Modeling landscape integrity in Colorado

Colorado Natural Heritage Program

Karin Decker and Michelle Fink

Introduction

Conservation organizations face the constant challenge of determining where to focus their efforts. The most viable conservation targets are usually located in areas least altered by human activity, hence the importance of considering the **landscape context** of a conservation target.

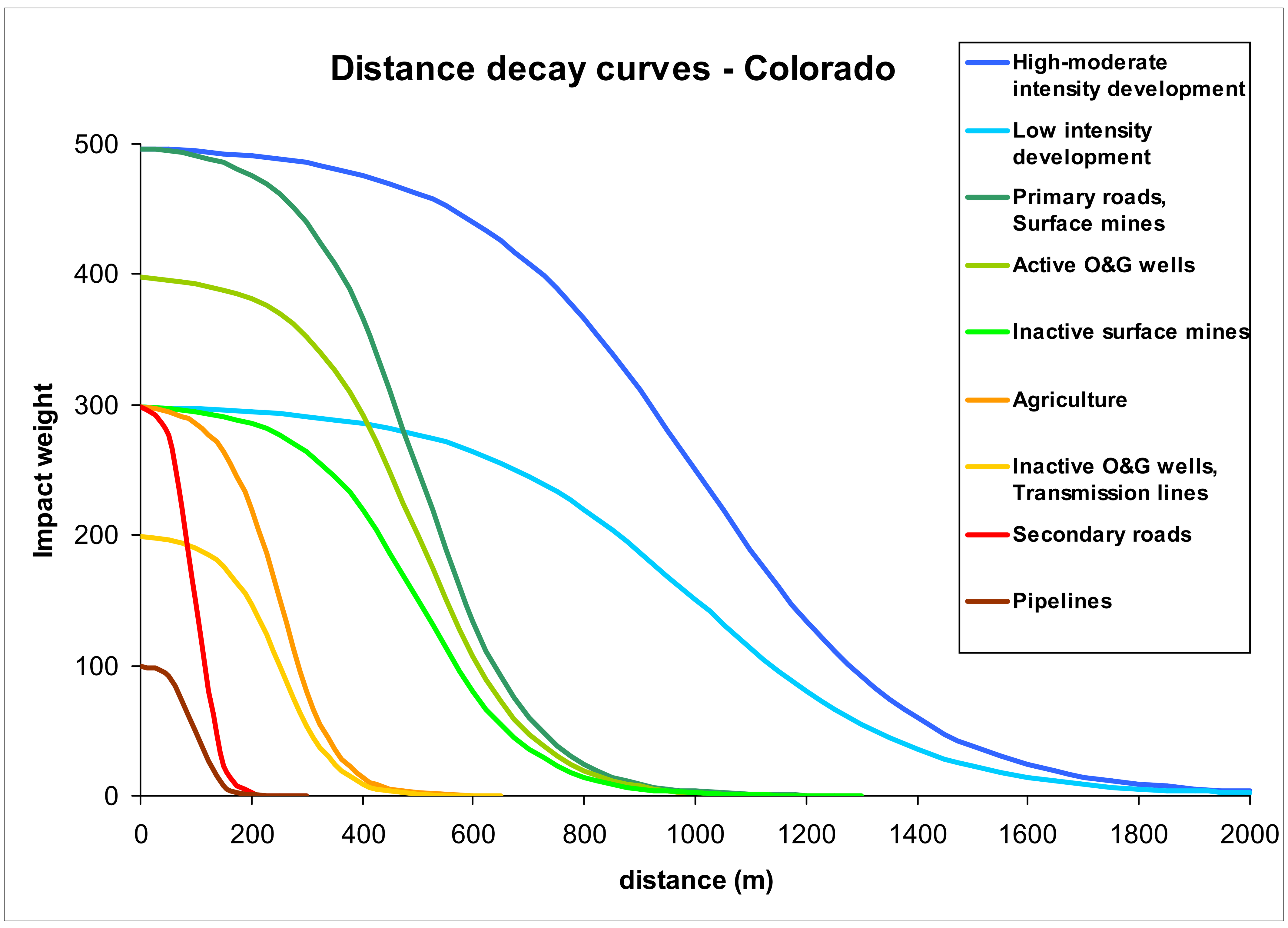
Landscape Context:
An integrated measure of the quality of the ecological processes maintaining the elements of an area, and the connectivity of the area with the surrounding landscape (Tuffley and Comer 2005).

Geographic information systems (GIS) provide tools to help prioritize areas on the landscape, identifying the highest priority, most viable sites for protection. The continuing expansion in digital mapping of infrastructure and landuse-landcover provides a wealth of data with which to investigate the spatial distribution of both human impacts to the environment and the biodiversity elements we wish to conserve.

As a surrogate for directly measuring the quality and connectivity of the landscape, we model the location and intensity of anthropogenic disturbances in the landscape, making the broad assumption that these disturbances are affecting the quality and connectivity of landscape processes, and, by extension, having an impact on the elements of biodiversity supported by that area.

We present a generalized methodology for using available data to construct landscape integrity models for large areas, and evaluate the usefulness of the Colorado model using independently collected information about the quality of mapped natural communities throughout the state.

Methods



The effects of anthropogenic changes to the landscape often extend some distance into the surrounding environment, beyond the actual footprint of disturbance. The effect generally decreases, or **decays,** with increasing distance.

Distance Decay:
The lessening in force of a phenomenon or interaction with increasing distance from the location of maximum intensity.

The distance-decay model of landscape integrity is a cumulative, continuous surface of relative impact. The distance-decay function represents a mathematical curve describing the decrease of impact over distance.

The choice of curve for the distance decay function is determined by how the disturbance is believed to behave in the real world.

Our model used a series of sigmoid curves based on the function:

$$y = \frac{1}{1+\exp(b(\frac{x}{c}-a))} \times w$$

where
a - shifts curve to right or left
b - determines spread of curve, or slope of the rapidly decreasing part of curve.
c - scalar to adjust total distance of interest (=distance in meters divided by 20)
x - distance in meters from threat
w - weight of threat (maximum value)

By adjusting the shift and spread of the curve (a and b), it can be tailored to specific threats. Different values of a and b were used to derive four decay curves describing gradual, moderate, moderately abrupt, and abrupt distance decay behavior. The inflection point of the curve marks the distance where the effect of the impact is reduced by half. These curves are asymptotic at both ends, therefore the results of the equation must be manually adjusted to equal the maximum weight at zero distance and minimum weight at a distance at which the weight becomes essentially zero ("cutoff distance").

curve type	*a*	*b*	inflection pt	cutoff
abrupt	1	5	100m	250m
moderately abrupt	2.5	2	300m	600m
moderate	5	1	500m	1,250m
gradual	10	0.5	1,000m	2,000m

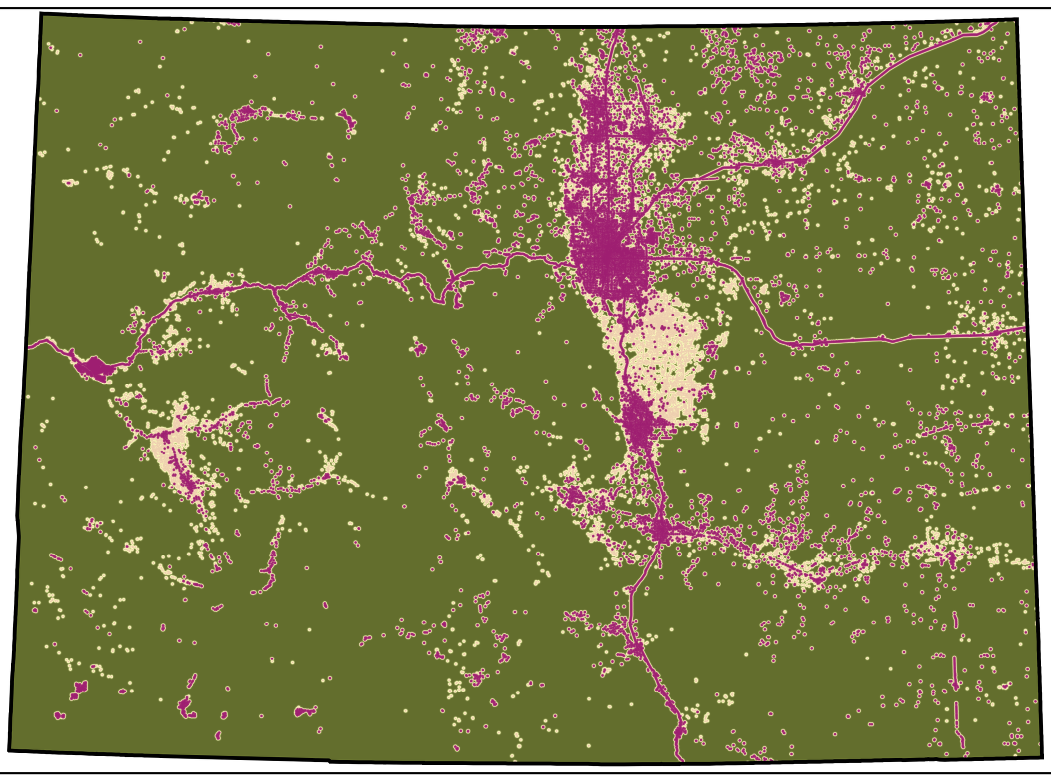
Threat type	weight	distance decay function type
High/med intensity development	500	gradual
Low intensity development	300	gradual
Agriculture	300	mod-abr
Roads - primary & secondary	500	moderate
Roads - local & rural, 4WD etc.	300	abrupt
Oil & gas wells - active	400	moderate
Oil & gas wells - inactive	200	mod-abr
Gas pipelines	100	abrupt
Transmission lines	200	mod-abr
Surface Mines - active	500	moderate
Surface Mines - inactive	300	moderate

Each individual impact type has its own relevant weight and decay function type. The individual layers are then additively combined to produce an overall landscape integrity layer.

Tobler's first law of geography:
"Everything is related to everything else, but near things are more related than distant things."
[Tobler, 1970, p.236].

Results

Urban Development

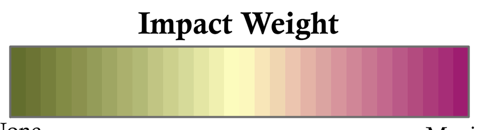


The Urban Development layer was derived from the Southwest Regional GAP (SWReGAP) Landcover. Different development intensities, as defined by the SWReGAP Landcover layer, were given different impact weights and their distance decay functions calculated separately. The final raster uses the maximum value from the two calculations to represent overall impact of urban development.

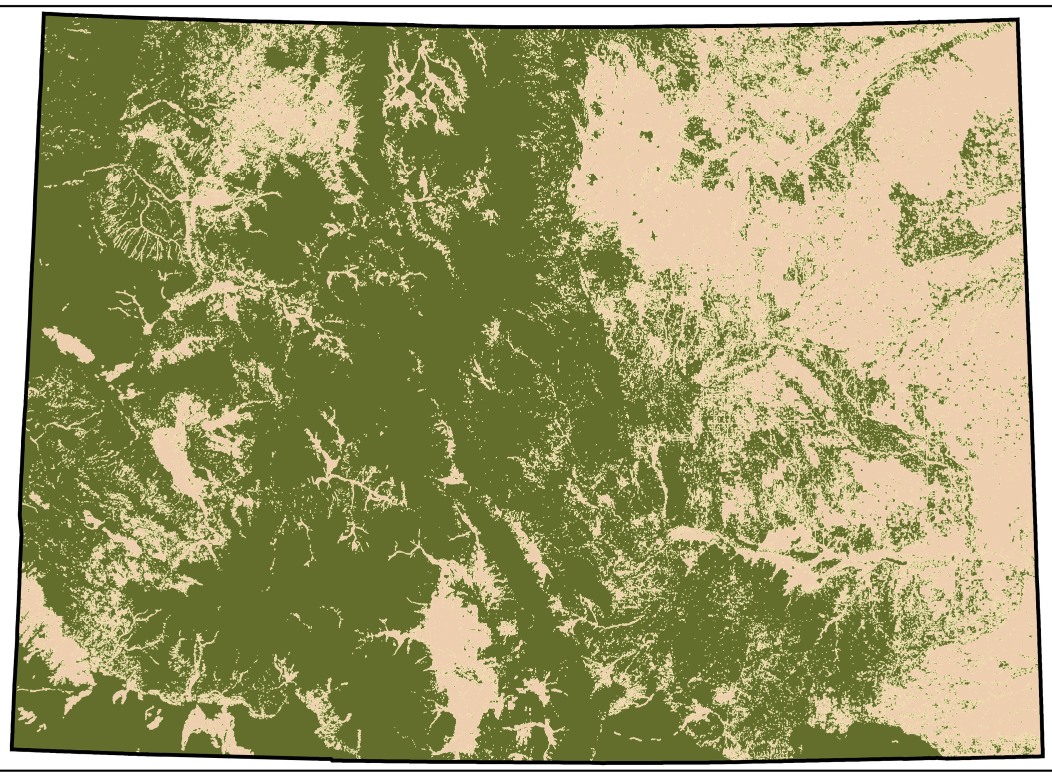
Impact type	Weight	DDF curve	Source
High/Medium	500	gradual	SWReGAP Value 112
Low	300	gradual	SWReGAP Value 111

Southwest Regional GAP Provisional Digital Landcover Dataset for the Southwestern United States. RS/GIS Laboratory, College of Natural Resources, Utah State University. Edition 1.0, 2004. Available online at http://earth.gis.usu.edu/swgap/.

Impact Weight



Tilled Agriculture

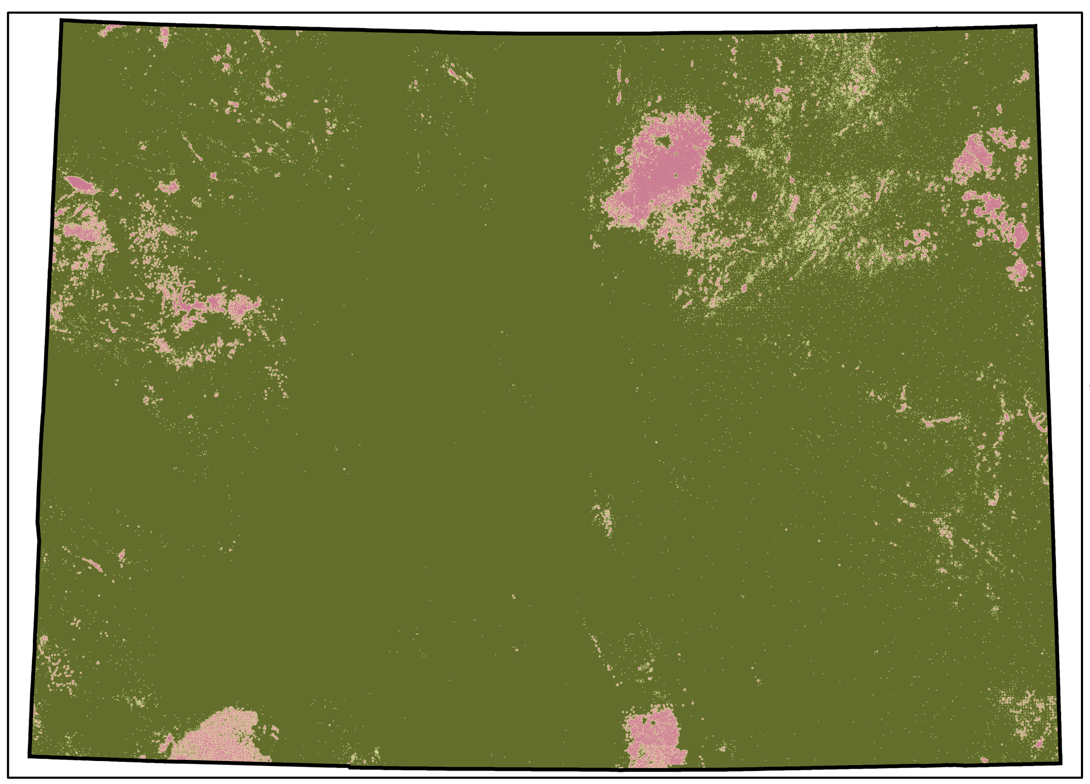


The Agriculture layer was also derived from the SWReGAP Landcover. This was considered the best source available, although the mapping of tilled land in this layer is known to be inaccurate in places.

Impact type	Weight	DDF curve	Source
Agriculture	300	moderate-abrupt	SWReGAP Value 114

Southwest Regional GAP Provisional Digital Landcover Dataset for the Southwestern United States. RS/GIS Laboratory, College of Natural Resources, Utah State University. Edition 1.0. Available online at http://earth.gis.usu.edu/swgap/.

Oil and Gas Wells

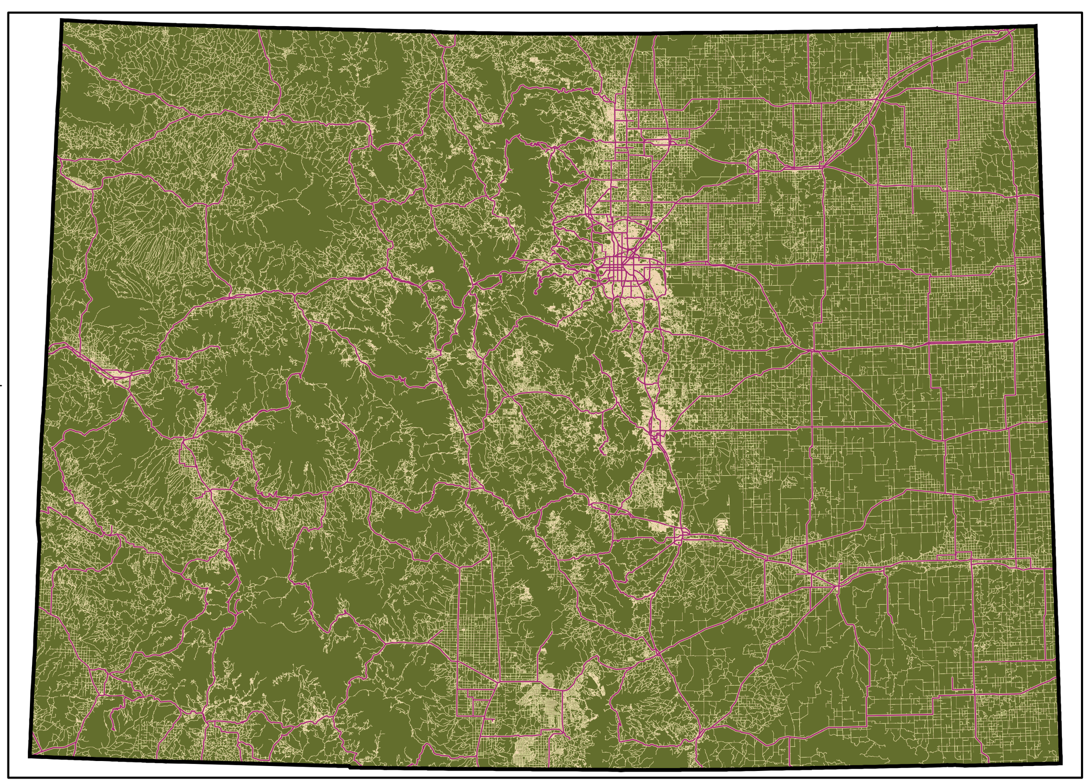


The Oil and Gas well layer was derived from the Colorado Oil and Gas Conservation Commission (COGCC) online wells data download. Actively producing wells were separated from inactive/old wells and given different impact weights and their distance decay functions calculated separately. The final raster uses the maximum value from the two calculations to represent overall impact of oil and gas development.

Impact type	Weight	DDF curve	Source
Active OG Wells	400	moderate	COGCC Wells
Inactive OG Wells	200	moderate/abrupt	COGCC Wells

COGCC Wells. The Colorado Oil and Gas Conservation Commission. Downloaded 01/22/2008. Available online at: http://oil-gas.state.co.us/.

Roads

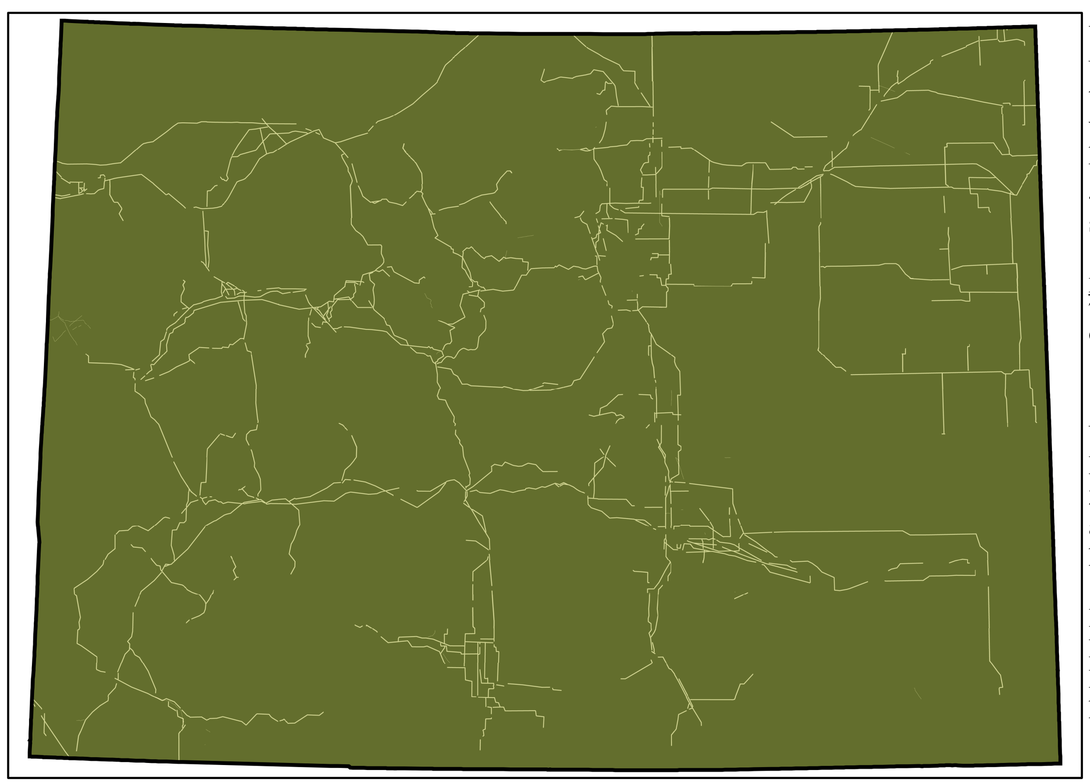


The roads layer was derived from the U.S. Census Bureau 2006 TIGER/Line files. Roads were separated into Primary/Secondary or Local/Primitive, given different impact weights and their distance decay functions calculated separately. The final raster uses the maximum value from the two calculations to represent overall impact of roads.

Impact type	Weight	DDF curve	Source
Roads-Primary/Secondary	500	moderate	TIGER\Line
Roads-Local/Primitive	300	abrupt	TIGER\Line

U.S. Department of Commerce, U.S. Census Bureau, Geography Division. TIGER/Line Files, 2006 Second Edition, Colorado. available online at http://www.census.gov/geo/www/tiger.

Major Utility Lines



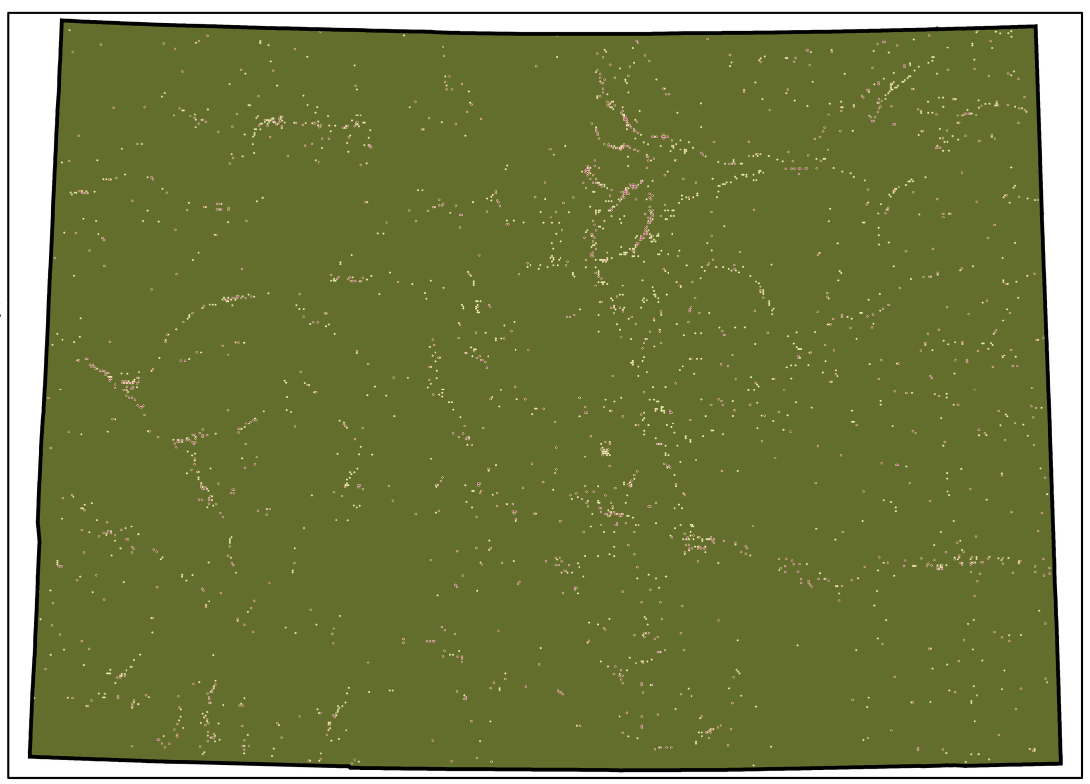
We were unable to acquire complete and unrestricted utility line (pipeline and power transmission line) data for Colorado, and so were left with using coarse scale data with known gaps and inaccuracies. Each utility was given a different impact weight and calculated separately.

Impact type	Weight	DDF curve	Source
Transmission lines	200	moderate/abrupt	DCW UTLINE
Gas Pipelines	100	abrupt	TIGER\Line

U.S. Department of Commerce, U.S. Census Bureau, Geography Division. TIGER/Line Files, 2006 Second Edition, Colorado. available online at http://www.census.gov/geo/www/tiger.

Environmental Systems Research Institute, Inc. Digital Chart of the World (DCW) Utilities layer. Published 1993. Available online at http://www.geocomm.com.

Surface Mines



The surface mine layer was derived from the Colorado Division of Reclamation, Mining, and Safety's database. Only surface mines were used. Mines were separated into active and inactive. Each type was given a different impact weight and calculated separately. The final raster uses the maximum value from the two to represent overall impact of surface mining activiites.

Impact type	Weight	DDF curve	Source
Active Mines	500	moderate	DRMS
Inactive Mines	300	moderate	DRMS

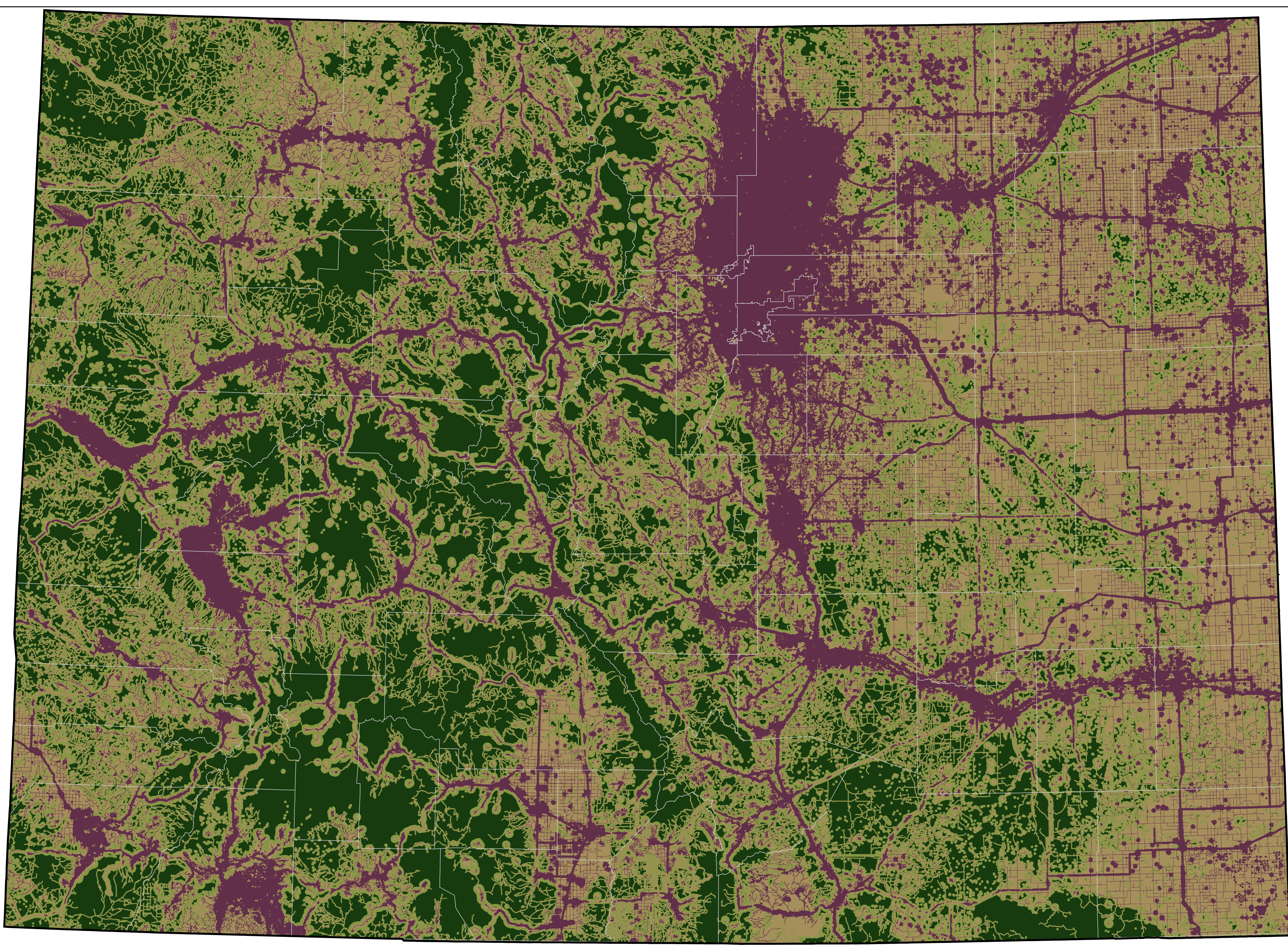
Colorado Division of Reclamation, Mining, and Safety. County/Operator Mining Data for all operations. Published 1/02/2008. Available online at http://mining.state.co.us/.

The individual impact layers were added together to create the final landscape integrity layer representing the cumulative impact to an area from the included land uses.

Final Landscape Integrity Layer:

Relative level of impact

None | Moderate
Low | High

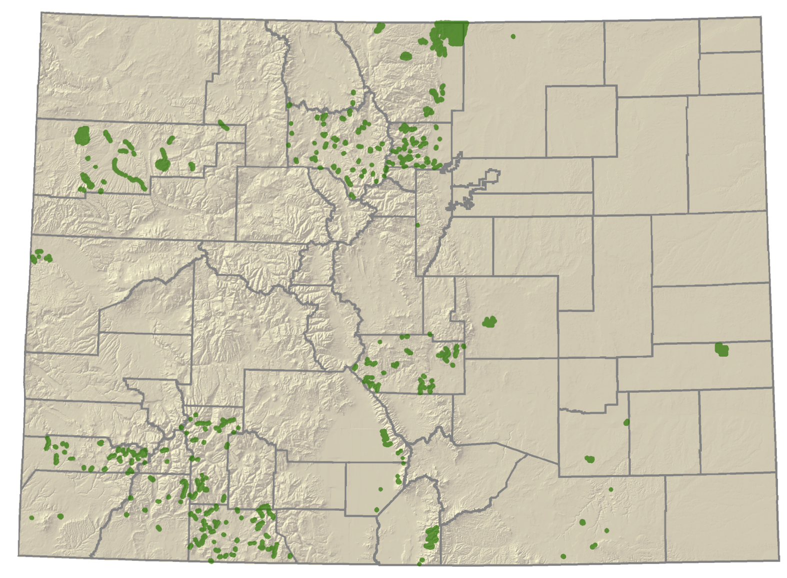


Discussion

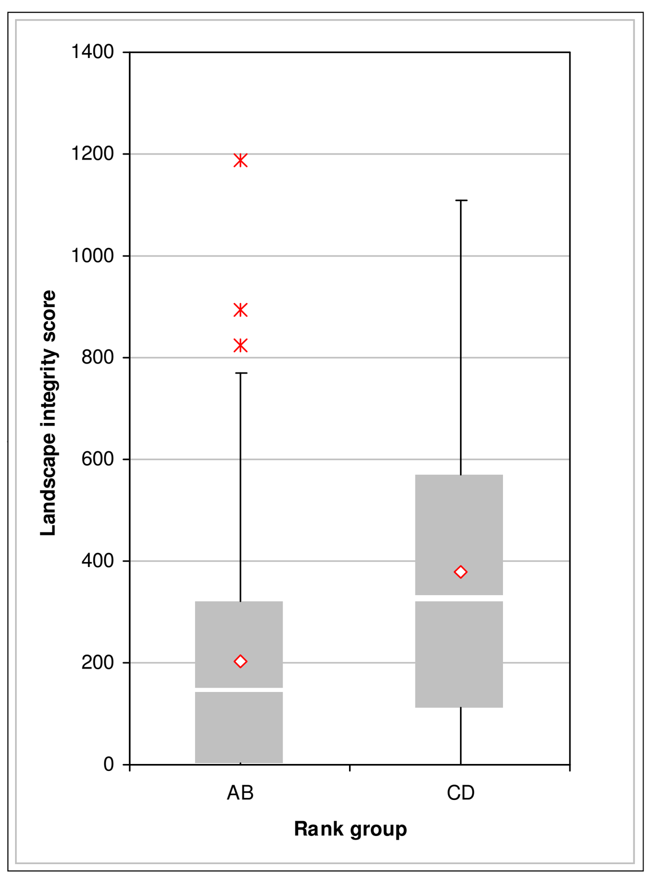
Testing the landscape integrity model against an independent evaluation of landscape integrity

We used a sample of plant community occurrence records from the CNHP Biotics database (2008) to generate landscape integrity scores, and compared the scores with the viability ranks of A, B, C, or D assigned by ecologists during field inventory work. The ranks typically reflect the degree of negative anthropogenic impact to a plant community observed by the ecologist in the field.

Rank	Viability	Rank Group
A	Excellent	AB – *good quality occurrences, likely to persist if current*
B	Good	*conditions continue in effect*
C	Fair	CD – *poor or marginal quality occurrences, not likely to*
D	Poor	*persist without direct intervention*



404 plant community occurrences visited within the last 5 years.

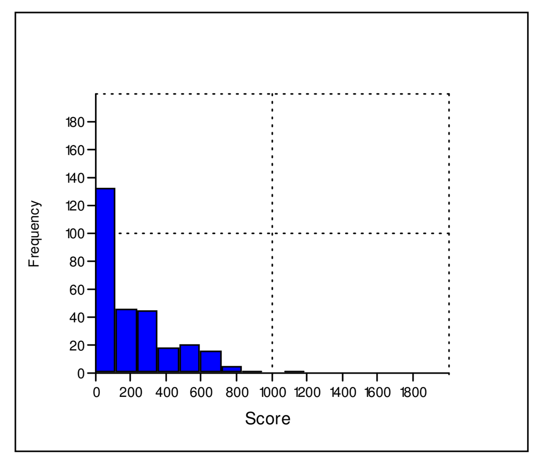


Test of difference in means
Welch's t = -5.7488, p << 0.0001

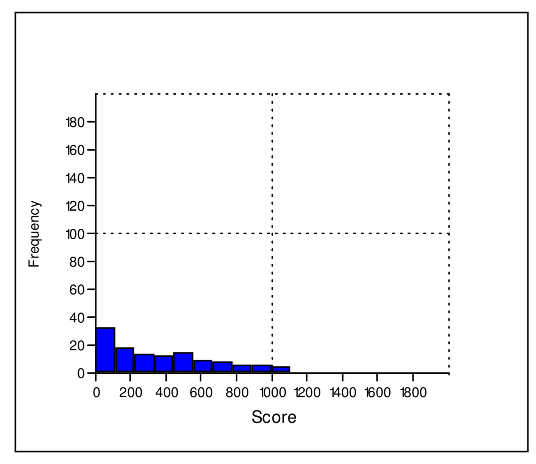
If landscape integrity scores are reflecting the ecologist's field evaluation of rank, we would expect:

- a difference in location of mean (AB-ranked with lower scores than CD-ranked)
- a difference in the shape of the distributions (due to zero-truncation of possible scores, the AB group is expected to have more zeros, and hence a more positively skewed distribution.

AB-ranked 17% zero scores



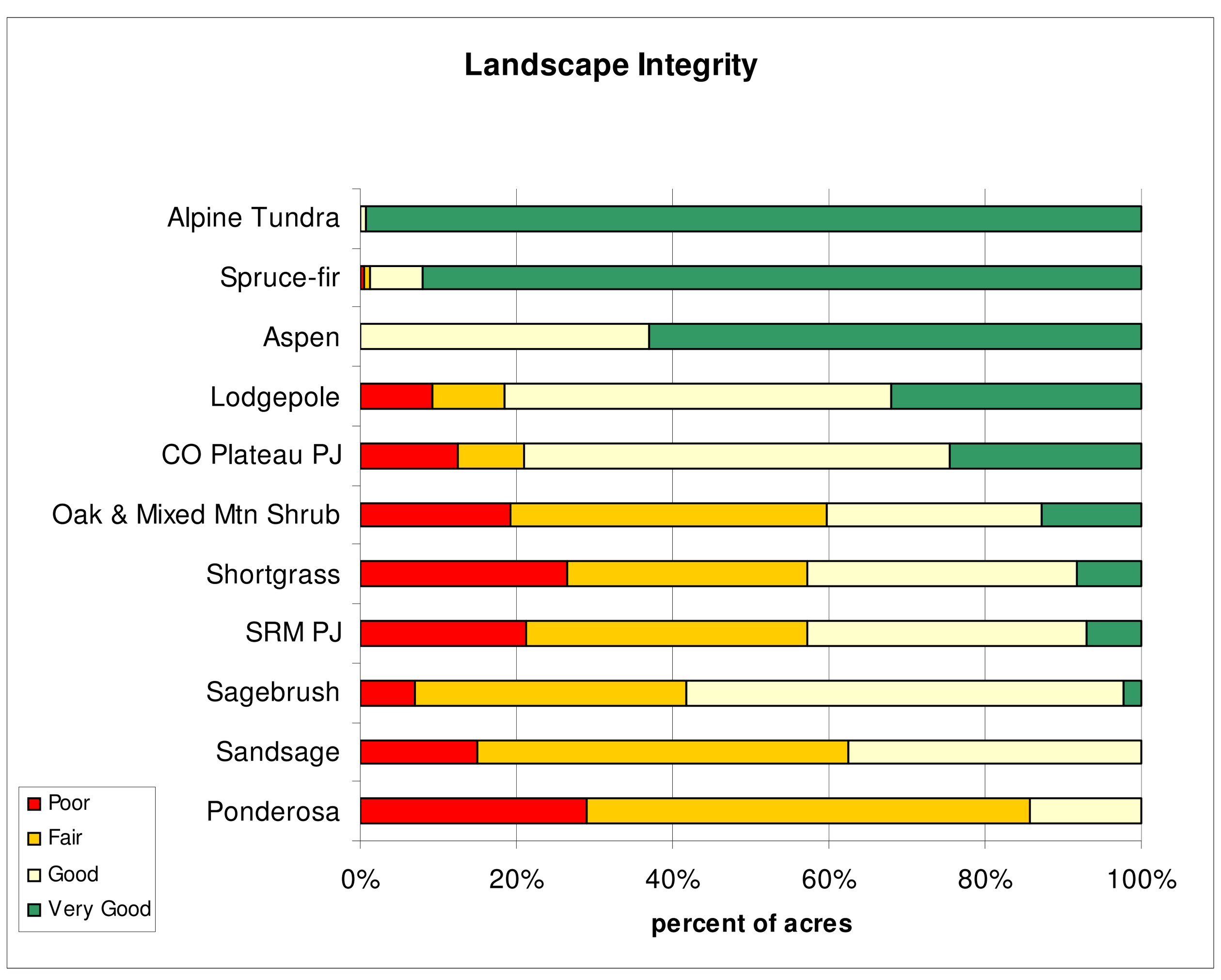
CD-ranked 4% zero scores



Applications

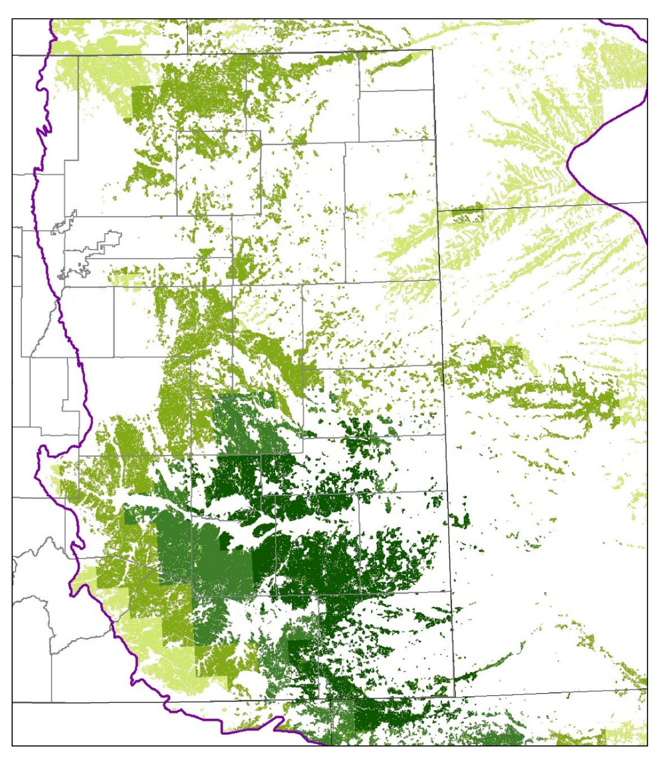
Colorado Biodiversity Scorecard

Landscape integrity was scored for eleven of Colorado's widespread ecological systems. Scores formed part of an overall biodiversity status score for occurrences of these ecosystems.



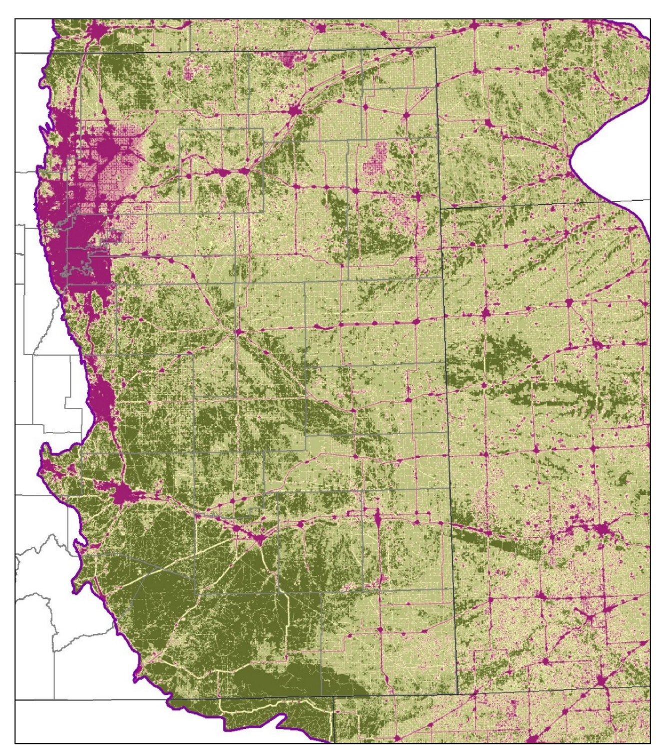
Shortgrass Prairie Partnership Conservation Evaluations

Similar methods were used in the Central Shortgrass Prairie to produce an ecoregional impacts assessment used as a filter in developing target conservation areas for species at risk.



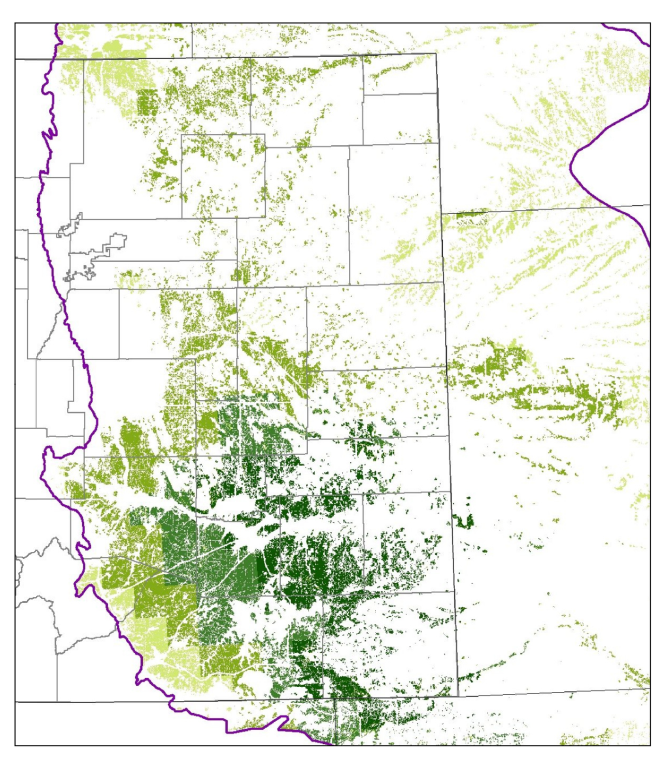
Vegetation optimal for Burrowing owl, with density from breeding bird survey.

+



Landscape integrity in the Central Shortgrass Prairie ecoregion.

=



Priority conservation areas for non-spatial evaluation

Conclusions

The model is not a substitute for on-the-ground evaluation

BUT

- It does reflect trends in viability as assessed by field ecologists
- It is useful as an initial evaluation for areas yet to be surveyed
- It is a good summary for landscape-level assessment where complete field survey is impractical

For more information

Colorado Natural Heritage Program
Warner College of Natural Resources
Colorado State University
254 General Services Bldg.
Fort Collins, CO 80523-8002

www.cnhp.colostate.edu

Colorado State University

The Nature Conservancy
Protecting nature. Preserving life.™

References

CNHP. 2008. BIOTICS database. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Tobler, W.R. 1970. A Computer Movie Simulating Urban Growth in the Detroit Region. Economic Geography, Vol. 46, Supplement: Proceedings. International Geographical Union. Commission on Quantitative Methods, (Jun., 1970), pp. 234-240.

Tuffly, M., and P. Comer. 2005. Calculating Landscape Integrity: A Working Model. Draft of 4/19/2005. NatureServe, Boulder, CO.