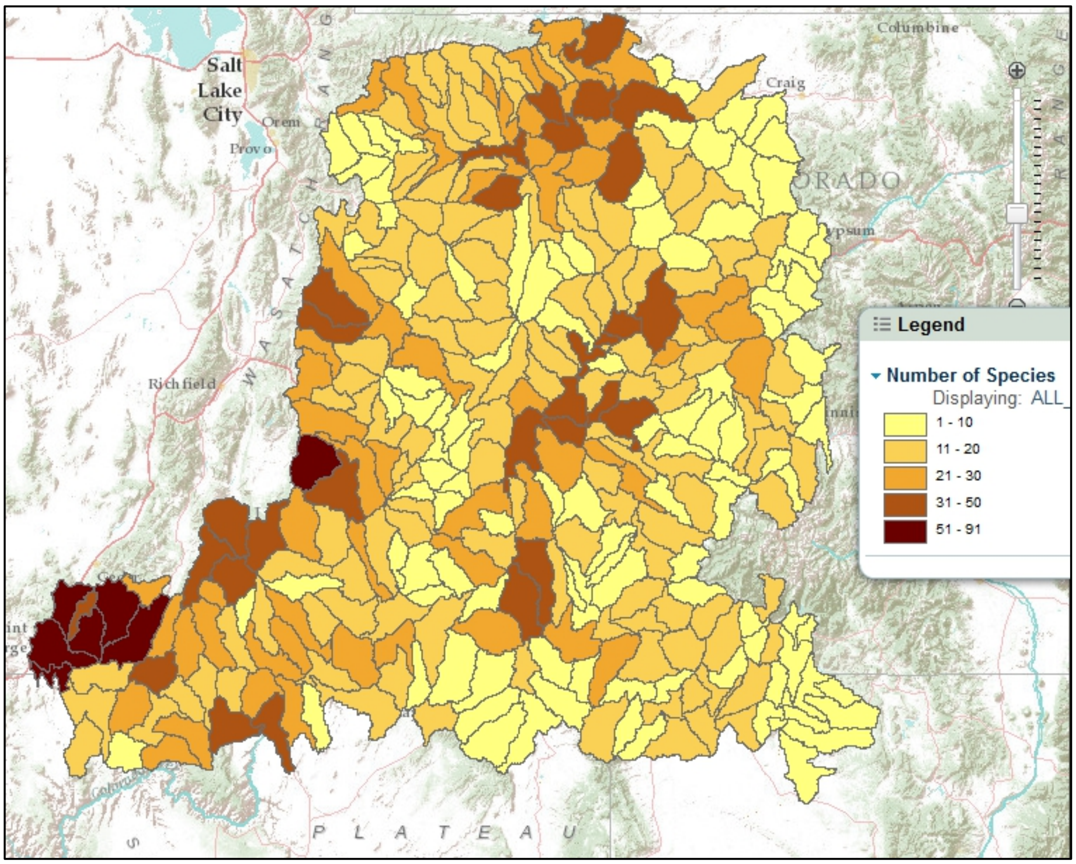


Current (solid color) and Near-term (cross-hatched) Intactness

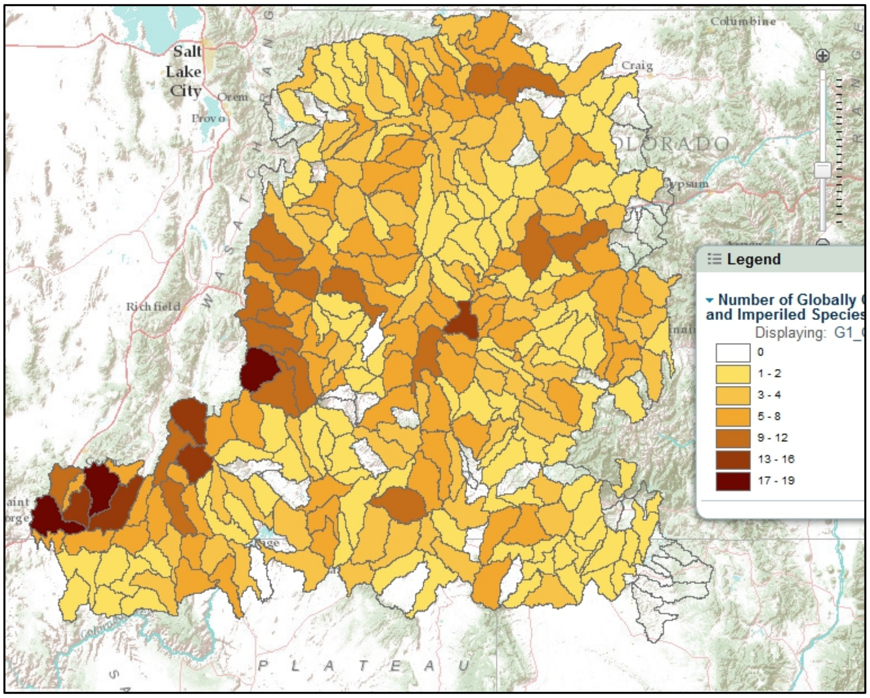
NatureServe Element Occurrence Data

BLM acquired species element occurrence data NatureServe Natural Heritage data enumerated by HUC for the REA. From the data, which was organized by 5th level HUC, four different map-based products were generated, including (1) number of all species, (2) number of globally critically imperiled and imperiled species (G1 and G2 species), (3) number of globally critically imperiled, imperiled, and vulnerable species (G1-G3 species), and (4) number of USFWS listed threatened and endangered species.

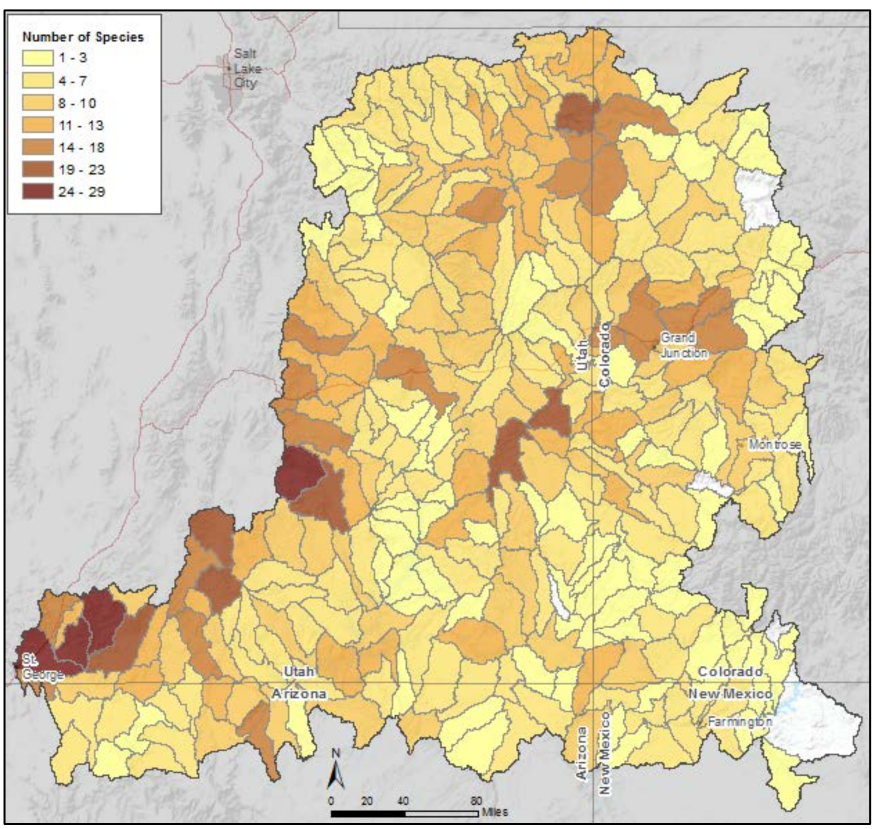
Number of All Species



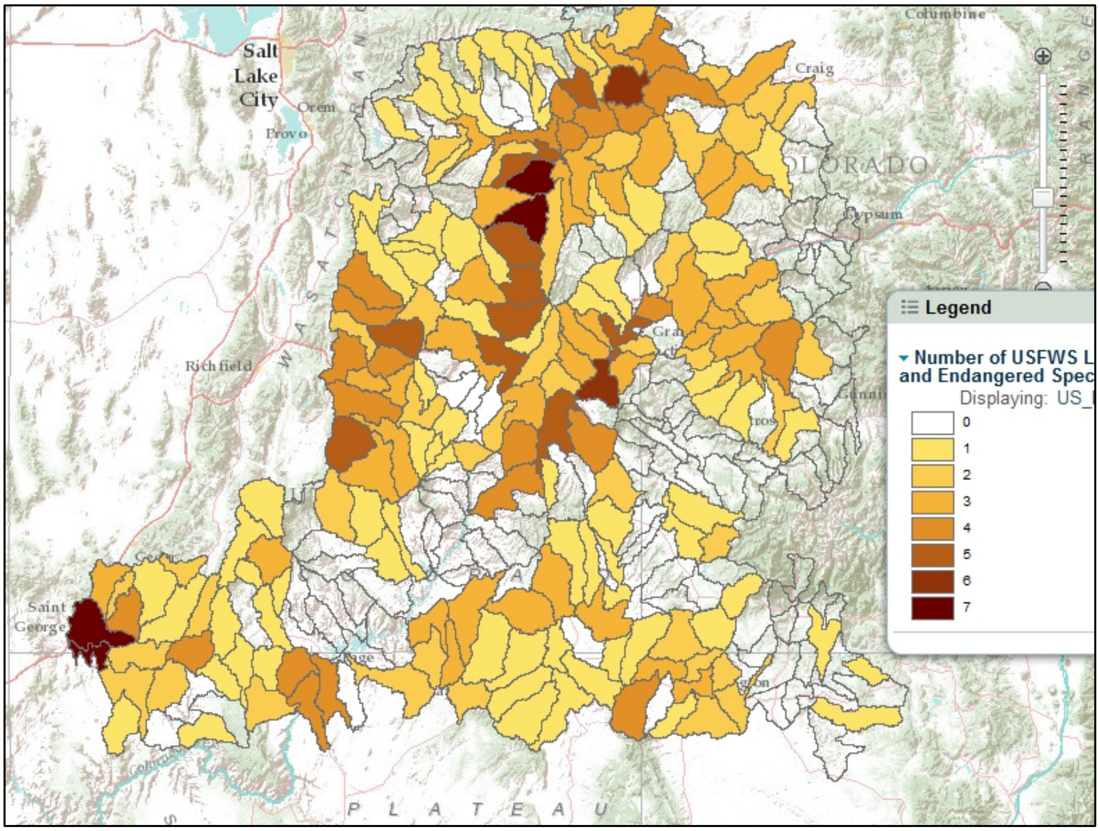
Number of G1 and G2 Species



Number of G1 – G3 Species



Number of USFWS Listed Species



Landscape Connectivity

Process

General landscape connectivity was assessed using a slightly modified version of a process developed for the State of California and presented below (Spencer et al. 2010). Procedure is outlined below with modifications highlighted in orange.

DATA BASIN SOURCES:

Easements

http://app.databasin.org/app/pages/datasetPage.jsp?id=99cae70ec0c94a16bc24fc704c2237fa

PAD-US 1.1

http://app.databasin.org/app/pages/datasetPage.jsp?id=305f2e83e5494609a2cfedaf3823e26c

BLM ground transportation

http://app.databasin.org/app/pages/datasetPage.jsp?id=7c3a671108b84051b74285795852e026

Fragmentation Classes

http://app.databasin.org/app/pages/datasetPage.jsp?id=c404f0f94740485d83c9b38abf8e3c48

LANDFIRE Existing veg type

http://app.databasin.org/app/pages/datasetPage.jsp?id=a124e55c66b24a339a8b7f6e4fa74ad8

REFERENCE:

Spencer, W.D., P. Beier, K. Penrod, K. Winters, C. Paulman, H. Rustigian-Romsos, J. Strittholt, M. Parisi, and A. Pettler. 2010. California Essential Habitat Connectivity Project: A Strategy for Conserving a Connected California. Prepared for California Department of Transportation, California Department of Fish and Game, and Federal Highways Administration.

This document and companion data files are available online at:
http://www.dot.ca.gov/hq/env/bio/program_efforts.htm
http://www.dfg.ca.gov/habcon
http://www.scwildlands.org

PROCESS:

A. Natural Landscape Blocks:

1. Reclassified Fragmentation Classes so that natural (1) had 1 but all others = 0 (new grid = natural)
2. Converted to polygon, calculated areas
3. Selected polygons with grid code = 1 and area >= 5000 acres and exported to new shapefile.

4. Converted output from 3 to grid. Expanded 17 cells (buffered the natural polygons by 510m). Converted back to shapefile.
5. Aggregated natural polygons ge 5000 acres within 1.2 km of each other: *spatial join with un-buffered polys ge 5000 acres(output from 3) as target and buffered polygons (output from 4) as join features to assign buffered ids to original polygons, dissolved on that id.*
6. Selected from BLM ground transportation and exported to new shapefile:
   CFF code: 103 highway, secondary, class 2
   MTFCC: S1100 Primary road; S1200 secondary road
   CFCC: A21 and A25 primary highways; A31 Secondary state and county highways
   This included some roads that clearly are not primary/secondary and omitted some sections of primary and secondary. Compared with Esri major roads (fcc interstate, primary us/state hwy, and secondary state/county) and added missing sections from BLM roads and deleted erroneous roads. Added all or sections of: CR 201, CR 25, SR 29, SR 122, SR 123, SR 124, SR264, SR 35, SR 44, SR 87, SR 96, SR 121, SR 12, SR 276, SR 163, SR 575, SR 330, SR 62, SR 90, SR 45, US 191.
7. Buffered output from 6 50m (**blm_prim_sec2_buf50.shp**)
8. Identity Output from 7 with output from 5, selected where outside the road buffer and exported. Exploded multipart into single part features. Assigned new id's to blocks broken up by primary/secondary road buffers. Dissolved on new ids. Calculated areas. Selected area ge 10000 acres = final blocks. (**final_blocks_ge_10k_acres.shp**)
   102 blocks ge 10000 acres
9. Used Feature to Point tool to create file of block centroids for connecting block pairs with least cost corridor modeling ().
10. Blocks contained many small islands of 'non-natural' habitat. For better visual display, eliminated these islands (dissolved into surrounding block; **blocks.shp**).

    Modifications: Selected natural vegetation from fragmentation classes. Converted to polygon and selected polygons greater than 5,000 acres (blocks1). Converted back to raster, expanded by 510 meters (buffer tool did not work) and converted back to polygon. Erased polygons using 50m buffer of road to create block neighborhoods. Used spatial join back to blocks1 to group blocks by neighborhood. Then selected blocks greater than 10,000 acres.

B. **<u>Sticks:</u>** Pairs of blocks to be connected are first represented as line segments or 'sticks' – placeholders showing which blocks need to be connected according to the following rules:

1. Each Natural Landscape Block was connected to its nearest neighbor (where nearness was defined edge to edge).
2. Each Natural Landscape Block was also connected to its second nearest neighbor if the second neighbor was < 15 km away (edge to edge)

Least cost corridor modeling is not necessary or appropriate for Road Fragmentation Areas, (where Natural Landscape Blocks are separated only by a road). Road fragmentation sticks were used to identify these areas: where the facing edges of two Natural Landscape Blocks were separated only by a road that may represent a barrier to wildlife movement. Rule = separated by road but within 1km = no corridor modeled (road stick). (For Roads - used output from Blocks step 6 above).

Created 89 corridor sticks and 52 road fragmentation sticks.

3. A group of two or more Natural Landscape Blocks connected by sticks is called a *constellation*. Once

all constellations were created by the above rules, each constellation was connected to its nearest neighboring constellation, if it was not already connected, starting with the smallest constellation. This added 1 corridor stick.

4. Collapsing corridor sticks: Where multiple sticks connected three or more Natural Landscape Blocks in a fairly linear configuration ("stepping stones"), they were consolidated by user judgment as one stick spanning the entire group between the centroids of the two farthest blocks, unless a least-cost corridor model between the two farthest blocks would be unlikely to connect all blocks in the group (in which case sticks were still drawn independently between the nearest-neighbor pairs as described above).

Resulted in 62 corridors (**sticks_corridors_collapsed.shp**) and 52 road fragmentation sticks (**sticks_rdfrag.shp**).

Modifications: Connected neighboring blocks using road sticks where they were only separated by a 500m buffer of major roads, or corridor stick if they were generally less than 15km apart edge-to-edge. Distances were obtained from the freehand measuring tool in ArcMap. In certain cases where least cost corridor modeling is still desirable, we connected blocks that were somewhat further part. For example, a block isolated from all neighbors by more than 15km was connected up to its nearest one or more neighbors (if multiple neighbors were roughly equidistant).

C. Cost surface:

1. Landcover Cost:
   a. Assigned costs to LANDFIRE Existing veg type following CALTRANS (see **landcover_cost.dbf**) and created grid lc_cost.
   b. Transportation: Primary and secondary roads (from blocks process above) were buffered by 25 m before conversion to a 30-m grid prim_sec_rd_c. Converted entire BLM ground transport to grid rds_cost. The grids of the 2 road types were combined into one, giving priority to primary/secondary roads (cost = 20) they overlapped other roads (cost = 18) using conditional: Con prim_sec_rd_c 20 rds_cost all_rds ""VALUE" = 20"
   c. The resulting transportation grid (rds_cost) was merged into the landcover grid, with higher cost overriding lower cost (combine lc_cost and rds_cost to create comb_rds_lc). Added f-cost to comb_rds_lc.vat. Selected rds_cost > lc_cost and calc f-cost = rds_cost. Switch selection and calc f-cost = lc_cost. Reclassify com_rds_lc.vat on f-cost to create lc_rd_cost.

2. Protection Status Cost:
   a. Added field 'new_gap' to PAD-US1.1. Assigned new_code per table below – with following exceptions gap_status = 'unknown' = new_code of 4, category = easements = new_gap of 2. Converted to grid on new_gap.

Resistance	GAP Protection Status
0	GAP1
1	GAP2
2	Conservation Easements
3	GAP3
4	GAP4

b. Converted Easements to grid with code =10 (added attribute 'code' to shapefile, calculated = 10, converted to grid on 'code'.
c. Added to output from a and reclassified: where gap status = 3 or 4 and easements are present (summed grid = 13 or 14) in easements database – calculated gapcost = 2; if overlap between gap status = 1 or 2 or PAD easements and easements, left gap cost as is (0, 1, 2).

3. Total Cost: Raster calculator: 1+ outputs from 1c and 2c . The final resistance surface was a 30-m grid with pixel scores ranging from 1 to 25 (Resistance = Landcover Score + Protection Score +1; **total_cost** (grid)).

D. Least Cost Corridor Modeling:

Least-cost corridor analysis was conducted between the centroids of each pair of Natural Landscape Blocks to be connected.

The analysis extent was defined by creating a 5-km buffer around the feature envelope of both Natural Landscape Blocks in a pair (select the pair of blocks for a corridor, 'feature envelope to polygon', calculate new id as 1, dissolve on new id, 'feature envelope to polygon' on dissolved, buffer envelope 5 km, convert to raster).

The cost-weighted distance was calculated from each of the two centroids for each pixel in the analysis extent. The two centroid-specific outputs were then summed to define the least-cost surface (see **corridor.aml**).

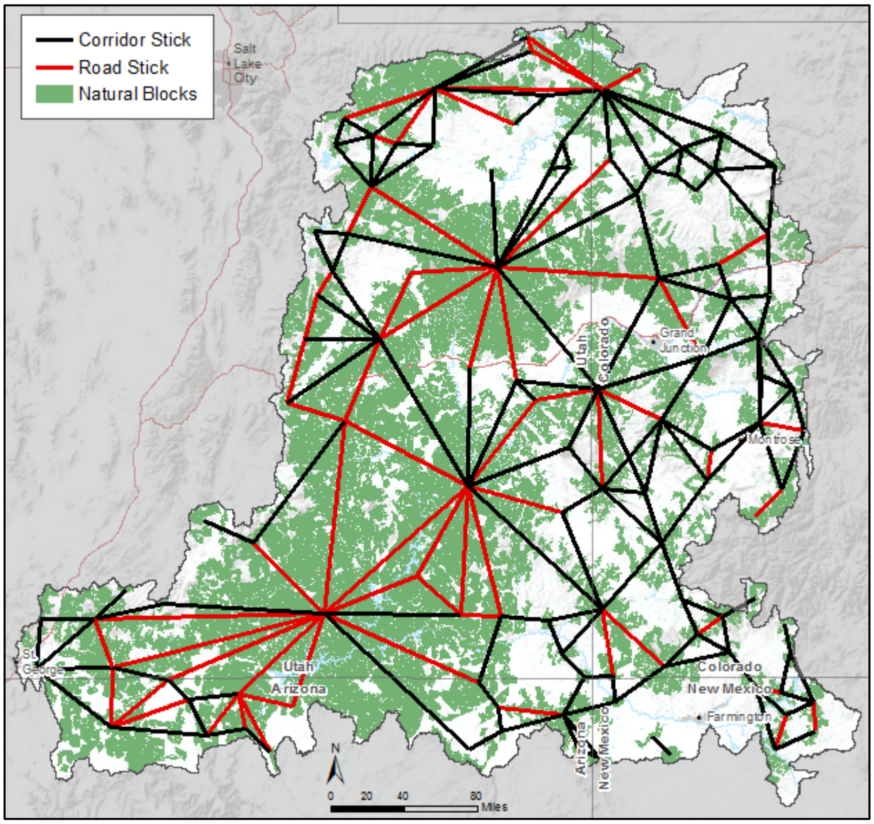
The continuous surface output was then sliced into equal-interval percentages to define the least-cost corridor. The top 5% least-cost corridor (i.e., the lowest-cost 5% of pixel values in the analysis window) was used to define the Essential Connectivity Areas (see **corridor2.aml**; **corridors.shp).**

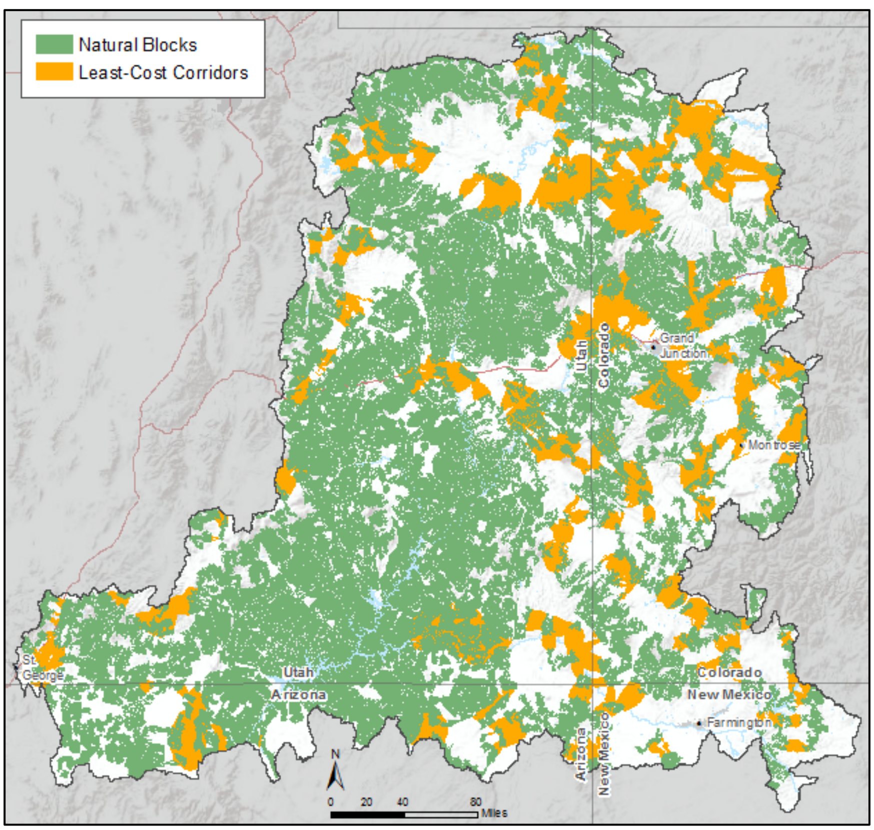
Modifications: For each pair of blocks connected by a corridor stick (road sticks were excluded from this analysis), we selected a 5 kilometer neighborhood around the extent of the pair for least-cost modeling. We clipped the cost surface to this extent, and then used the standard ArcGIS tool "Cost Distance" for each block in the pair. The results from each of these cost paths were then input to the "Corridor" ArcGIS tool. The corridor was then sliced into 20 equal width classes, and the lowest 5% of the cost corridor was extracted. This was then mosaicked across all pairs of blocks and converted to polygons.

The corridors were modeled between edges of blocks in the pair. Due to the way that the cost distance and corridor tools operate, least cost corridors did overlap with the natural landscape blocks. For display, it is recommended to overlay the blocks on top of this layer.

Display note:
Because each analysis was run from centroid to centroid, instead of from edge to edge of the Natural Landscape Block pair, a portion of the least-cost corridor output occurred within each Natural Landscape Block. To best display the Essential Connectivity Areas on a map, arrange in this order, top to bottom: sticks_corridors; sticks_rdfrag; blocks; corridors.

Results


Corridor Stick
Road Stick
Natural Blocks
Salt Lake City
Grand Junction
Utah
Colorado
Montrose
St. George
Utah
Arizona
Colorado
New Mexico
Farmington
Arizona
New Mexico
N
0 20 40 80 Miles


Natural Blocks
Least-Cost Corridors
Grand Junction
Utah
Colorado
Montrose
St. George
Utah
Arizona
Colorado
New Mexico
Farmington
Arizona
New Mexico
N
0 20 40 80 Miles

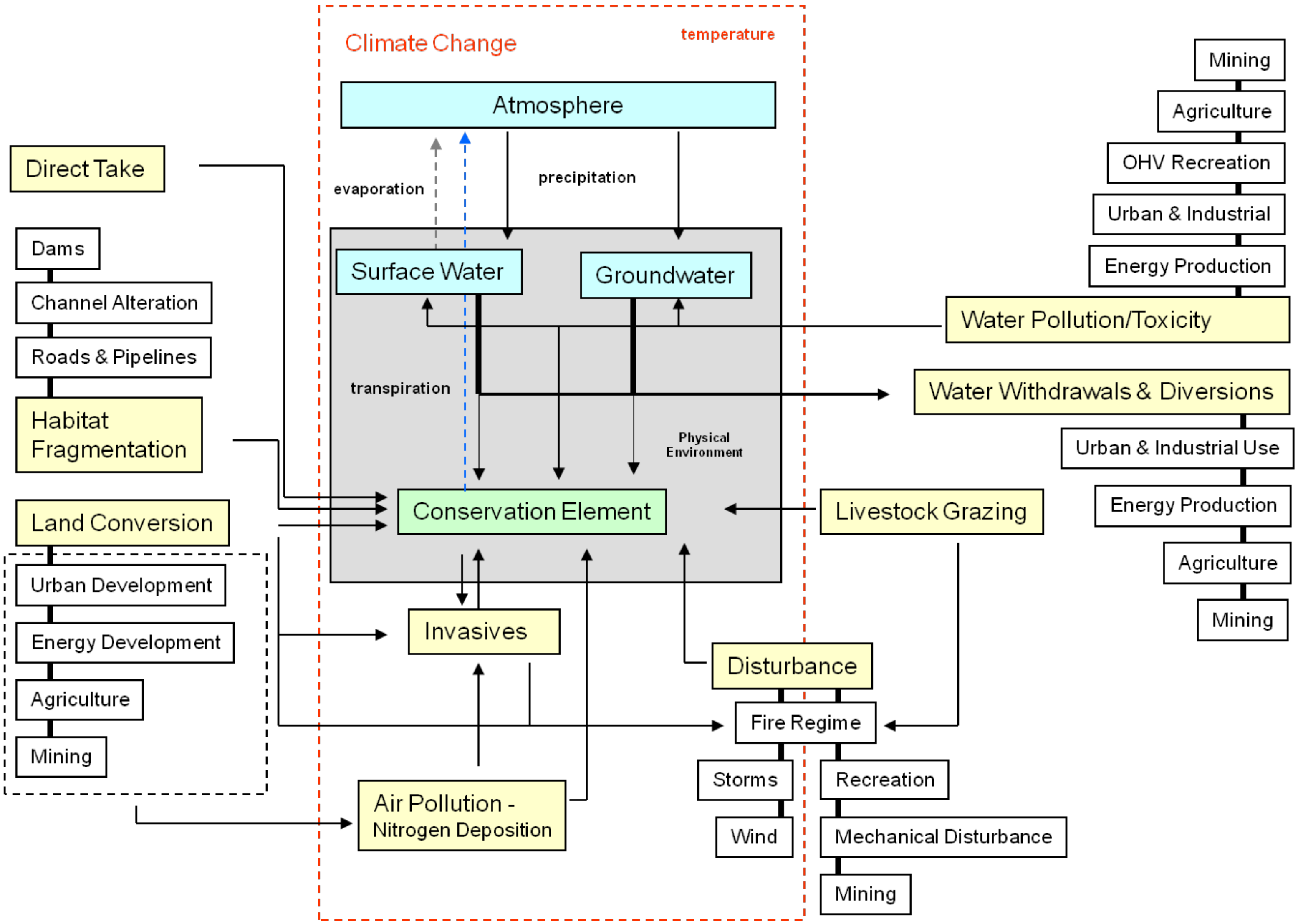
Appendix D – Logic Models

Organization of Appendix D

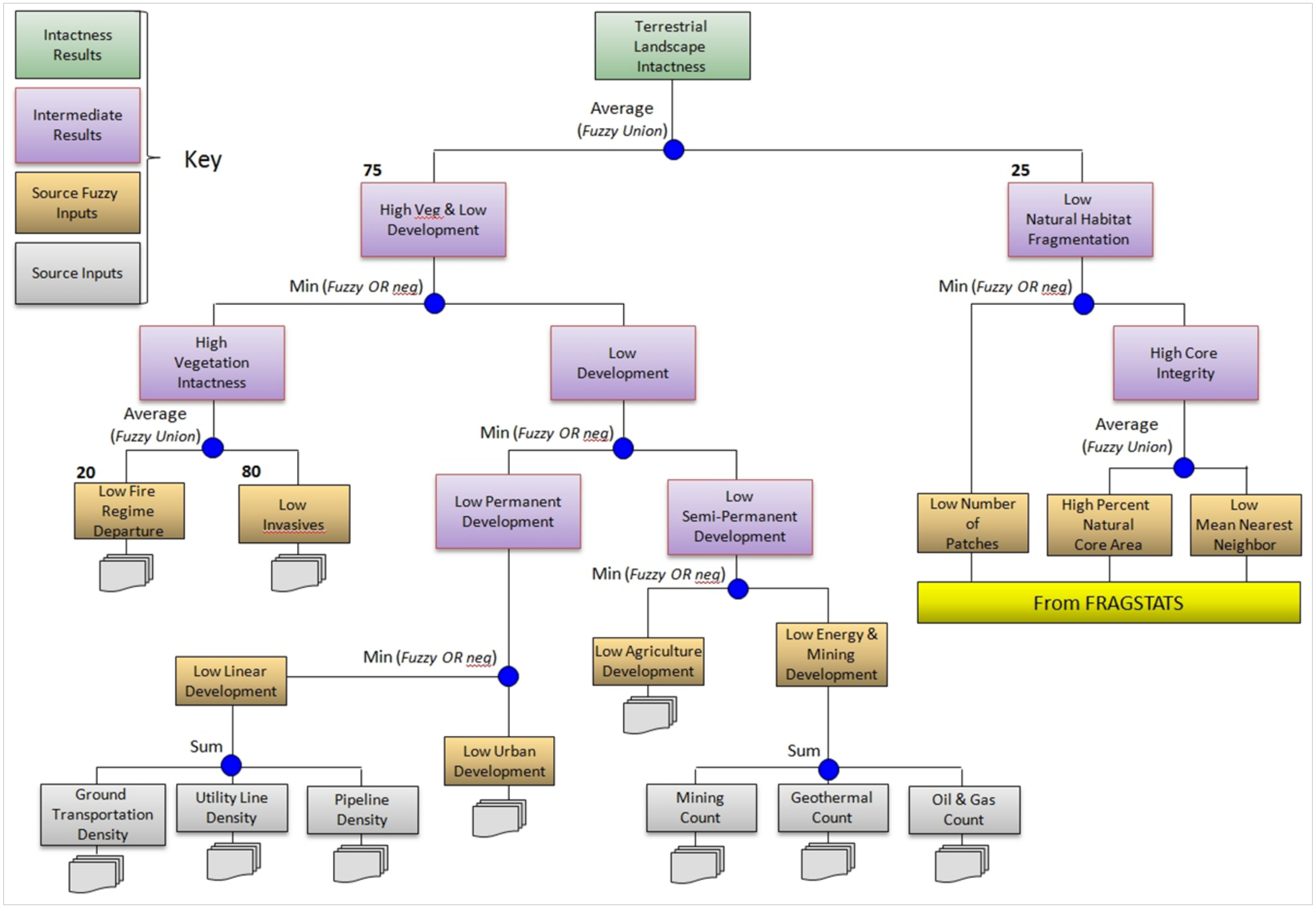
For the Colorado Plateau REA, six issues questions relied on development of more complicated fuzzy logic modeling, including current terrestrial landscape intactness, current aquatic intactness, near-term future (2025) terrestrial landscape intactness, near-term future (2025) aquatic intactness, current development, near-term future (2025) development, maximum (long term) potential energy development, and potential climate change impacts (2060) on conservation elements. All of these models were used to address multiple management questions and they cover different aspects of change agents operating on the landscape. The relationship of the factors modeled above can be viewed as part of a larger, generalized conceptual diagram regarding change agents (conceptual model next page).

For each of the eight models, the logic model is presented first, followed by a table of data sources, an assessment of data quality and overall confidence in the model, and threshold tables. The mapped results are presented in a 4 km X 4 km grid reporting unit and/or 5th level Hydrologic Unit (HUC5), as appropriate for each issue.

Generalized Change Agent Conceptual Diagram



Current Terrestrial Landscape Intactness Logic Model



Data Sources for Current Terrestrial Landscape Intactness

Model Input Label	Data Source	Relative Quality
Ground Transportation Density	BLM Ground Transportation Linear Features	Fair-Good – surface type would be useful addition
Utility Line Density	Powerlines in the Western United States (USGS)	Good
Pipeline Density	Pipelines (proprietary, provided by BLM)	Good
Low Urban Development	Impervious Surfaces (NLCD 2006)	Very Good
Low Agriculture Development	LANDFIRE - Existing Vegetation Type (version 1.1)	Very Good
Mining Count	Arizona Mines (Arizona Electronic Atlas)	Good
	Uranium Mines in Arizona (BLM, digitized by CBI)	Good
	Colorado Mines (Colorado Division of Reclamation, Mining and Safety)	Good
	Active Mines and Mineral Processing Plants (USGS)	Good
	New Mexico Mines (New Mexico GIS Resource Program)	Good
	Utah Mines (Automated Geographic Reference Center)	Good
Geothermal Count	Geothermal Wells in Utah (Utah Geological Survey)	Good
	Geothermal Wells in Arizona, Colorado, and New Mexico (Idaho National Engineering and Environmental Laboratory; digitized by CBI)	Good
Oil & Gas Count	Oil & Gas Wells (proprietary, provided by BLM)	Good
Low Fire Regime Departure	Current Fire Regime and Vegetation Departure (see Appendix A MQE3)	Fair
Low Invasives	Current Predicted Distribution of Major Invasive Vegetation Species (see Appendix A MQF1)	Fair
Low Natural Habitat Fragmentation	Natural Vegetation Fragmentation (4KM) (CBI)	Fair-Good

Overall Model Certainty: **High** – biggest weaknesses are lack of detailed invasives data, and additional recreation (OHV) and grazing condition data.

Model output reported using both 4km x 4km grid cells and 5th level HUCs.

Current Terrestrial Landscape Intactness (see threshold explanation, Chapter 3) Thresholds – 4km x 4km grid cells

Item	Data Type	Data Range	True Threshold	False Threshold
Fire Regime	Percent Area	13–98	13[1]	98
Invasive Grasses & Tamarisk	Percent Area	0–88	0[3]	33
Linear Development	Linear Density	0–18	0[1]	2.5
Urban Percent	Percent Area	0–99	0[3]	15
Agriculture Percent	Percent Area	0–90	0[3]	20
Energy & Mining Development	Point Density	0–37	0[2]	1.25
Number of Patches	Number	1–1,455	1[4]	700
Mean Nearest Neighbor	Linear Distance	60–272	60[1]	180
Percent Natural Core Area	Percent Area	0.56–95	100[3]	20

1: Used full range or full range with a few outliers ignored; 2: Skewed data range = 1 Standard Deviation from the mean; 3: Skewed data range = 2 Standard Deviations from the mean; 4: Skewed data range = 2.5 Standard Deviations from the mean

Thresholds – 5th level HUC

Item	Data Type	Data Range	True Threshold	False Threshold
Fire Regime	Percent Area	28–65	13[1]	98
Invasive Grasses & Tamarisk	Percent Area	0–36	0[3]	33
Linear Development	Linear Density	0–6	0[1]	2.5
Urban Percent	Percent Area	0–23	0[3]	15
Agriculture Percent	Percent Area	0–34	0[3]	20
Energy & Mining Development	Point Density	0–13	0[2]	1.25
Number of Patches	Number	45–3,901	1[4]	700
Mean Nearest Neighbor	Linear Distance	60–115	60[1]	180
Percent Natural Core Area	Percent Area	14–86	100[3]	20

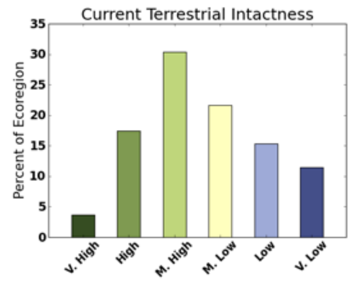
1: Used full range or full range with a few outliers ignored; 2: Skewed data range = 1 Standard Deviation from the mean; 3: Skewed data range = 2 Standard Deviations from the mean; 4: Skewed data range = 2.5 Standard Deviations from the mean

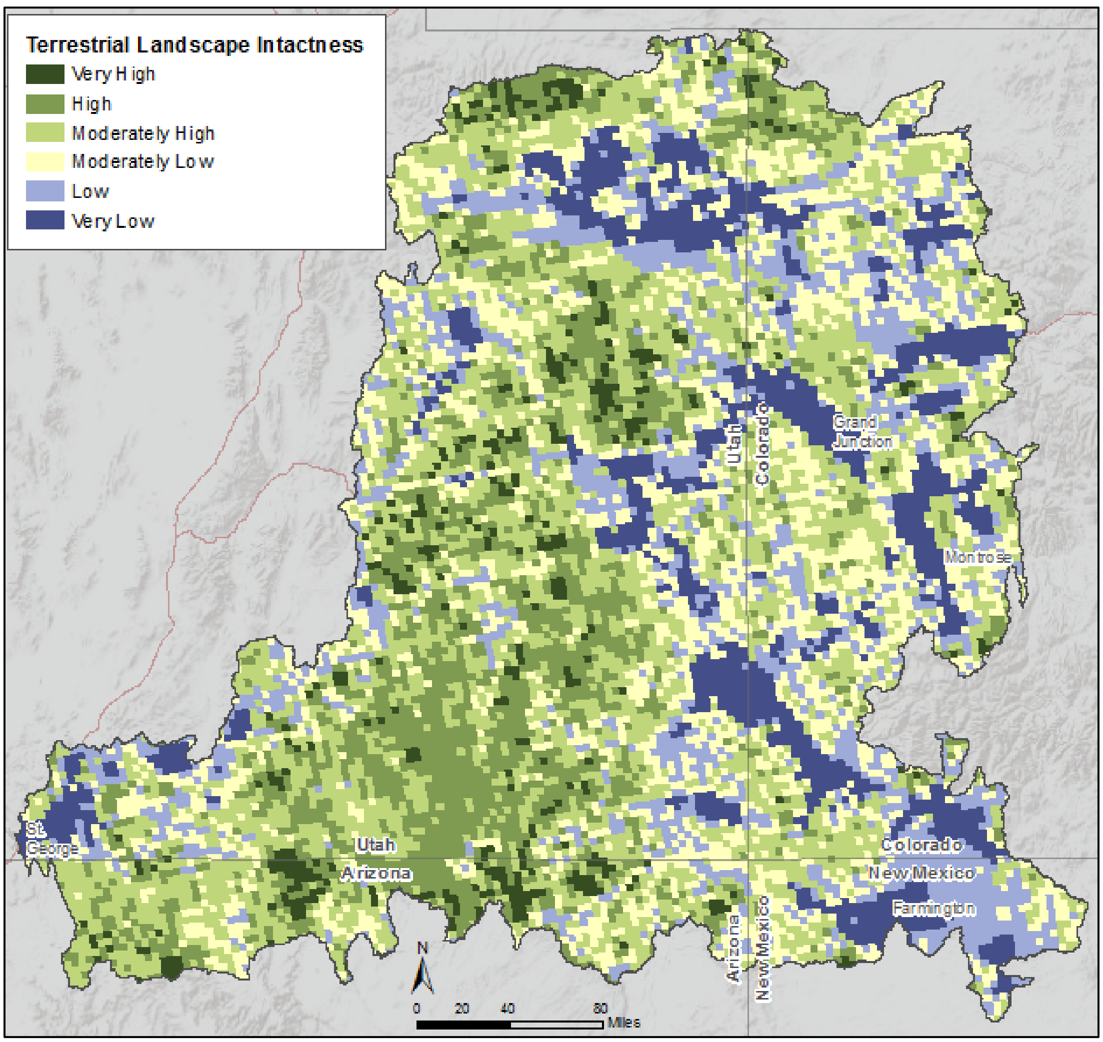
Intactness Value Ranges and Legend Descriptions

Intactness Value	Legend
-1.000 to -0.750	Very Low
-0.750 to -0.500	Low
-0.500 to 0.000	Moderately Low
0.000 to 0.500	Moderately High
0.500 to 0.750	High
0.750 to 1.000	Very High

Results for Current Terrestrial Landscape Intactness

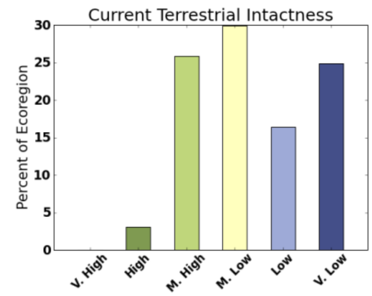
4km x 4km grid cells

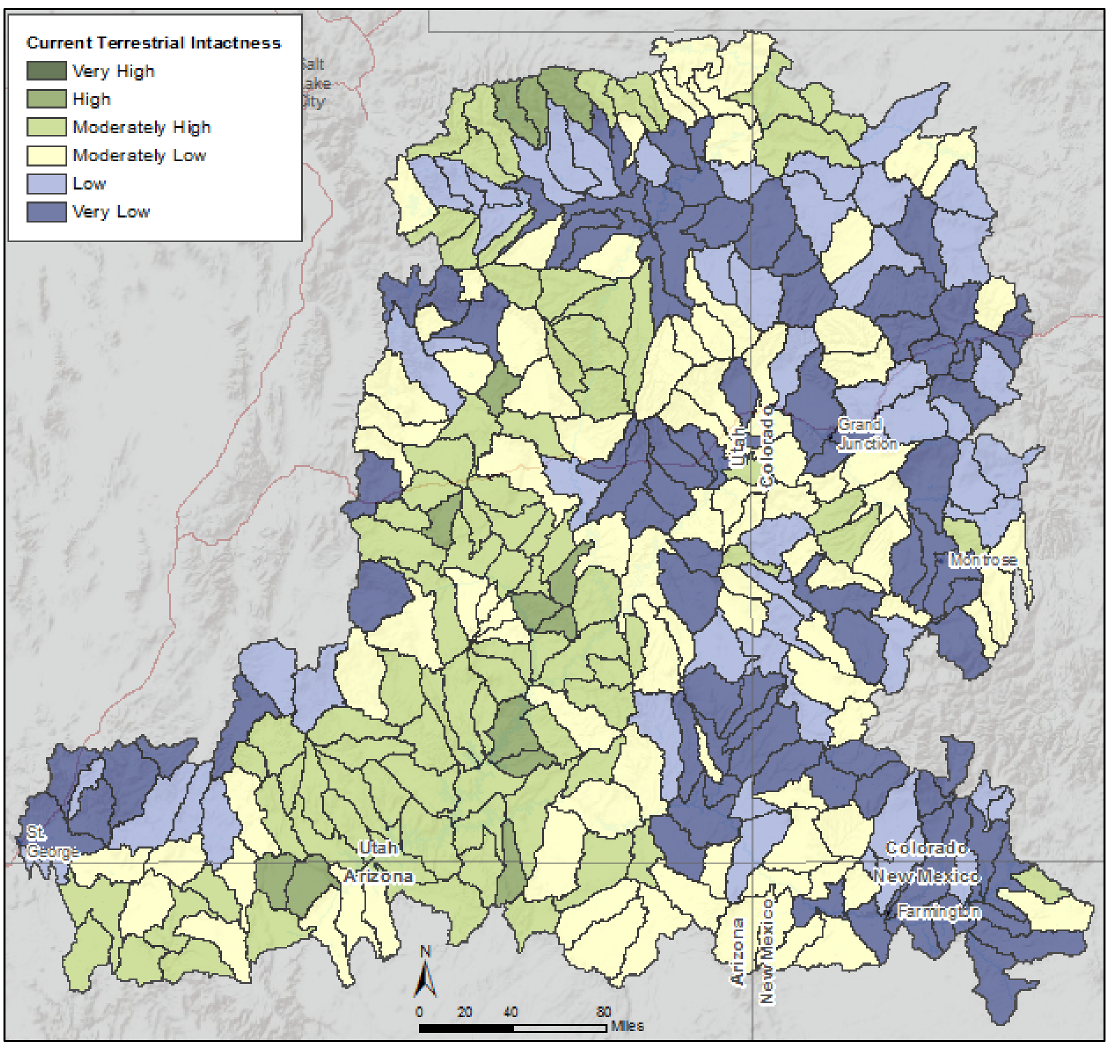




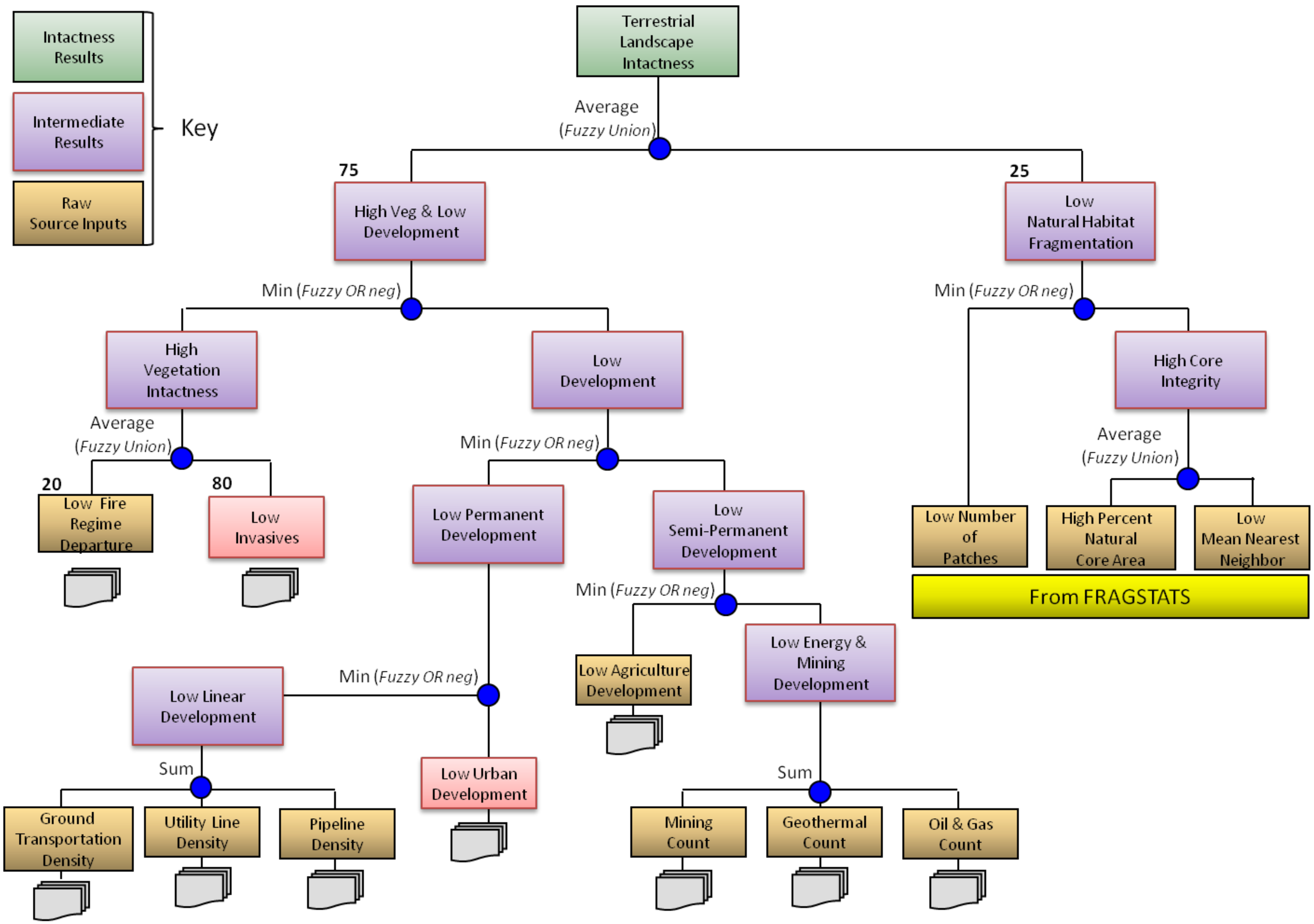
Results for Current Terrestrial Landscape Intactness

5th level HUC





Near-Term Future (2025) Terrestrial Landscape Intactness Logic Model



Data Sources for Near Term Future Terrestrial Landscape Intactness

Model Input Label	Data Source	Relative Quality
Ground Transportation Density	BLM Ground Transportation Linear Features	Fair-Good – surface type would be useful addition
Utility Line Density	Powerlines in the Western United States (USGS)	Good
Pipeline Density	Pipelines (proprietary, provided by BLM)	Good
Low Urban Development	Impervious Surfaces (NLCD 2006)	Very Good
	Development Risk, Contiguous US (David Theobald 2010)	Fair-Good
Low Agriculture Development	LANDFIRE - Existing Vegetation Type (version 1.1)	Very Good
Mining Count	Arizona Mines (Arizona Electronic Atlas)	Good
	Uranium Mines in Arizona (BLM, digitized by CBI)	Good
	Colorado Mines (Colorado Division of Reclamation, Mining and Safety)	Good
	Active Mines and Mineral Processing Plants (USGS)	Good
	New Mexico Mines (New Mexico GIS Resource Program)	Good
	Utah Mines (Automated Geographic Reference Center)	Good
Geothermal Count	Geothermal Wells in Utah (Utah Geological Survey)	Good
	Geothermal Wells in Arizona, Colorado, and New Mexico (Idaho National	Good
Oil & Gas Count	Oil & Gas Wells (proprietary, provided by BLM)	Good
Low Fire Regime Departure	Current Fire Regime and Vegetation Departure (see Appendix A MQE3)	Fair
Low Invasives	Near-term Predicted Distribution of Major Invasive Vegetation Species (see	Fair
Low Natural Habitat Fragmentation	Natural Vegetation Fragmentation (4KM) (CBI)	Fair-Good

Overall Model Certainty: **Moderately Low –** In addition to data gaps in Current Intactness model, a number of key datasets could not be projected (e.g. ground transportation density), resulting in a model that significantly under-estimates the near-term impacts.

Model output reported using both 4mk x 4km grid cells and 5th level HUC.
Boxes and accompanying rows shaded in pink indicate new data for near-term intactness.

Near Term Terrestrial Landscape Intactness (see threshold explanation, Chapter 3) Thresholds – 4km x 4km grid cells

Item	Data Type	Data Range	True Threshold	False Threshold
Fire Regime	Percent Area	13–98	13[1]	98
Invasive Grasses & Tamarisk	Percent Area	0–88	0[3]	33
Linear Development	Linear Density	0–18	0[1]	2.5
Urban Percent	Percent Area	0–99	0[3]	15
Agriculture Percent	Percent Area	0–90	0[3]	20
Energy & Mining Development	Number	0–37	0[2]	1.25
Number of Patches	Number	1–1,455	1[4]	700
Mean Nearest Neighbor	Linear Distance	60–272	60[1]	180
Percent Natural Core Area	Percent Area	.56–95	100[3]	20

1: Used full range or full range with a few outliers ignored; 2: Skewed data range = 1 Standard Deviation from the mean; 3: Skewed data range = 2 Standard Deviations from the mean; 4: Skewed data range = 2.5 Standard Deviations from the mean

Thresholds – 5th level HUC

Item	Data Type	Data Range	True Threshold	False Threshold
Fire Regime	Percent Area	28–65	13[1]	98
Invasive Grasses & Tamarisk	Percent Area	0–36	0[3]	33
Linear Development	Linear Density	0–6	0[1]	2.5
Urban Percent	Percent Area	0–23	0[3]	15
Agriculture Percent	Percent Area	0–34	0[3]	20
Energy & Mining Development	Point Density	0–13	0[2]	1.25
Number of Patches	Number	45–3,901	1[4]	700
Mean Nearest Neighbor	Linear Distance	60–115	60[1]	180
Percent Natural Core Area	Percent Area	14–86	100[3]	20

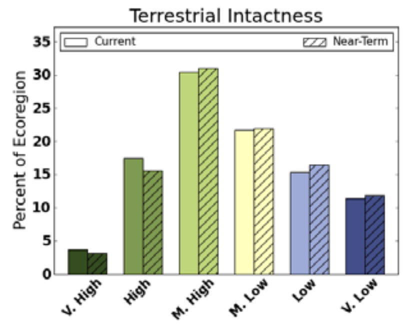
1: Used full range or full range with a few outliers ignored; 2: Skewed data range = 1 Standard Deviation from the mean; 3: Skewed data range = 2 Standard Deviations from the mean; 4: Skewed data range = 2.5 Standard Deviations from the mean

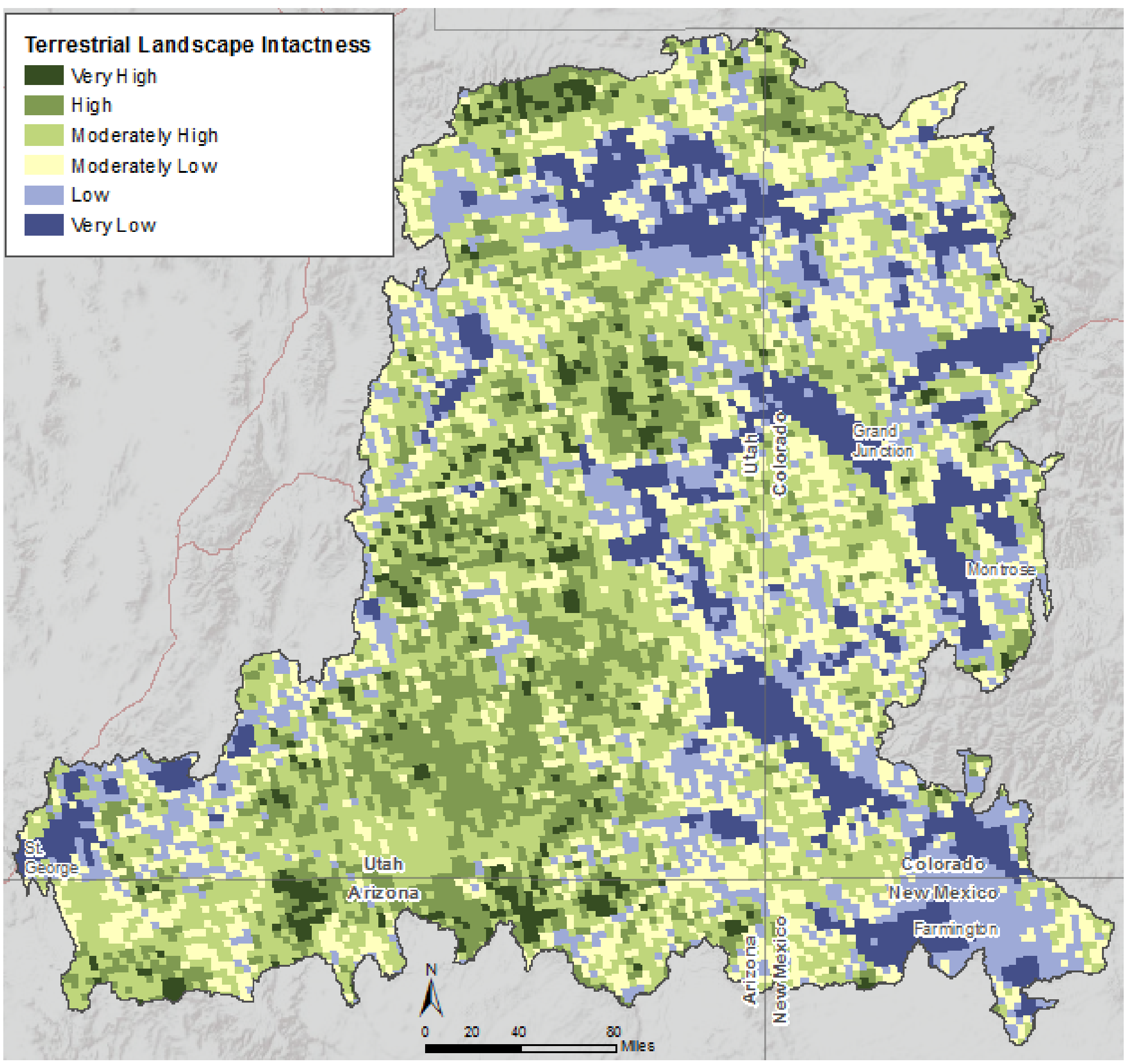
Intactness Value Ranges and Legend Descriptions

Intactness Value	Legend
-1.000 to -0.750	Very Low
-0.750 to -0.500	Low
-0.500 to 0.000	Moderately Low
0.000 to 0.500	Moderately High
0.500 to 0.750	High
0.750 to 1.000	Very High

Results for Near Term Future Terrestrial Landscape Intactness

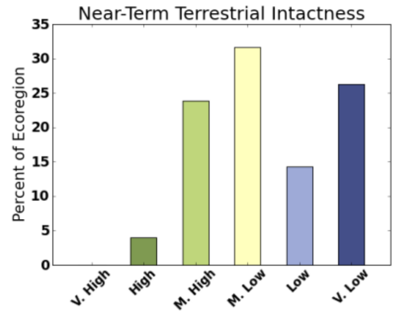
4km x 4km grid cells

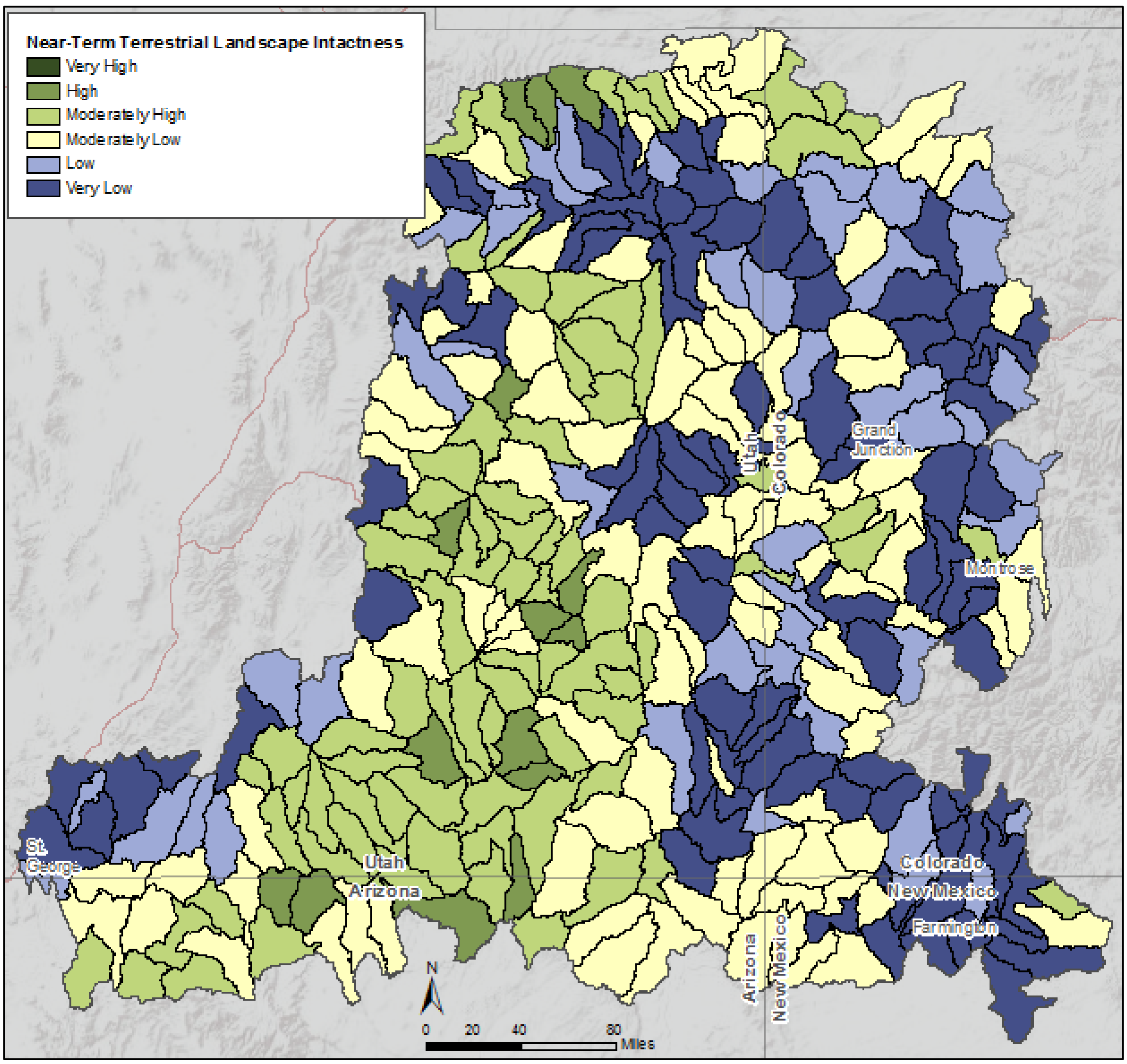




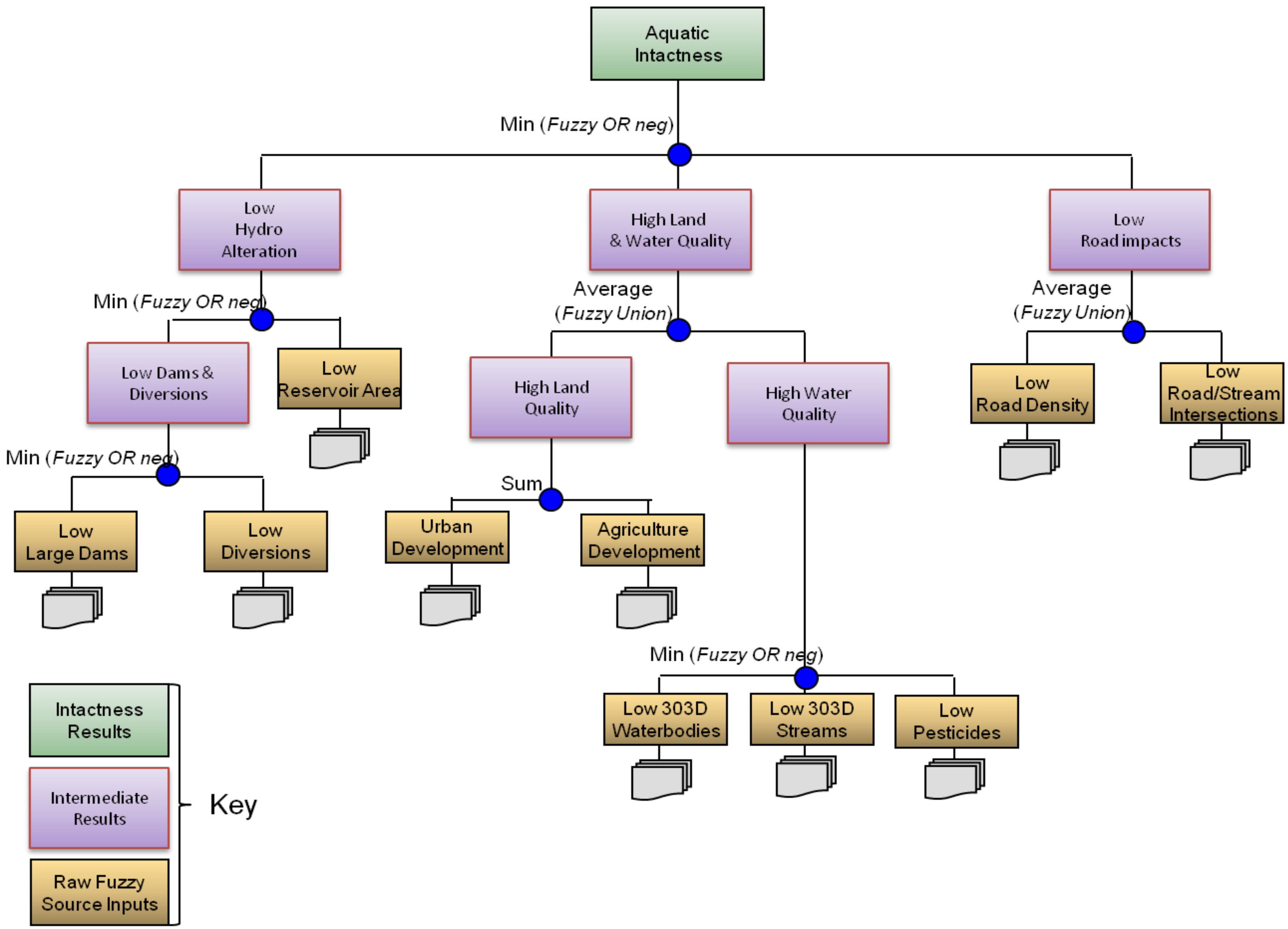
Results for Near Term Future Terrestrial Landscape Intactness

5th level HUC





Current Aquatic Intactness Logic Model



Data Sources for Current Aquatic Intactness

Model Input Label	Data Source	Relative Quality
Low Large Dams	National Inventory of Dams (US Army Corps of Engineers)	Very Good
Low Diversions	Utah Surface Water Diversions (Utah Department of Natural Resources,	Very Good
	Surface Water Rights in Arizona (Arizona Department of Water	Very Good
	Colorado Surface Water Diversions (Colorado Division of Water	Very Good
	New Mexico Surface Water Diversions (New Mexico Water	Very Good
Low Reservoir Area	National Hydrography Dataset (waterbodies) (USGS)	Very Good
Urban Development	Impervious Surfaces (NLCD 2006)	Very Good
Agriculture Development	LANDFIRE - Existing Vegetation Type (version 1.1)	Very Good
Low 303D Waterbodies	EPA Office of Water (OW): 303(d) Listed Impaired Waters (waterbodies	Very Good
Low 303D Streams	EPA Office of Water (OW): 303(d) Listed Impaired Waters (waterbodies	Very Good
Low Pesticides	Agricultural Pesticide Use in the Conterminous United States (USGS)	Very Good
Low Road Density	BLM Ground Transportation Linear Features	Fair-Good – surface type would be useful addition
Low Road/Stream Intersections	National Hydrography Dataset (flowlines) (USGS)	Fair-Good – surface type would be useful addition
	BLM Ground Transportation Linear Features	Fair-Good – surface type would be useful addition

Overall Model Certainty: Fairly High – BUT a number of potentially valuable datasets were not available that would have improved this model (e.g. grazing density, exotic species, and streamside habitat quality).

Model output reported at 5th level HUC only.

Current Aquatic Intactness (see threshold explanation, Chapter 3)

Thresholds

Item	Data Type	Data Range	True Threshold	False Threshold
Low Large Dams	Point Density	0–0.089	0[1]	0.028
Low Diversions	Point Density	0–8.35	0[1]	1.7
Low Reservoir Area	Percent Area	0–20	0[2]	2
Land Use	Percent Area	0–39	0[3]	20
Low 303D Waterbodies	Percent Area	0–7.62	0[4]	1
Low 303D Streams	Linear Density	0–1.09	0[2]	0.2
Low Pesticides	Weighted Sum	0–0.038	0[5]	0.02
Low Road Density	Linear Density	0–18	0[1]	2.5
Low Road/Stream Intersections	Percent Area	0–0.56	0[2]	0.28

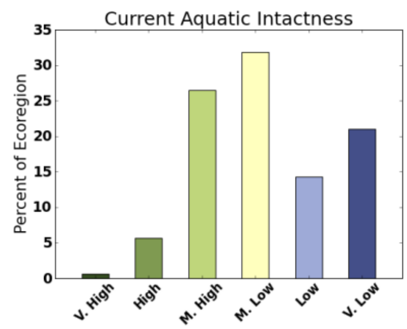
1. Skewed data range: 2 Standard Deviations from the mean; 2. Skewed data range: 1 Standard Deviation from the mean; 3. Skewed data range: 2.5 Standard Deviation from the mean; 4. Skewed data range: 3 Standard Deviations from the mean; 5. Skewed data range: outlier cutoff

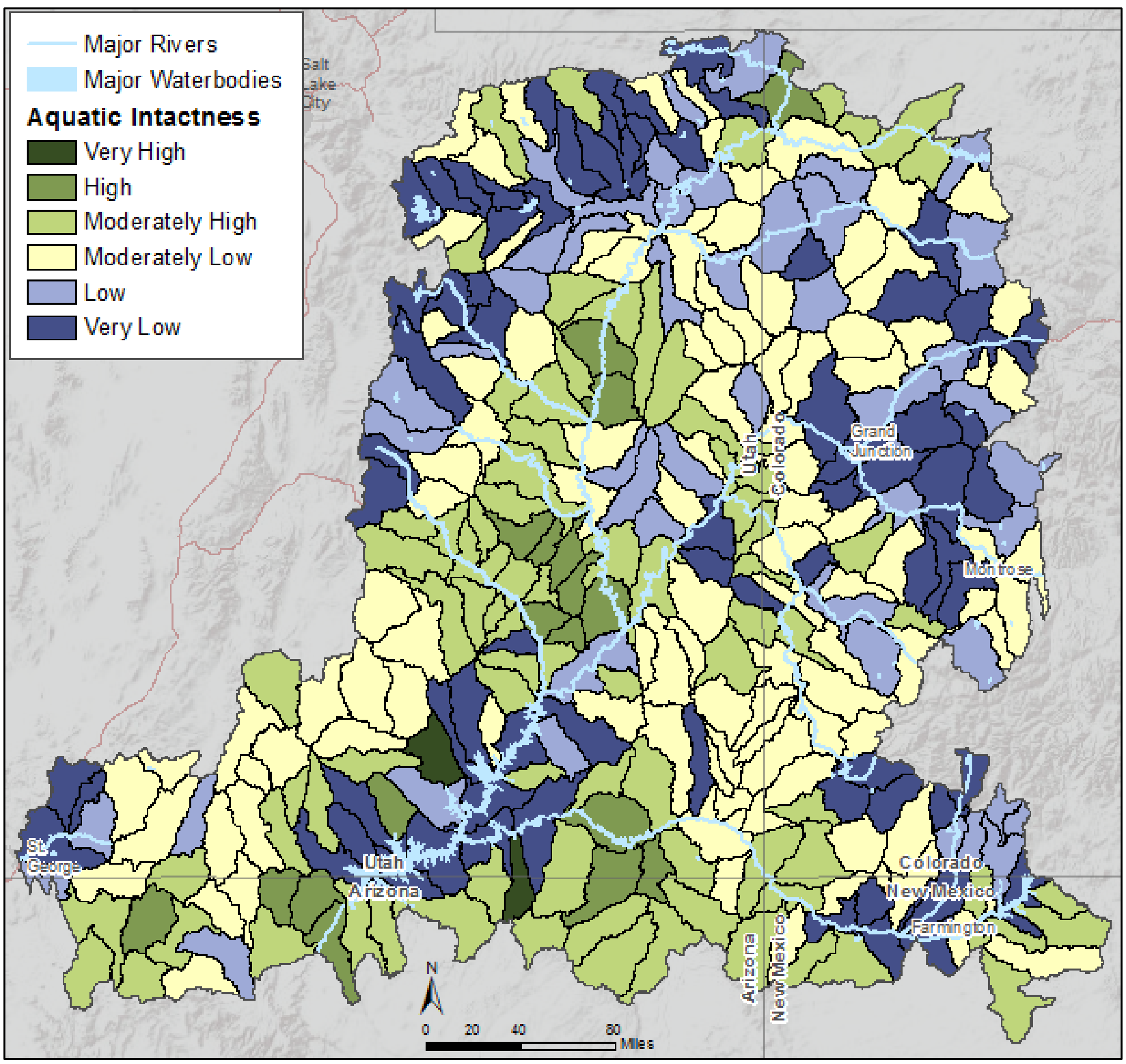
Intactness Value Ranges and Legend Descriptions

Intactness Value	Legend
-1.000 to -0.750	Very Low
-0.750 to -0.500	Low
-0.500 to 0.000	Moderately Low
0.000 to 0.500	Moderately High
0.500 to 0.750	High
0.750 to 1.000	Very High

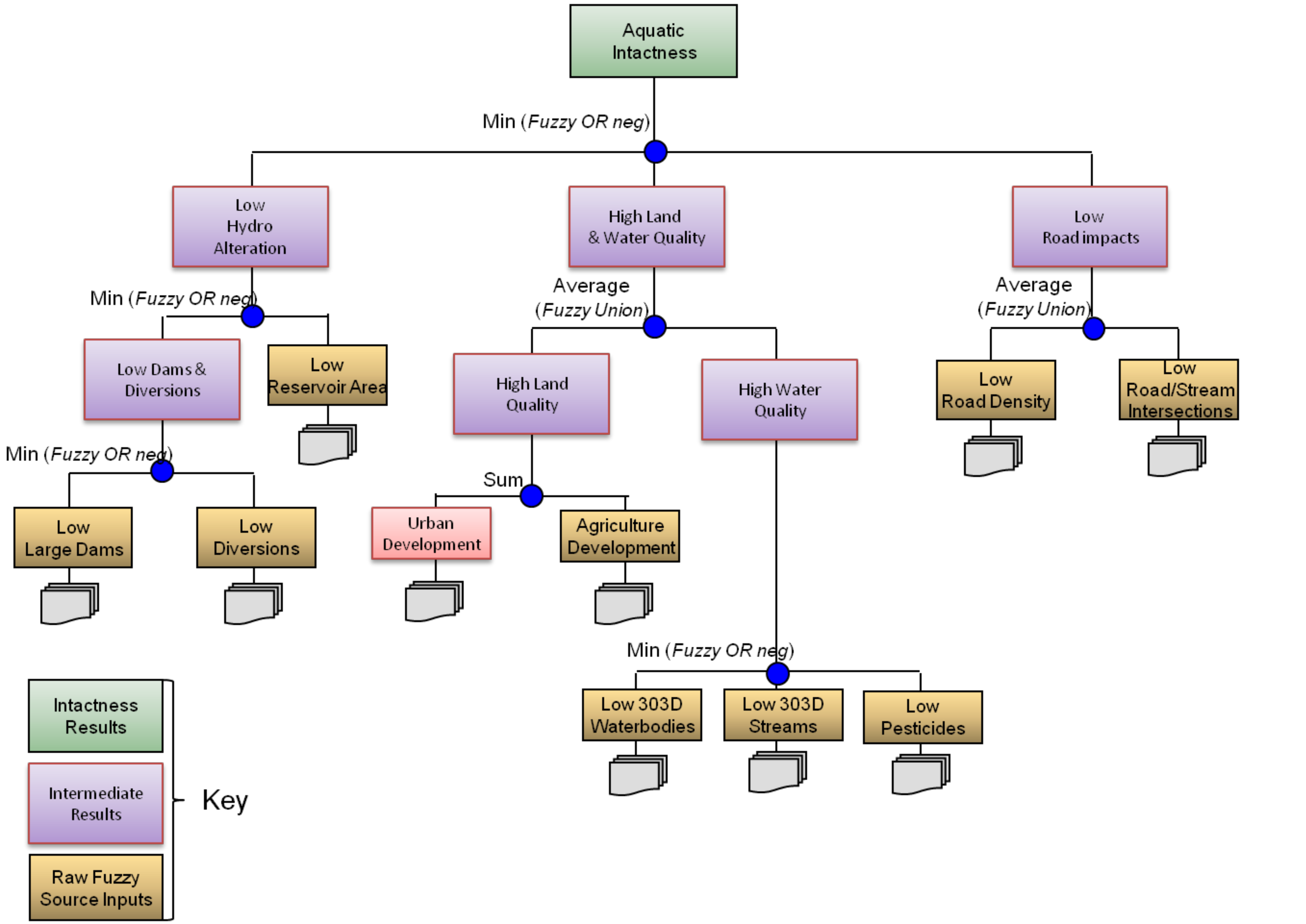
Results for Current Aquatic Intactness

5th level HUC





Near-Term Future (2025) Aquatic Intactness Logic Model



Data Sources for Near Term Future Aquatic Intactness

Model Input Label	Data Source	Relative Quality
Low Large Dams	National Inventory of Dams (US Army Corps of Engineers)	Very Good
Low Diversions	Utah Surface Water Diversions (Utah Department of Natural Resources,	Very Good
	Surface Water Rights in Arizona (Arizona Department of Water	Very Good
	Colorado Surface Water Diversions (Colorado Division of Water	Very Good
	New Mexico Surface Water Diversions (New Mexico Water	Very Good
Low Reservoir Area	National Hydrography Dataset (waterbodies) (USGS)	Very Good
Urban Development	Impervious Surfaces (NLCD 2006)	Very Good
	Development Risk, Contiguous US (David Theobald)	Fair-Good
Agriculture Development	LANDFIRE - Existing Vegetation Type (version 1.1)	Very Good
Low 303D Waterbodies	EPA Office of Water (OW): 303(d) Listed Impaired Waters (waterbodies	Very Good
Low 303D Streams	EPA Office of Water (OW): 303(d) Listed Impaired Waters (waterbodies	Very Good
Low Pesticides	Agricultural Pesticide Use in the Conterminous United States (USGS)	Very Good
Low Road Density	BLM Ground Transportation Linear Features	Fair-Good – surface type would be useful addition
Low Road/Stream Intersections	National Hydrography Dataset (flowlines) (USGS)	Fair-Good – surface type would be useful addition
	BLM Ground Transportation Linear Features	Fair-Good – surface type would be useful addition

Overall Model Certainty: Moderately Low – A number of key datasets could not be projected (e.g. OHV and ground transportation density, grazing), resulting in a model that significantly under-estimates the near-term impacts.

Model output reported at 5th level HUC only.

Boxes and accompanying rows shaded in pink indicate new data for near-term aquatic intactness.

Near Term Future Aquatic Intactness (see threshold explanation, Chapter 3) Thresholds

Item	Data Type	Data Range	True Threshold	False Threshold
Low Large Dams	Point Density	0–0.089	0[1]	0.028
Low Diversions	Point Density	0–8.35	0[1]	1.7
Low Reservoir Area	Percent Area	0–20	0[2]	2
Land Use	Percent Area	0–39	0[3]	20
Low 303D Waterbodies	Percent Area	0–7.62	0[4]	1
Low 303D Streams	Linear Density	0–1.09	0[2]	0.2
Low Pesticides	Weighted Sum	0–0.038	0[5]	0.02
Low Road Density	Linear Density	0–18	0[1]	2.5
Low Road/Stream Intersections	Percent Area	0–0.56	0[2]	0.28

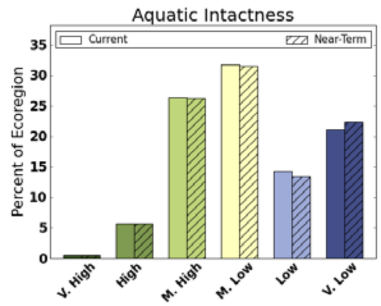
1. Skewed data range: 2 Standard Deviations from the mean; 2. Skewed data range: 1 Standard Deviation from the mean; 3. Skewed data range: 2.5 Standard Deviation from the mean; 4. Skewed data range: 3 Standard Deviations from the mean; 5. Skewed data range: outlier cutoff

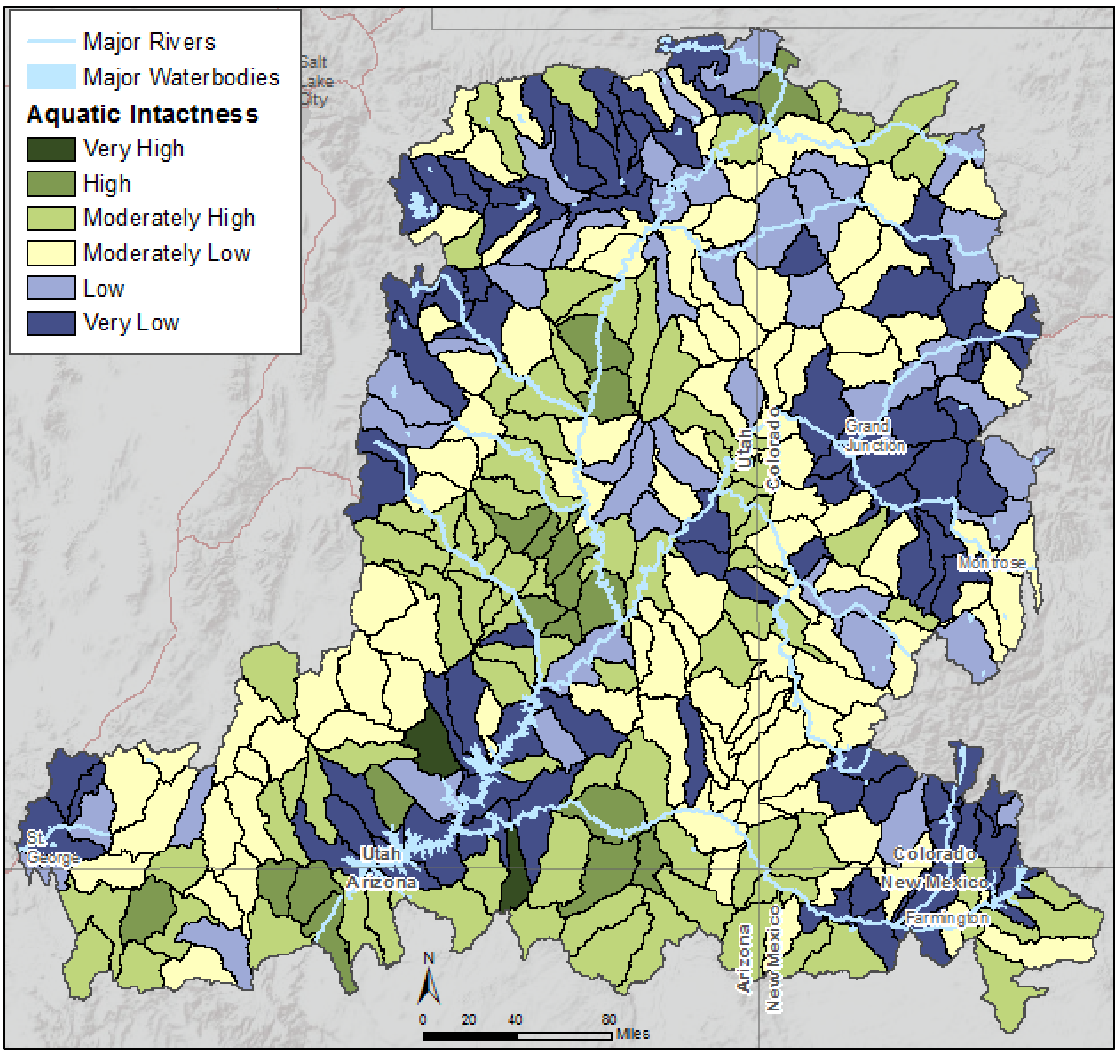
Intactness Value Ranges and Legend Descriptions

Intactness Value	Legend
-1.000 to -0.750	Very Low
-0.750 to -0.500	Low
-0.500 to 0.000	Moderately Low
0.000 to 0.500	Moderately High
0.500 to 0.750	High
0.750 to 1.000	Very High

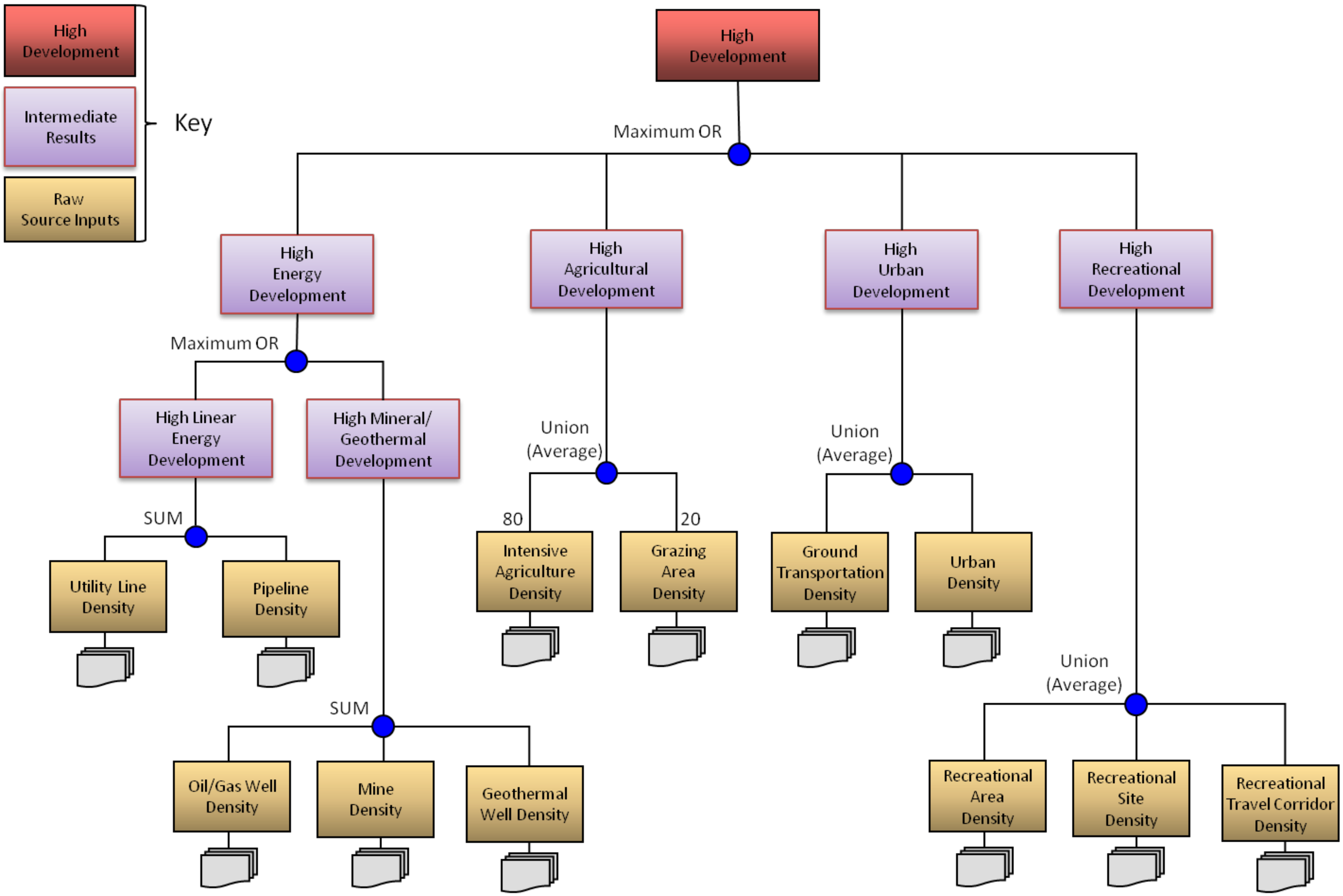
Results for Near Term Future Aquatic Intactness

5th level HUC





Current Development Logic Model



Data Sources for Current Development

Model Input Label	Data Source	Relative Quality
Utility Line Density	Powerlines in the Western United States (USGS)	Good
Pipeline Density	Pipelines (proprietary, provided by BLM)	Good
Oil/Gas Well Density	Oil & Gas Wells (proprietary, provided by BLM)	Good
Mine density	Arizona Mines (Arizona Electronic Atlas)	Good
	Uranium Mines in Arizona (BLM, digitized by CBI)	Good
	Colorado Mines (Colorado Division of Reclamation, Mining and Safety)	Good
	Active Mines and Mineral Processing Plants (USGS)	Good
	New Mexico Mines (New Mexico GIS Resource Program)	Good
	Utah Mines (Automated Geographic Reference Center)	Good
Geothermal Well Density	Geothermal Wells in Utah (Utah Geological Survey)	Good
	Geothermal Wells in Arizona, Colorado, and New Mexico (Idaho	Good
Intensive Agriculture Density	LANDFIRE - Existing Vegetation Type (version 1.1)	Very Good
Grazing Area Density	BLM and USFS Grazing Allotments (MQH4)	Poor-Fair – herd density history or current would be useful
Ground Transportation Density	BLM Ground Transportation Linear Features	Fair-Good – surface type would be useful
Urban Density	Impervious Surfaces (NLCD 2006)	Very Good
Recreational Area Density	Land-Based Recreation Areas – areas (MQH1)	Fair-Poor - no standard source; missing data likely
Recreational Site Density	Land-Based Recreation Areas – points (MQH1)	Fair-Poor - no standard source; missing data likely
Recreational Travel Corridor Density	Land-Based Recreation Travel Corridors (MQH2)	Fair-Good

Overall Model Certainty: Fairly High – BUT a number of potentially valuable datasets were not available that would have improved this model (e.g. grazing density, recreation data, OHV data).

Model reported at 4km x 4km grid only.

Current Development Model (see threshold explanation, Chapter 3) Thresholds – 4km x 4km grid cells

Item	Data Type	Data Range	True Threshold	False Threshold
High Linear Energy	Linear Density	0–5.2	0.64	0
High Mineral/Geothermal	Point Density	0–37	4.11	0
Intensive Agriculture Density	Percent Area	0–90	18.5	0
Grazing Density	Percent Area	0–91	91	0
Ground Transportation Density	Linear Density	0–100	4	0
Urban Density	Percent Area	0–99	10	0
Recreational Area Density	Area Density	0–44	1.15	0
Recreational Site Density	Point Density	0–4.6	0.12	0
Recreational Travel Corridor Density	Linear Density	0–16	2.5	0

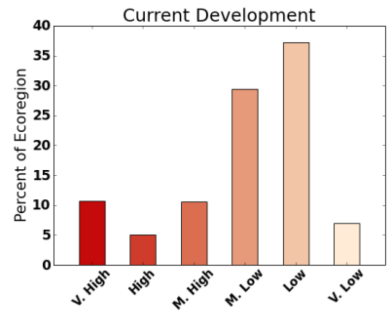
All thresholds based on 2 standard deviations from the mean value for each component.

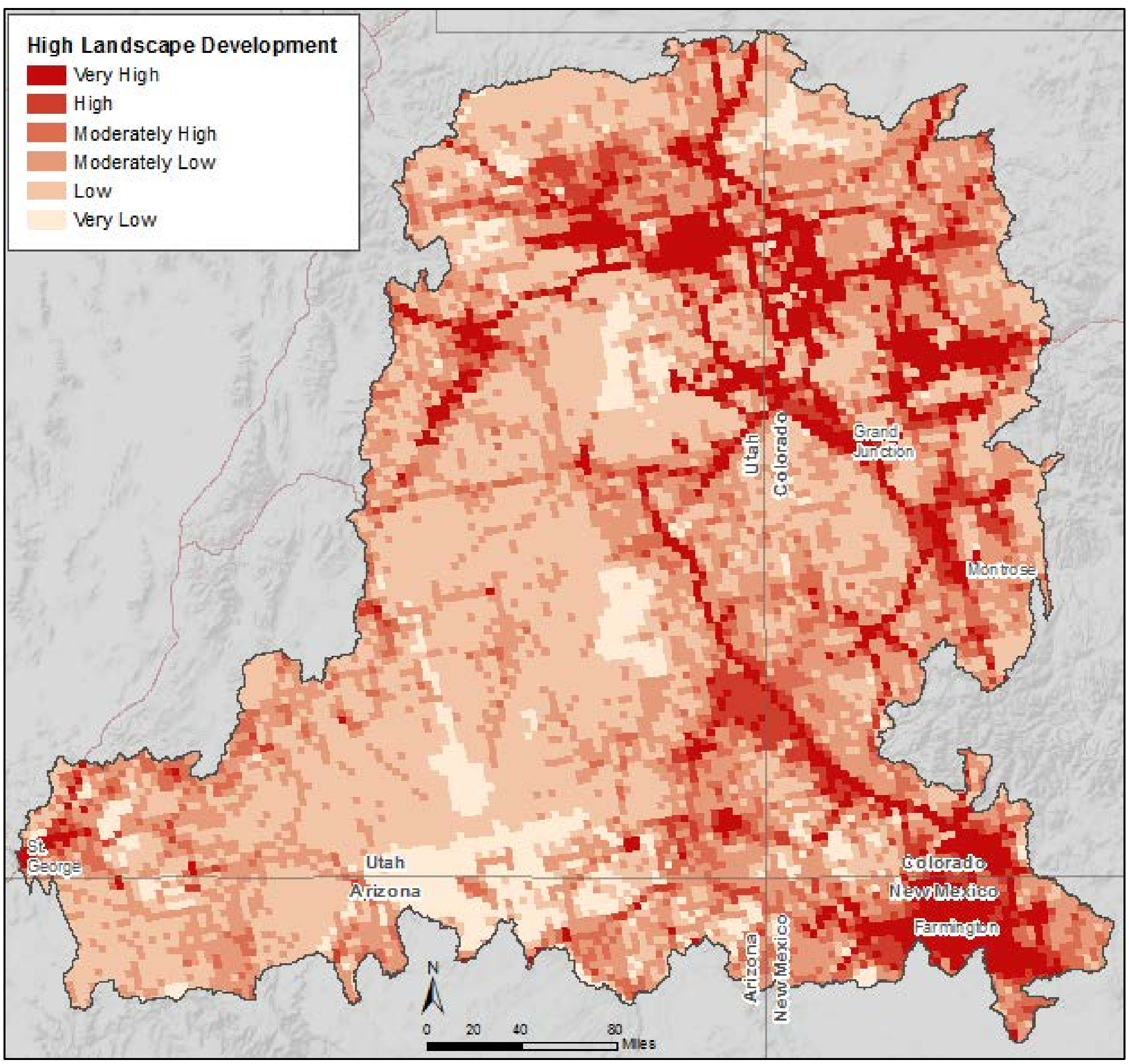
Intactness Value Ranges and Legend Descriptions

Intactness Value	Legend
-1.000 to -0.750	Very Low
-0.750 to -0.500	Low
-0.500 to 0.000	Moderately Low
0.000 to 0.500	Moderately High
0.500 to 0.750	High
0.750 to 1.000	Very High

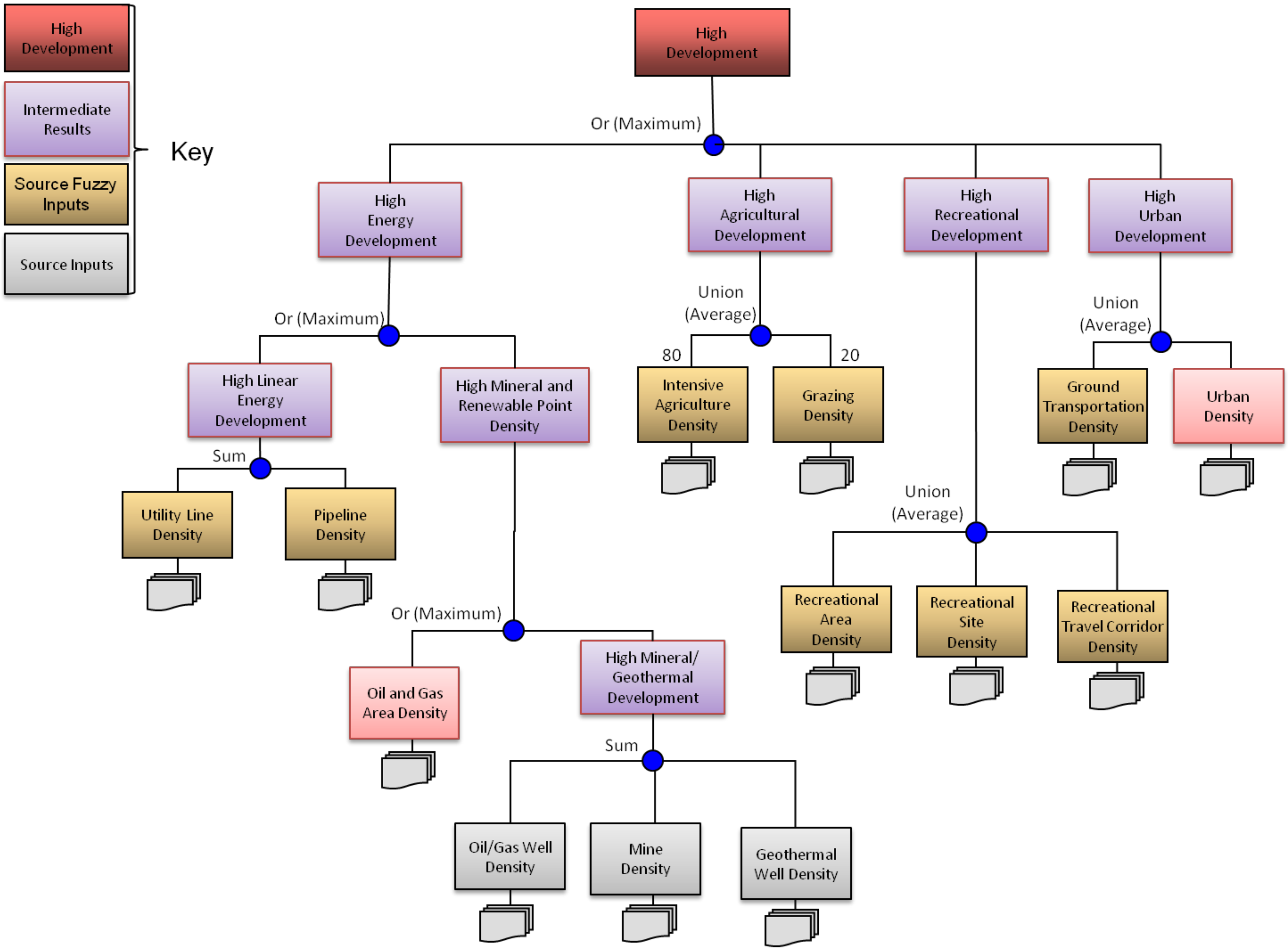
Results for Current Development

4km x 4km grid cells





Near-term Future (2025) Development Logic Model



Data Sources for Near Term Future Development

Model Input Label	Data Source	Relative Quality
Utility Line Density	Powerlines in the Western United States (USGS)	Good
Pipeline Density	Pipelines (proprietary, provided by BLM)	Good
Oil/Gas Well Density	Oil & Gas Wells (proprietary, provided by BLM)	Good
	Intermountain West Oil and Gas Potential-Anticipated Oil Wells	Good
Mine density	Arizona Mines (Arizona Electronic Atlas)	Good
	Uranium Mines in Arizona (BLM, digitized by CBI)	Good
	Colorado Mines (Colorado Division of Reclamation, Mining and Safety)	Good
	Active Mines and Mineral Processing Plants (USGS)	Good
	New Mexico Mines (New Mexico GIS Resource Program)	Good
	Utah Mines (Automated Geographic Reference Center)	Good
Geothermal Well Density	Geothermal Wells in Utah (Utah Geological Survey)	Good
	Geothermal Wells in Arizona, Colorado, and New Mexico (Idaho	Good
Intensive Agriculture Density	LANDFIRE - Existing Vegetation Type (version 1.1)	Very Good
Grazing Area Density	BLM and USFS Grazing Allotments (MQH4)	Poor-Fair – herd density history or current would be useful
Ground Transportation Density	BLM Ground Transportation Linear Features	Fair-Good – surface type would be useful
Urban Density	Impervious Surfaces (NLCD 2006)	Very Good
	Development Risk, Contiguous US (David Theobald)	Fair-Good
Recreational Area Density	Land-Based Recreation Areas – areas (MQH1)	Fair-Poor - no standard source; missing data likely
Recreational Site Density	Land-Based Recreation Areas – points (MQH1)	Fair-Poor - no standard source; missing data likely
Recreational Travel Corridor Density	Land-Based Recreation Travel Corridors (MQH2)	Fair-Good

Overall Model Certainty: **Moderately Low –** A number of key datasets could not be projected (e.g. ground transportation density, future grazing density, future recreation), resulting in a model that significantly under-estimates the near-term impacts.

Model output reported at 4km x 4km grid

Near Term Future Development Model (see threshold explanation, Chapter 3) Thresholds

Item	Data Type	Data Range	True Threshold	False Threshold
High Linear Energy	Linear Density	0–5.2	0.64	0
High Oil/Mineral/Geothermal	Point Density	0–37	4.11	0
High Oil/Gas Polygons	Percent Area	0–100	7.35	0
Intensive Agriculture Density	Percent Area	0–90	18.5	0
Grazing Density	Percent Area	0–91	91	0
Ground Transportation Density	Linear Density	0–100	4	0
Urban Density	Percent Area	0–99	10	0
Recreational Area Density	Area Density	0–44	1.15	0
Recreational Site Density	Point Density	0–4.6	0.12	0
Recreational Travel Corridor Density	Linear Density	0–16	2.5	0

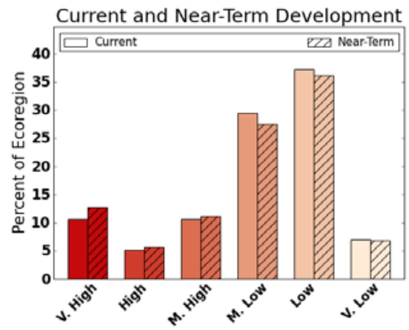
All thresholds based on 2 standard deviations from the mean value for each component.

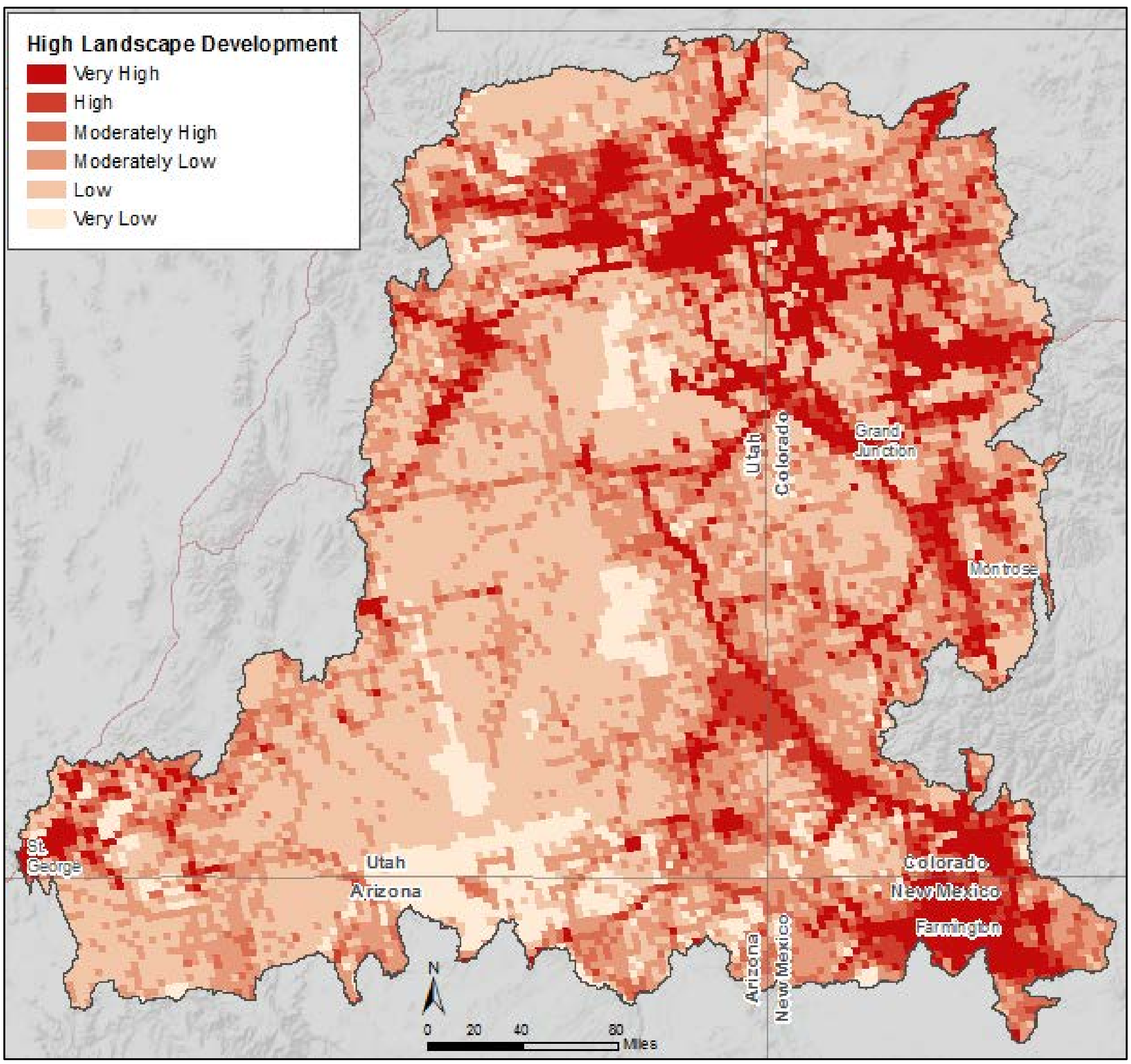
Intactness Value Ranges and Legend Descriptions

Intactness Value	Legend
-1.000 to -0.750	Very Low
-0.750 to -0.500	Low
-0.500 to 0.000	Moderately Low
0.000 to 0.500	Moderately High
0.500 to 0.750	High
0.750 to 1.000	Very High

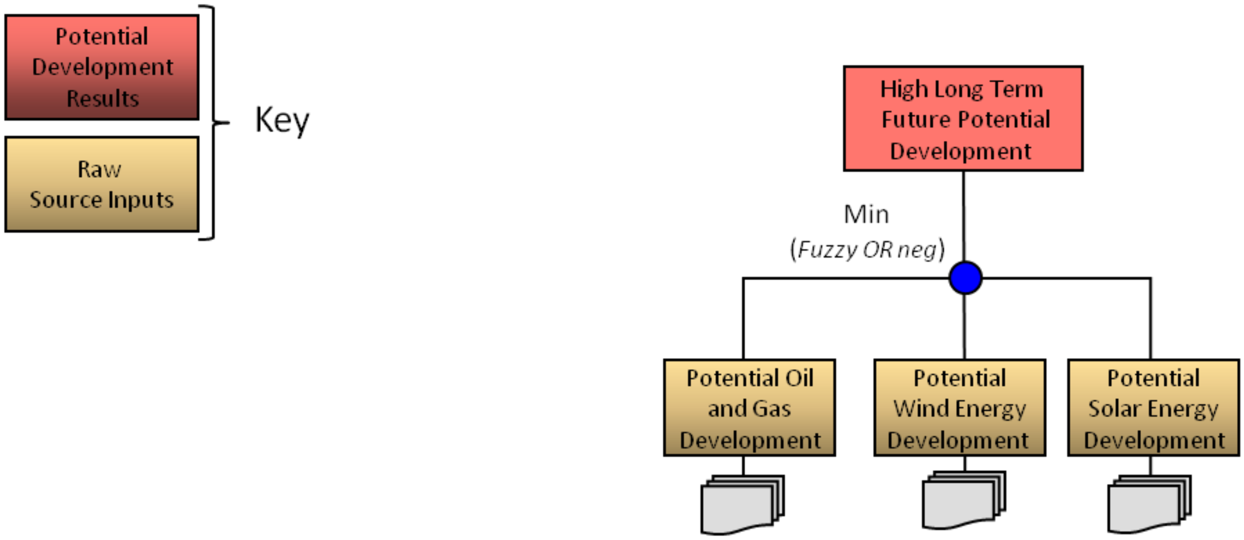
Results for Near Term Future (2025) Development

4km x 4km grid cells





Maximum (Long Term) Potential Energy Development Logic Model



Data Sources for Maximum Potential Energy Development

Model Input Label	Data Source	Relative Quality
Potential Oil and Gas Development	Allowable Leasing Footprints For Tar Sand Extraction in Special Tar Sands Areas of Utah (PEIS Alternative B) (BLM)	Very Good
	Allowable Leasing Footprints for Oil Shale Extraction in Colorado (PEIS Alternative B) (BLM)	Very Good
	Allowable Leasing Footprints for Oil Shale Extraction in Utah (PEIS Alternative B) (BLM)	Very Good
	BLM Colorado Oil and Gas Lease Stipulations	Very Good
	BLM New Mexico Oil and Gas Leases	Very Good
	BLM Utah Oil and Gas Leases	Very Good
	Oil and Gas Fields (US Depts of the Interior, Agriculture & Energy)	Good
	Intermountain West Oil and Gas Potential (Copeland et al. 2009)	Good
Potential Wind Energy Development	Wind Power Density (W/m2) at 50 Meters Above Ground Level	Good
	Utah BLM Wind Energy Priority Areas	Good
Potential Solar Energy Development	Average Solar Resource Potential (filtered to less than 1% slope)	Good

Removed protected areas using PAD-US (CBI Edition) v 1.1 – GAP codes 1&2

Overall Model Certainty: Fairly High – BUT this is just POTENTIAL energy. Not all of these areas are likely to be developed.

Model reported for 4km x 4km grid cells only.

Maximum (Long Term) Potential Energy Development Model (see threshold explanation, Chapter 3)

Thresholds – 4km x 4km grid cells

Item	Data Type	Data Range	True Threshold	False Threshold
Oil and Gas	Percent Area	0–100	0	100
Solar	Percent Area	0–100	0	100
Wind	Percent Area	0–100	0	100

Thresholds – 5th level HUC

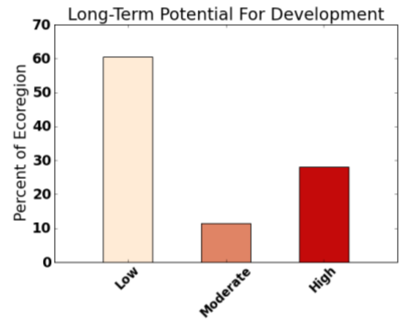
Item	Data Type	Data Range	True Threshold	False Threshold
Oil and Gas	Percent Area	0–100	0	100
Solar	Percent Area	0–27	0	27
Wind	Percent Area	0–78	0	78

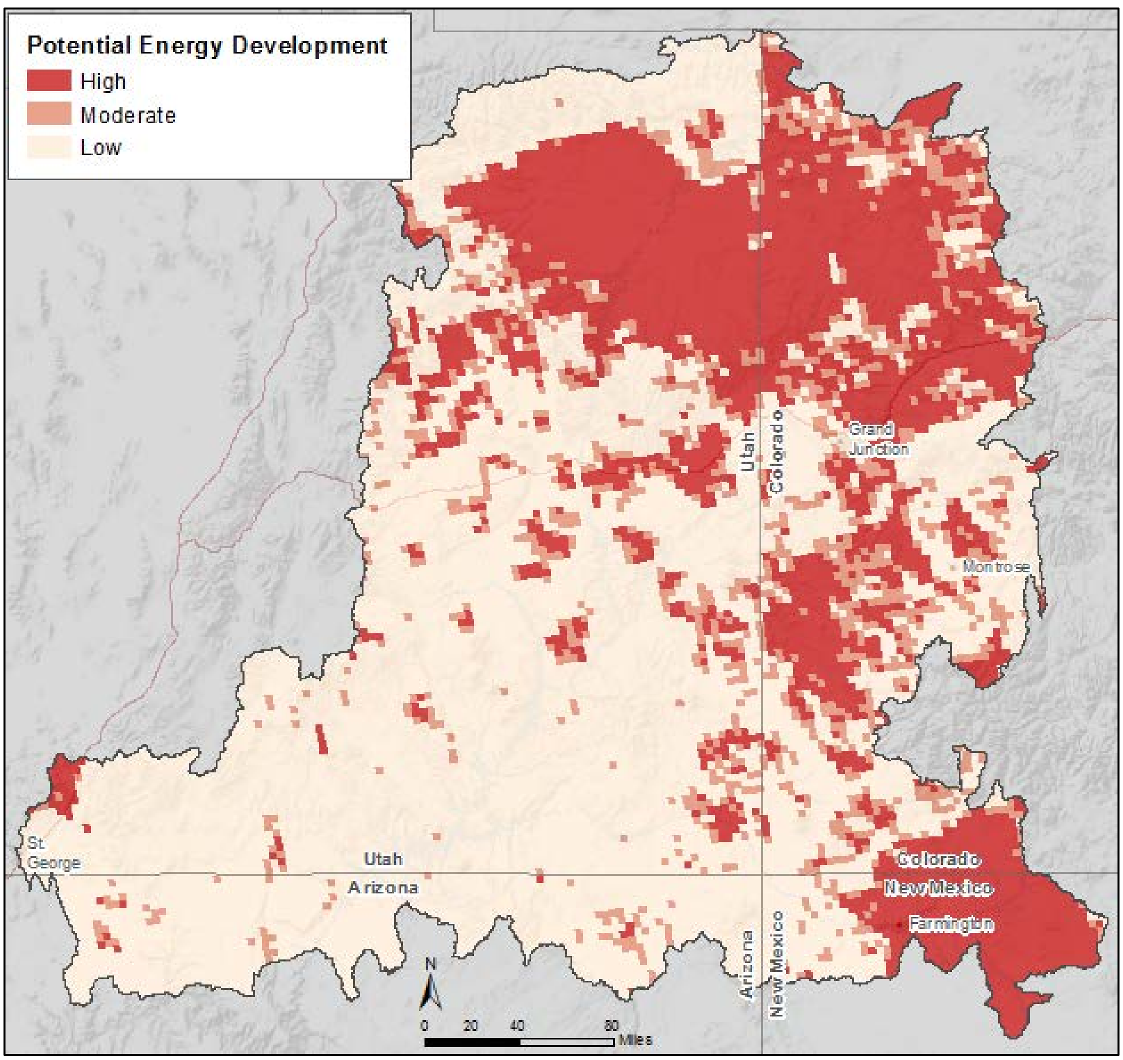
Intactness Value Ranges and Legend Descriptions

Intactness Value	Legend
0.333 to 1.0	High
--0.333 to 0.333	Medium
-0.333 to -1.0	Low

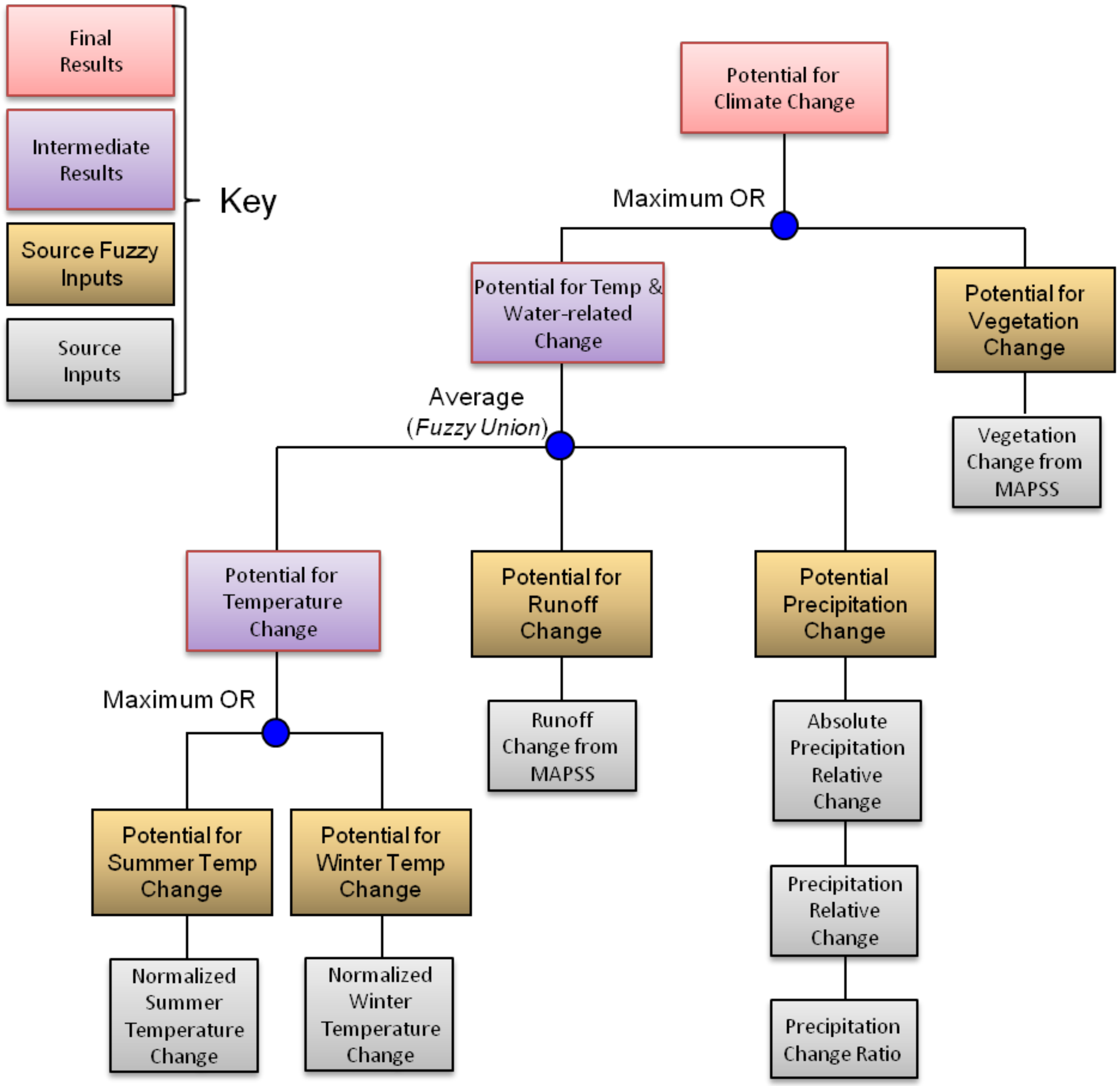
Results for Maximum (Long Term) Potential Energy Development

4km x 4km grid cells





Potential Climate Change Impacts



Data Sources for Potential Climate Change Impacts

Model Input Label	Data Source	Relative Quality
Potential for Summer Temp Change	RegCM3 ECHAM5	Fair
Potential for Winter Temp Change	RegCM3 ECHAM5	Fair
Potential for Runoff	MAPSS model output	Fair
Potential Precipitation Change	RegCM3 ECHAM5	Fair
Potential for Vegetation Change	MAPSS model output	Fair

Overall Model Certainty: Moderately Low – The climate change data are the best available and the basic trends and general patterns posses fairly high certainty; however, there is inherent uncertainty as discussed in the text that cautions over-interpretation, especially as it applies to site-specific scales.

Model output reported at 4km x 4km grid cells only.

Potential Climate Change Impacts Model (see threshold explanation, Chapter 3) Thresholds – 4km x 4km grid cells

Item	Data Type	Data Range	True Threshold	False Threshold
Potential for Summer Temp Change	See Below	1.14–3.74	3.74	1.14
Potential for Winter Temp Change	See Below	0.47–1.44	1.44	0.47
Potential for Runoff	Percent Change	0–10	2[1]	0
Potential Precipitation Change	See Below	0–2.16	2.16	0
Potential for Vegetation Change	Percent Area	0–100	100	0

1. Tail cutoff

Thresholds – 5th level HUC

Item	Data Type	Data Range	True Threshold	False Threshold
Potential for Summer Temp Change	See Below	1.59–3.26	3.26	1.59
Potential for Winter Temp Change	See Below	0.51–1.33	1.33	0.51
Potential for Runoff	Percent Change	0.63–8.17	2[1]	0
Potential Precipitation Change	See Below	0.34–1.94	1.94	0.34
Potential for Vegetation Change	Percent Area	0–100	100	0

1. Tail cutoff

For temperature, potential for change calculated by RegCM3 (ECHAM5) 2045–2060 TEMP – PRISM TEMP/SD PRISM TEMP; values are unit-less

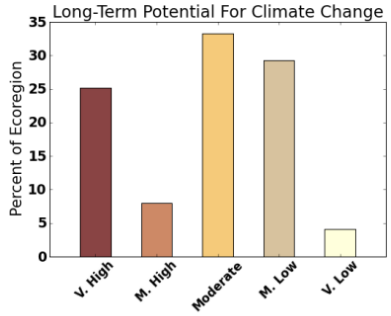
For precipitation, potential for change calculated by RegCM3 (ECHAM5) 2045–2060 PRECIP – PRISM PRECIP/PRISM PRECIP/SD PRISM PRECIP; values are unit-less

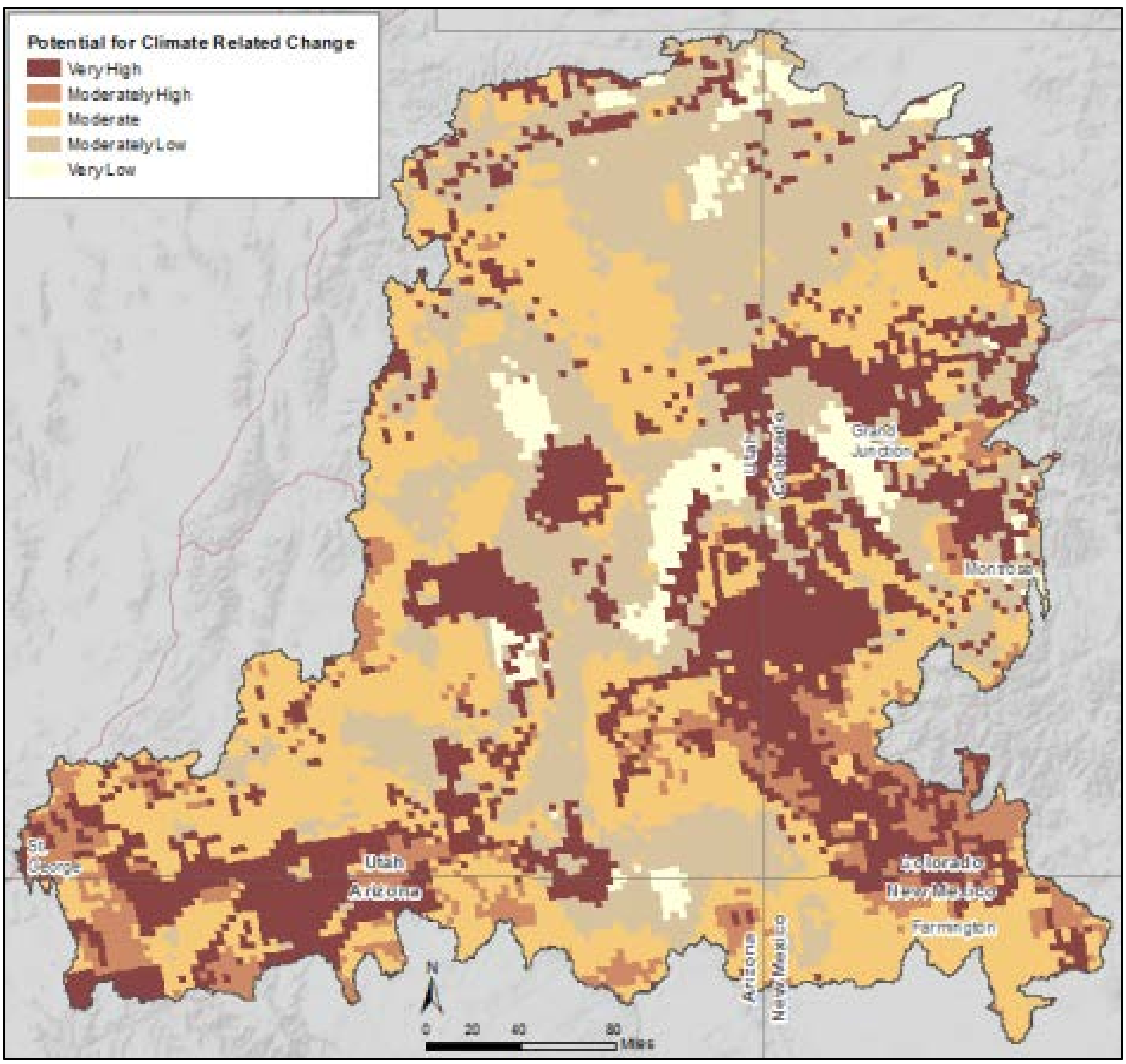
Intactness Value Ranges and Legend Descriptions

Intactness Value	Legend
-1.00 to -0.66	Very Low
-0.66 to -0.22	Moderately Low
-0.22 to 0.22	Moderate
0.22 to 0.66	Moderately High
0.66 to 1.00	Very High

Results for Potential Climate Change Impacts

4 km x 4 km grid cells





Data Request Method

Rapid Ecoregional Assessments (REAs)—National Operations Center, CO

Individual REA data layers and some other products are still available but are no longer being published.

If you would like to obtain more information, including data and model zip files* (containing Esri ModelBuilder files for ArcGIS 10.x and relevant Python scripts), please email **BLM_OC_REA_Data_Portal_Feedback_Team@blm.gov**.
*Note that a few models require software that BLM does not provide such as R, Maxent, and TauDEM.

Models associated with individual REAs may require data links to be updated to function properly. REA reports, technical appendices, and model overviews (for some REAs) contain detailed information to determine what products are available and what datasets are necessary to run a certain model.

Please include the report name and any specific data information that you can provide with your request.

Other BLM data can be found on the Geospatial Business Platform Hub (https://gbp-blm-egis.hub.arcgis.com).