Appendix B – Colorado Statewide Forest Resource Assessment

Data Sources and Methods

Table of Contents

Forest Types

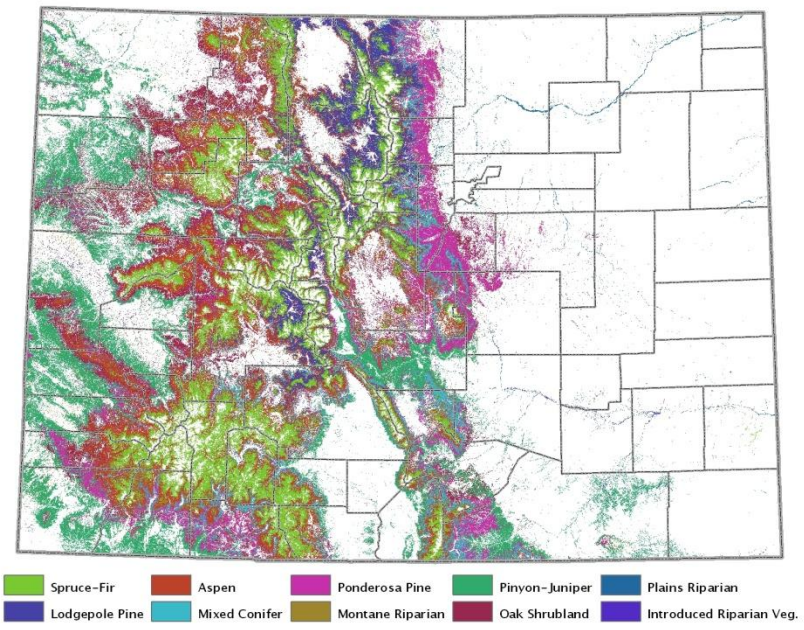
LANDFIRE vegetation data was used to identify the forests in Colorado. These data were reclassified into 10 forest types: spruce-fir, lodgepole, aspen, mixed conifer, ponderosa pine, montane riparian, piñon-juniper, oak shrubland, plains riparian and introduced riparian.

Reclassification criteria

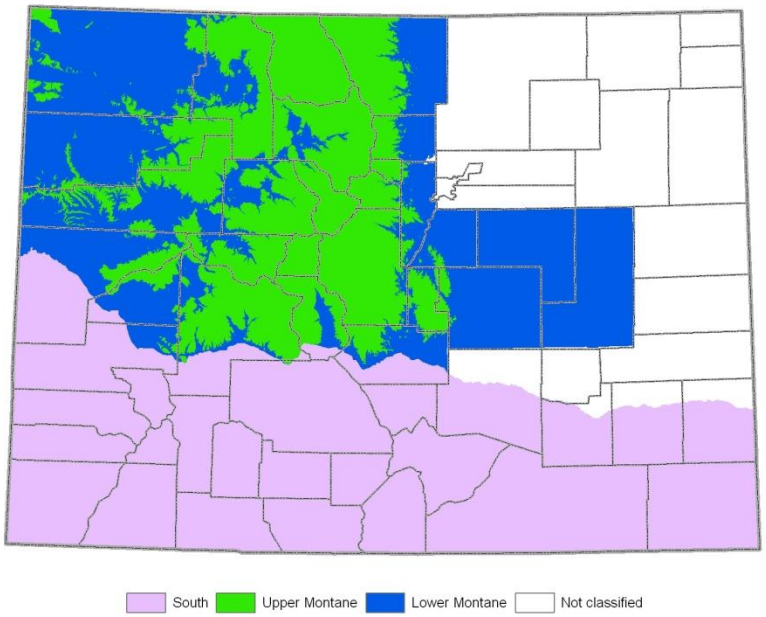
Table D1 describes the crosswalk between LANDFIRE vegetation classes and the forest types used in the assessment. One LANDFIRE class (2051 Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland) was known to be incorrect in the lower montane areas and was reclassified to ponderosa pine. The lower montane is defined as north of Highway 50; Arkansas River and Gunnison and Colorado rivers; and elevations below 8,500 feet in the southern counties, 8,000 feet in the central counties and 7,500 feet in the northern counties. The upper montane is defined as north of Highway 50; Arkansas River and Gunnison and Colorado rivers; and above 8,500 feet in the southern counties, 8,000 feet in the central counties and 7,500 feet in the northern counties. See map on next page for more detail.

Geoprocessing in ArcMap involved the initial reclassification based on LANDFIRE vegetation classes. A conditional statement then was used to divide the LANDFIRE class 2051 into mixed conifer for the upper montane and ponderosa pine for the lower montane.

Forest Types



Zones for Classifying Mixed Conifer



Data Sources

Vegetation - LANDFIRE existing vegetation type, 2006, www.landfire.gov.

Table D1 - Vegetation Crosswalk from LANDFIRE EVT to Forest Types

Spruce-Fir
- 2046 Northern Rocky Mountain Subalpine Woodland and Parkland
- 2055 Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
- 2056 Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland

Lodgepole
- 2050 Rocky Mountain Lodgepole Pine Forest
- 2167 Rocky Mountain Poor-Site Lodgepole Pine Forest

Aspen
- 2011 Rocky Mountain Aspen Forest and Woodland
- 2061 Intermountain Basins Aspen-Mixed Conifer Forest and Woodland

Mixed Conifer
- 2051 Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland (Upper Montane only)
- 2052 Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland
- 2208 Abies concolor Forest Alliance
- 2057 Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland

Ponderosa Pine

- 2051 Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland (Lower Montane only)
- 2054 Southern Rocky Mountain Ponderosa Pine Woodland
- 2117 Southern Rocky Mountain Ponderosa Pine Savanna
- 2166 Middle Rocky Mountain Montane Douglas-Fir Forest and Woodland

Piñon-Juniper

- 2059 Southern Rocky Mountain Piñon-Juniper Woodland
- 2119 Southern Rocky Mountain Juniper Woodland and Savanna
- 2049 Rocky Mountain Foothill Limber Pine-Juniper Woodland
- 2016 Colorado Plateau Piñon-Juniper Woodland
- 2115 Intermountain Basins Juniper Savanna

Oak Shrubland

- 2107 Rocky Mountain Gambel Oak-Mixed Montane Shrubland
- 2217 Quercus Gambelii Shrubland Alliance

Montane Riparian

- 2159 Rocky Mountain Montane Riparian Systems
- 2160 Rocky Mountain Subalpine / Upper Montane Riparian Systems
- 2154 Intermountain Basins Montane Riparian Systems

Plains Riparian

- 2162 Western Great Plains Floodplain Systems
- 2111 Western Great Plains Mesquite Woodland and Shrubland
- 2155 North American Warm Desert Riparian Systems

Introduced Riparian Vegetation

- 2180 Introduced Riparian Vegetation

Lands Available for Wood Products/Biomass

Lands available for wood products/biomass are those forested lands with a slope less than 50 degrees that are not designated roadless (2000 definition), wilderness area, a national park or national monument.

Methods

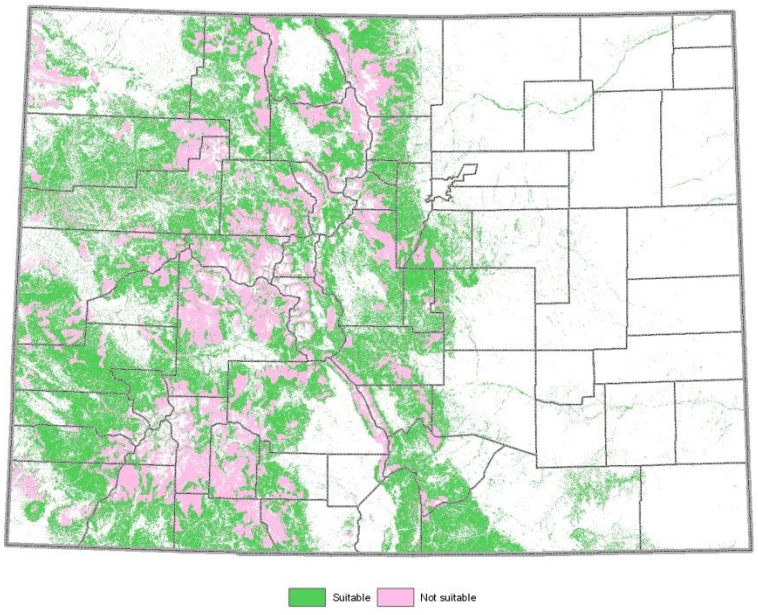
These lands were identified by the following steps:
Step 1. Wilderness areas, national parks and national monuments
Using COMaP, the following query was used "[MGMT_DESCRIPTION] LIKE '*Wilderness*' or [MGMT_DESCRIPTION] LIKE '*National Park*' or [MGMT_DESCRIPTION] LIKE '*National Monument*'."

Step 2. The geometry in the shapefiles for wilderness areas, national parks, national monuments and roadless areas was merged. An attribute was created to indicate "Presence" and set to 1.

Step 3. The merged geometry shapefile was converted to a 30-m raster using "Presence" as the value.

Step 4. The raster for the designated areas unsuitable for forest management and the raster of areas with a slope > 50 percent (based on 30-m digital elevation model (DEM)) were added and reclassed to a value of 1 for suitable lands and 0 for unsuitable lands for forest management.

Lands Available For Wood Products/Biomass



Data Sources

COMaP - Theobald, D.M., G. Wilcox, S.E. Linn, N. Peterson, and M. Lineal. 2008. Colorado Ownership, Management and Protection v7 database. Human Dimensions of Natural Resources and Natural

Resource Ecology Lab, Colorado State University, Fort Collins, Colo. 15 September. www.nrel.colostate.edu/projects/comap.

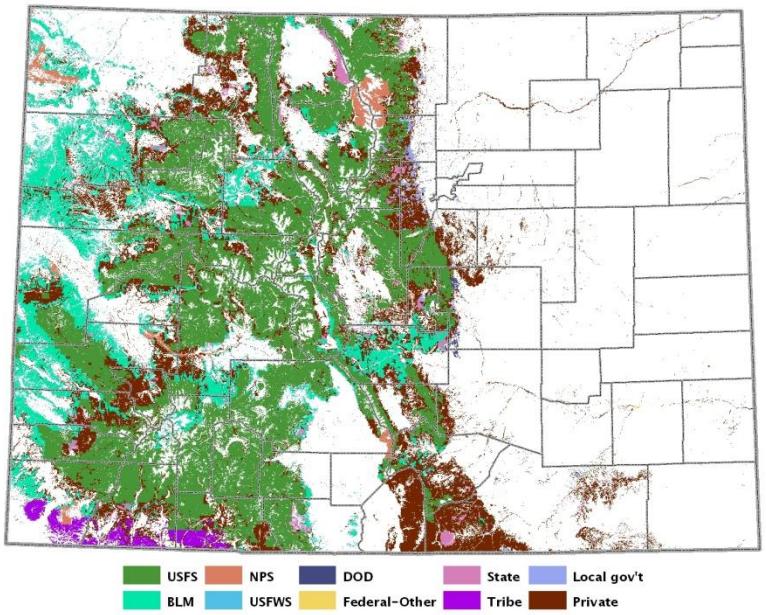
Roadless areas – USFS, 2000.

DEM (used for slope calculation) – USGS.

Forest Ownership

The Colorado Ownership, Management and Protection (COMaP) v.7 database was developed by Theobald et al., 2008, and provides extensive information on ownership and protected lands in Colorado. Ownership was grouped into 10 major categories: USFS, BLM, NPS, USFWS, DOD, other Federal, State, Tribe, Local Government and Private.

Ownership in the Forest



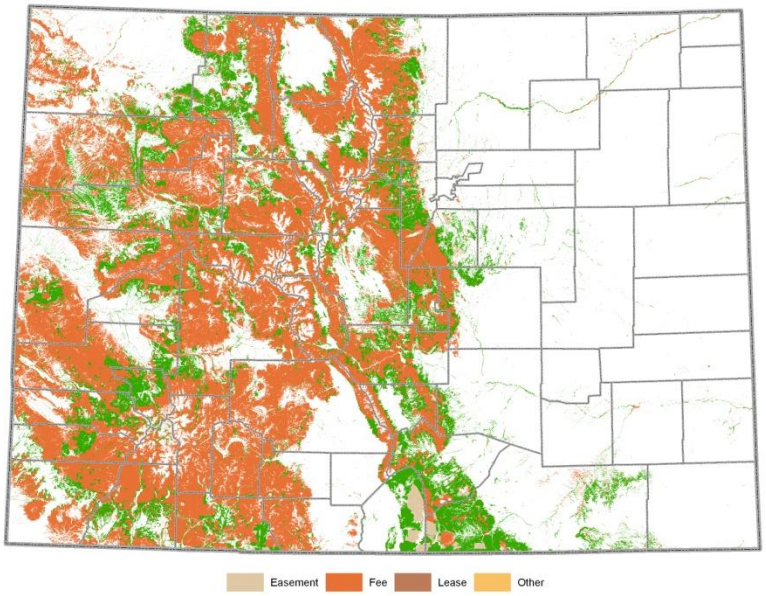
Data Source

COMaP - Theobald, D.M., G. Wilcox, S.E. Linn, N. Peterson, and M. Lineal. 2008. Colorado Ownership, Management and Protection v7 database. Human Dimensions of Natural Resources and Natural Resource Ecology Lab, Colorado State University, Fort Collins, Colo. 15 September. www.nrel.colostate.edu/projects/comap.

Protected Lands

The Colorado Ownership, Management and Protection (COMaP) v.7 database was developed by Theobald et al., 2008, and provides extensive information on ownership and protected lands in Colorado. Protected lands were grouped into four major categories: Fee, Easement, Lease and Other. Fee properties are those protected by ownership and include federal lands. Conservation easements, leases on the property, and other mechanisms such as deed restrictions are additional methods of conserving the land.

Protected Lands in the Forest



Data Source

COMaP - Theobald, D.M., G. Wilcox, S.E. Linn, N. Peterson, and M. Lineal. 2008. Colorado Ownership, Management and Protection v7 database. Human Dimensions of Natural Resources and Natural Resource Ecology Lab, Colorado State University, Fort Collins, Colo. 15 September. www.nrel.colostate.edu/projects/comap.

Core Data Layers

In order to answer key questions for the assessment such as “Where does priority wildlife habitat have a high risk of wildfire?,” the core data layers were reclassified to a common scale so that they could be combined.

The scale for each data layer ranges from 0 to 4 and the values correspond to the following:

0 No Data or Not Applicable
1 Low
2 Moderate
3 High
4 Very High

The method used to rank the core data layers varies for each dataset and is documented in the section that described the individual data layer.

Departure from Modeled Historical Conditions

Departure from modeled historical conditions is an indication of the difference between the current vegetation composition and structure and modeled composition and structure conditions at the time of pre-European settlement. Note that LANDFIRE refers to the data layer as Fire Regime Condition Class (FRCC) Departure Index, but in actuality, the LANDFIRE National FRCC data layer describes changes in vegetation composition and structure, and is only partially related to fire (Smith, 2009). Land conversion and management practices also impact departure.

Fire Regime Condition Class (FRCC) is the departure index divided into three equal categories (that is, FRCC 1 corresponds to a departure index of 0-33 percent; FRCC2 34 percent to 66 percent; FRCC3 67 percent to 100 percent).

Methods (by LANDFIRE)

Modeled conditions at the time of pre-European settlement were obtained by simulating natural vegetation succession and disturbance over many hundreds of years using models developed by local experts. The results of many simulations were integrated to create an approximation of the percent of vegetation in each vegetation class (e.g. early seral, late seral) at the time of pre-European settlement. See Table D2 for an example of modeled conditions for the Southern Rocky Mountain Ponderosa Pine Woodland Biophysical Setting. See www.landfire.gov for a full description of the terms and concepts used in LANDFIRE.

Table D2. Example of Pre-European Conditions (taken from the LANDFIRE National Model Description of the Southern Rocky Mountain Ponderosa Pine Woodland Biophysical Setting).

Class	Description	Percent In Class
A	Openings with up to 10% cover by overstory dominated by ponderosa pine and sometimes Douglas-fir. Some openings may persist.	10%
B	Greater than 50% canopy cover in the northern Front Range (above c. 6,500 feet) and >30% canopy cover in the southern Front Range.	10%
C	Greater than 50% canopy cover in the northern Front Range (above c. 6,500 feet) and <30% canopy cover in the southern Front Range.	25%
D	Less than 50% canopy cover in the northern Front Range (above c. 6,500 feet) and <30% canopy cover in the southern Front Range.	40%
E	Greater than 50% canopy cover in the northern Front Range (above c. 6,500 feet) and >30% canopy cover in the southern Front Range.	15%

Current vegetation age class and structure were estimated from data layers derived from LANDSAT TM imagery (1999-2001). LANDFIRE National FRCC is computed for each Biophysical Setting (BpS) for each Ecological Subsection (see www.landfire.gov).

The actual departure index is computed as 100 minus Similarity, where Similarity is the sum of the minimum of Pre-European and Current percentage across the seral stages (Smith, 2009; Hann et al. 2004). See below for an example using the Southern Rocky Mountain Ponderosa Pine Woodland (values are approximate). For this example, the departure from modeled historical conditions is 50 percent, which is 100 minus the total Similarity (the sum of the final row).

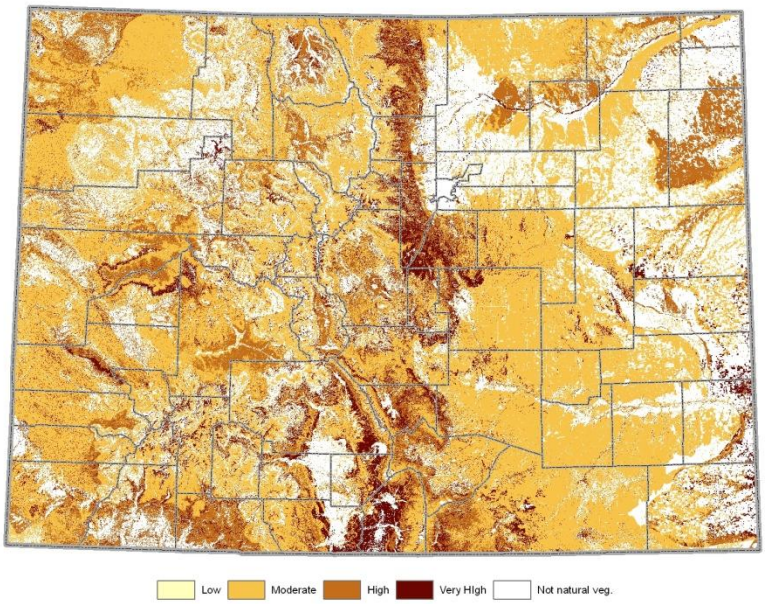
Class	A	B	C	D	E
Pre-European	10%	10%	25%	40%	15%
Current	10%	53%	32%	4%	1%
Similarity	10%	10%	25%	4%	1%

LANDFIRE has extensive documentation describing their large-scale effort. See www.landfire.gov for a more detailed description of the Development of the Departure from Modeled Conditions data layer.

Ranking

Departure index values were categorized into equal intervals in a similar fashion to FRCC. Whereas FRCC divided the departure index into three equal 33-percent categories, we used four equal 25-percent categories (Low, Moderate, High and Very High Departure).

Departure Index



Data Sources

Departure Index – FRCC departure index, LANDFIRE, 2006, http://www.landfire.gov.

Smith, J. – personal communication, 2009.

References

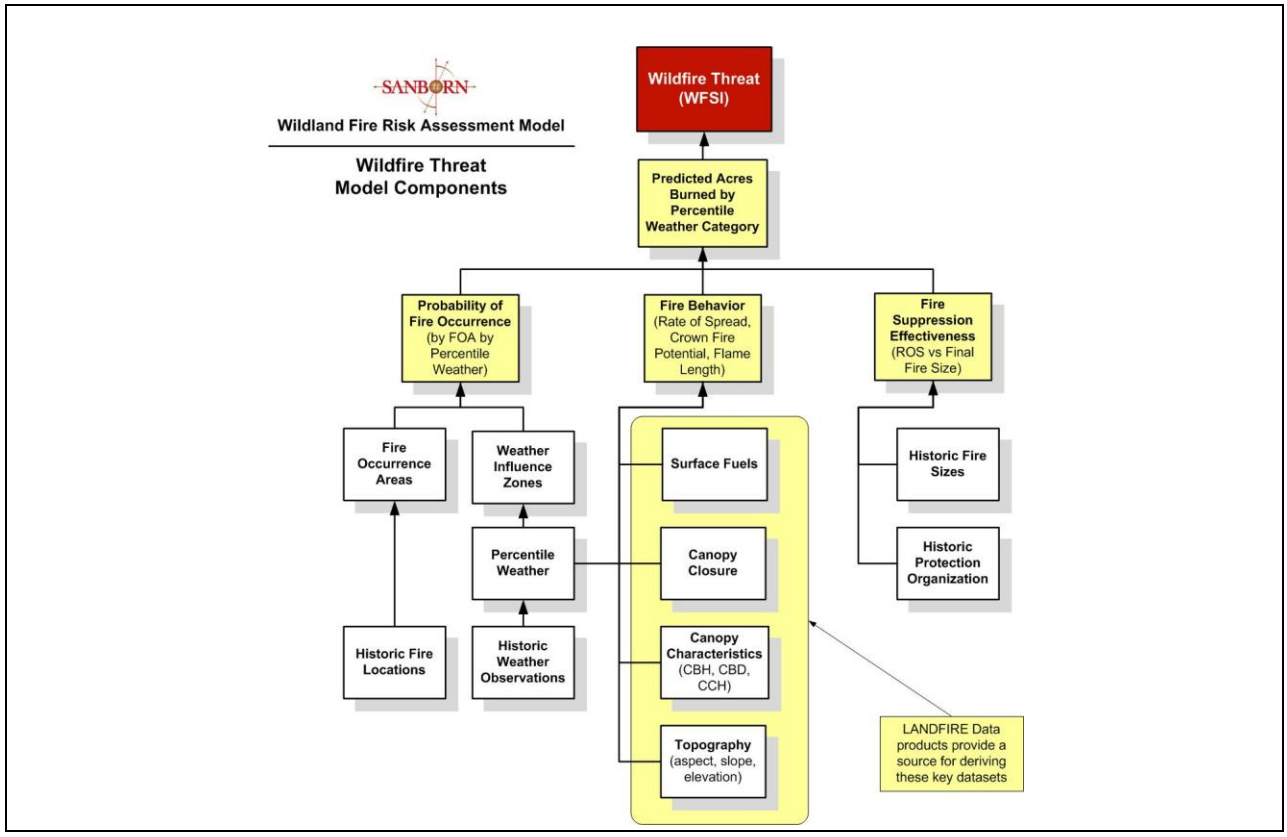
Hann, W.; Shlisky, A.; Havlina, D.; Schon, K.; Barrett, S.; DeMeo, T.; Pohl, K.; Menakis, J.; Hamilton, D.; Jones, J.; Levesque, M.; Frame, C. 2004. Interagency Fire Regime Condition Class Guidebook. Last update January 2008: Version 1.3.0 [Homepage of the Interagency and The Nature Conservancy fire regime condition class website, USDA Forest Service, US Department of the Interior, The Nature Conservancy, and Systems for Environmental Management]. [Online]. Available: www.frcc.gov.

Wildland Fire Susceptibility Index

The Wildland Fire Susceptibility Index (WFSI) is a measure of wildfire threat representing the probability of a wildfire occurring. The dataset was developed by Sanborn Map Company (Colorado Springs, Colo.), a contractor to CSFS, as part of a western Colorado risk assessment conducted in 2006-2007. The dataset uses an updated version of LANDFIRE data products (surface fuels, canopy characteristics) in combination with Sanborn's wildfire risk assessment methods to provide a quantitative measure of wildfire threat for western Colorado.

Methods (by Sanborn)

The following diagram presents the general WFSI model.



The WFSI model combines the following datasets to derive wildfire threat:

- landscape characteristics, such as surface fuels, canopy characteristics and topography to determine fire behavior outputs
- historical weather observations to derive percentile weather
- historical fire ignition locations to derive fire occurrence
- historical fire report data that reflects suppression effectiveness

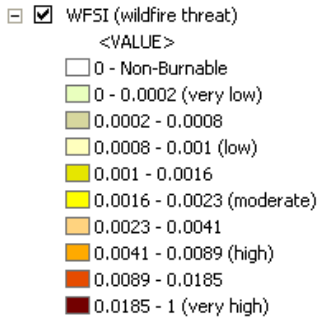
These datasets are parameterized using analysis that includes calibration of predicted acres burned versus historical acres burned to ensure the model does not over-predict future probabilities.

WFSI is calculated using the standard LANDFIRE 30m-by-30m cell resolution. WFSI is calculated on a percentile weather category basis for burnable areas within the project area. The four values from the four Percentile Weather Categories are added to obtain the final WFSI– a probability value that a fire will occur at that location. The model includes spatial operations to smooth calculated cell results based on spatial statistics.

Threat classes (i.e. Very Low to Very High) are defined using a frequency histogram of the WFSI output values, and the WFSI is presented as a classified map. The calculated WFSI dataset includes probability values for each 30m cell, and this dataset is ideal for identifying and categorizing the wildfire threat to Communities-at-Risk, as well as other areas of concern, such as watersheds, basins, planning districts, counties, etc.

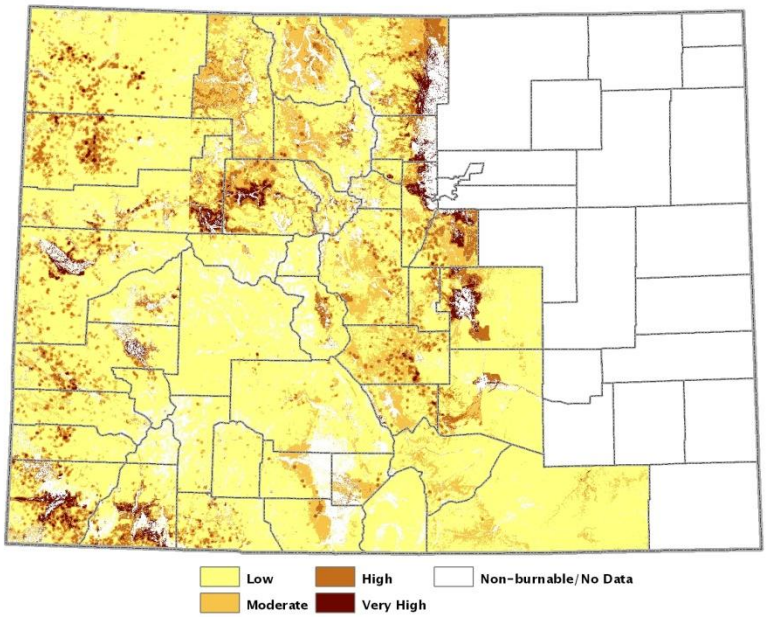
Ranking

The following classes were defined for WFSI based on an analysis of the calculated output values:



These nine default classes were reduced to the standard four categories of the assessment by combining classes, without changing the class breaks developed by Sanborn.

Wildland Fire Susceptibility Index (WFSI)



Data Sources

Input:

- LANDFIRE 2001 datasets (surface fuels, canopy closure, crown base height, canopy bulk density, tree height, elevation, vegetation) - http://www.landfire.gov/
- Fire history reports and ignition locations (2002-2006)
- Historical weather observations (1988-2008)
- Pine beetle survey data (2002-2006)
- Fire burn severity (2000-2004 for fires larger than 4,000 acres)

Intermediate output:

- Updated LANDFIRE fuels and canopy datasets
- Weather influence zones
- Percentile weather
- Fire occurrence areas
- Aspect and slope (derived from LANDFIRE data)
- Rate of spread (four weather percentiles)

Colorado State Forest Service (CSFS) 2008. Colorado Fire Risk Assessment. Fort Collins, Colo. (work done by Sanborn under contract to CSFS).

References

http://www.southernwildfirerisk.com/

Wildland Fire Intensity Index

The Wildland Fire Intensity Index (WFII) was developed by the USFS in order to capture areas at risk of crown fire. The data layer supplements the WFSI (described in the previous section), which primarily highlights concerns from rate of spread.

Methods (by USFS)

The input data used for the development of the WFII came from the Colorado Wildfire Risk Assessment Statewide dataset prepared by Sanborn (see section on the WFSI). FlamMap was used to calculate flame length and crown fire activity.

The Colorado Risk Assessment (CRA) leveraged LANDFIRE data products by utilizing fuels and canopy data as the primary input data sources. As part of the CRA, the LANDFIRE fuels and canopy data were updated to reflect insect and large wildfire activity since 2000. The following layers from the CRA were utilized to prepare landscape (.lcp) files for each of the nine Weather Influence Zones (WIZ) created for the CRA.

Input Data	Units
Elevation	Meters
Slope	Degrees
Aspect	Categories 1-25
Fuel Model	Standard fuel models; original 13 models and Scott & Burgan models.
Canopy Cover	Categories 1-4
Tree Height	Meters*10
Crown Base Height	Meters*10
Crown Bulk Density	kg/m3*100,

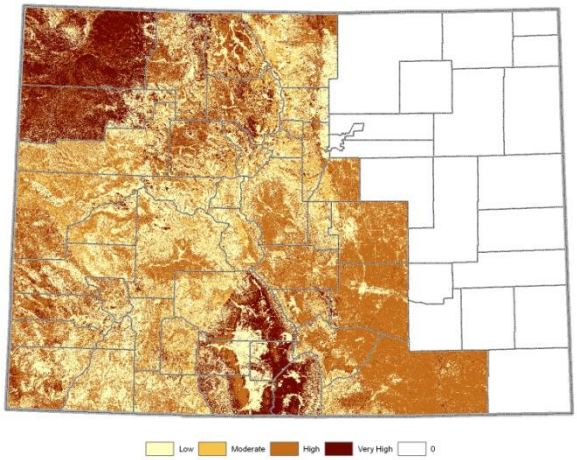
For each WIZ, the high percentile weather from the CRA was utilized in FlamMap to categorize fire behavior in the WIZ by flame length and crown fire activity. Two adjustments were made to the weather inputs 1) wind direction was assumed to be uphill (aligned with slope) in all instances, and 2) the 10-minute average wind speed was adjusted to reflect the maximum probable gust associated with the average wind speed.

Outputs from FlamMap were categorized as follows:

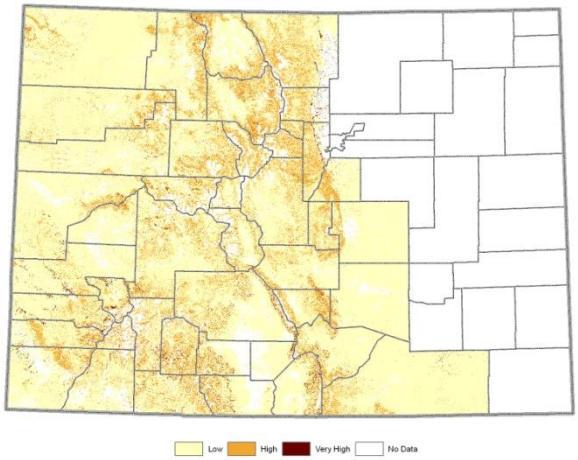
Class	Flame Length
1	0-4 feet
2	4-8 feet
3	8-11 feet
4	11-15 feet
5	15-50 feet
6	50-250 feet

Class	Crown Fire
0	None
1	Surface
2	Passive
3	Active

Flame Length



Crown Fire Activity



FlamMap outputs then were combined for the nine WIZ and then reclassified as follows:

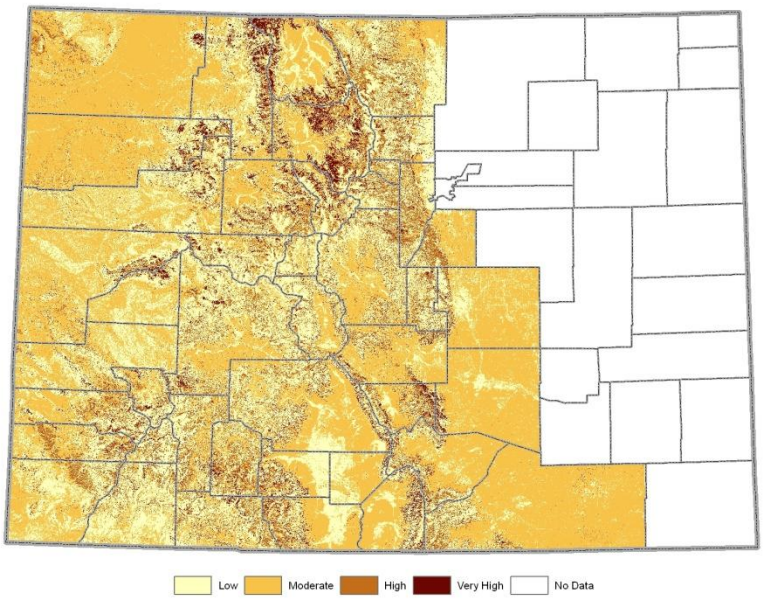
Flame Length	
0-4 feet	Low
4-8 feet	Moderate
8-15 feet	High
> 16 feet	Very High

Crown Fire	
None	Non burnable
Surface	Low
Passive	High
Active	Very High

Ranking

The final data layer was created by weighting the crown fire activity by 65 percent and the flame length by 35 percent. The Natural Breaks method was used to rank the data according to Low, Moderate, High and Very High.

Wildland Fire Intensity Index (WFII)



Data sources

Colorado State Forest Service (CSFS) 2008. Colorado Fire Risk Assessment. Fort Collins, Colo.

LANDFIRE. (2007, January - last update). [Homepage of the LANDFIRE Project, U.S. Department of Agriculture, Forest Service; U.S. Department of Interior], [Online]. Available: http://www.landfire.gov/index.php [2009, June 12].

References

FlamMap, version 3.0 http://www.firemodels.org/content/view/14/28/.

Insect and Disease Mitigation Potential

The U.S. Forest Service developed a data layer for the assessment to indicate areas where the potential exists for forest management to mitigate the potential for unwanted impacts from insects and disease. The data layer is a combination of insect and disease activity, and level of risk of infestation based on the basal area.

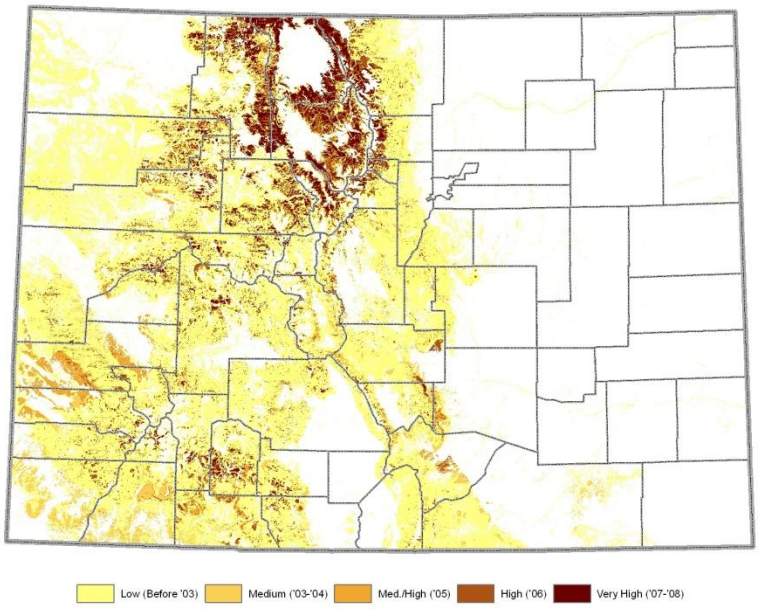
Methods (by USFS)

Insect and Disease Activity

The purpose of this data layer is to identify areas where significant insect and disease (I&D) activity has or is about to occur. Two data layers were used: 1) Recent I&D Activity and 2) I&D Activity Frequency. Recent activity is based on aerial survey data, with 2007-2008 data being given a very high ranking, 2006 data a high ranking, etc. The frequency data layer refers to areas that have had several years of impacts.

To create the final I&D activity layer, the layers were weighted (Recent Activity 83 percent; Activity Frequency 17 percent) and combined.

Insect and Disease Activity



Risk Due to Stocking Levels

The risk data layer provides an indication of forested areas with stocking levels that place forest stands at risk to I&D activity. Based on 20 tree-species models used in Colorado for the 2006 national Insect and Disease Risk Map, a basal area of 80 square feet was determined to be an approximate value at which risk to I&D begins, and a basal area of 160 square feet on average is the approximate value at

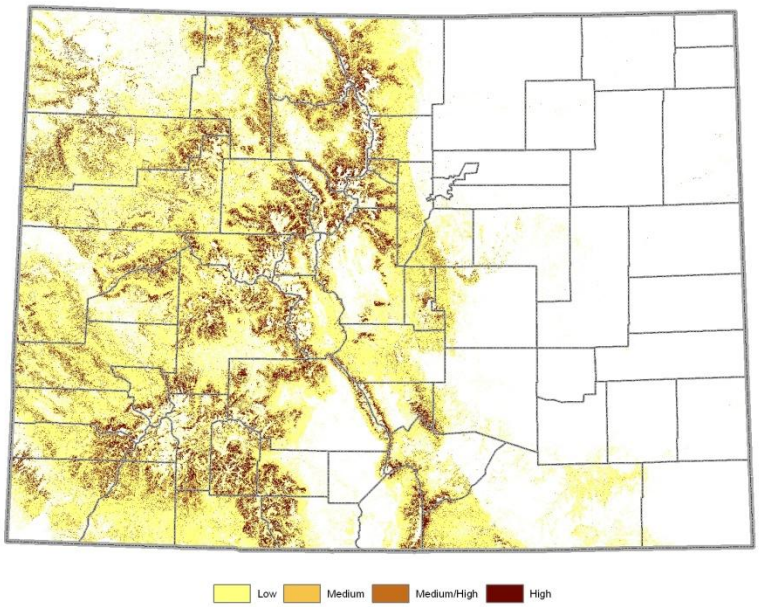
which the risk peaks. Table D3 shows the basal area at which risk begins and peaks for several agent/host pairs.

Table D3. Basal Area at which Risk Begins and Peaks for Several Agent/Host Pairs

Agent	Host	BA - Risk Begins	BA - Risk Peaks
Douglas Fir Beetle	Douglas Fir	100	250
Western Spruce Budworm	Douglas Fir	80	100
Mountain Pine Beetle	Limber Pine	80	120
Mountain Pine Beetle	Lodgepole Pine	80	120
IPS Engraver Beetle	Ponderosa Pine	80	150
Mountain Pine Beetle	Ponderosa Pine	80	120
Roundheaded Pine Beetle	Ponderosa Pine	60	320
Western Pine Beetle	Ponderosa Pine	80	120
Spruce Beetle	Spruce	100	150
Western Balsam Bark Beetle	Subalpine Fir	60	260
Western Spruce Budworm	Subalpine Fir	80	100
Mountain Pine Beetle	Southwestern White Pine	80	120
Western Spruce Budworm	White Fir	80	100
Mountain Pine Beetle	Whitebark Pine	80	120

The data layer was created by categorizing basal area according to level of risk.

Risk of Insect and Disease Infestation from Overstocking



Insect and Disease Mitigation Potential

In order to determine areas with mitigation potential, forest in the highest insect and disease category was dropped from the analyses because it was determined that the forest in those locations was too damaged for forest management to be helpful.

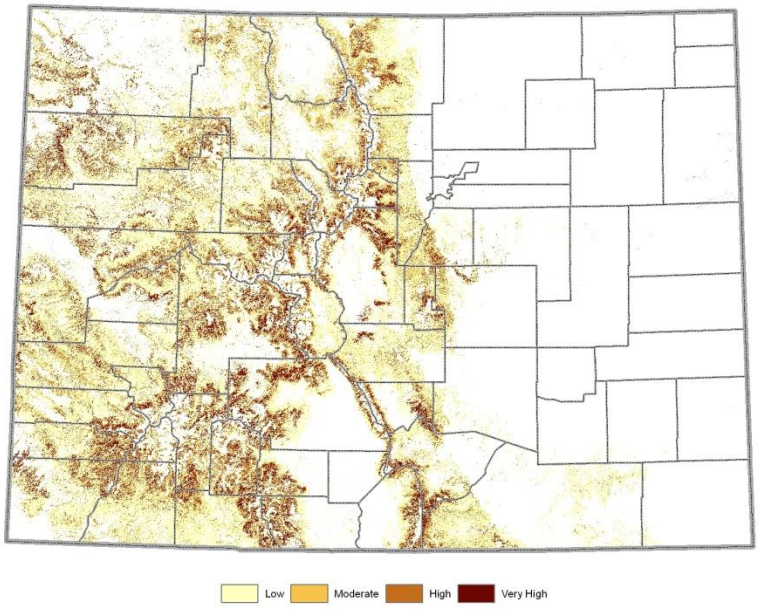
The risk of infestation due to overstocking data layer was weighted 65 percent and the I&D activity layer was weighted 35 percent to create the final layer. The data layer shows areas that are most at risk that have the best chance of benefiting from forest management.

Ranking

The data was reclassed according to the following criteria, as recommended by the USFS:

Original classification by USFS	**Rank**
0 - 4	Low
5 - 6	Moderate
7 - 8	High
9 - 10	Very High

Insect and Disease Mitigation Potential



Data Sources

Aerial survey data – USFS, 2003 – 2008.

30m basal area – USFS/FHTET, 2009 (ground verification of data is currently in progress).

Insect and Disease Mitigation Potential – USFS/FHTET, Frank Krist, 2009.

References

Risk Map – http://www.fs.fed.us/foresthealth/technology/pdfs/FHTET2007-06_RiskMap.pdf.

Basal Area and Risk of Infestation – http://www.fs.fed/us/foresthealth/tehcnology/pdfs/IW_Workbook_2007.pdf.

Potential Post-fire Erosion Risk in Important Watersheds for Drinking Water

The priority watersheds for the assessment were determined by evaluating the risk of potential post-fire soil erosion within forested watersheds that are important for drinking water. First, the method for identifying the relevant watersheds is discussed and then the method for ranking the relative risk of erosion within these watersheds is covered.

Important Watersheds for Drinking Water

To determine the important watersheds for drinking water, HUC12s (also known as sixth-level watersheds) were identified that contain one or more of the following:

1) A source intake for drinking water
2) A reservoir that is upstream from a source intake
3) A withdrawal point for a transbasin diversion
4) Within 5 miles of one of the above

Following are details for determining the HUC12s associated with each of the criteria:

- Source Intakes – Source intake refers to the works or structures at the head of a conduit through which water is diverted from a source (e.g., river or lake) into the treatment plant. The locations of the source intakes for drinking water were part of a restricted dataset and were obtained from the Colorado Department of Public Health and Environment. The associated HUC12s were determined using "Select By Location" in ArcGIS.

- Upstream Reservoirs – TNC, in conjunction with CSU, has developed a fully connected stream network for Colorado. A toolset called FLoWS developed at CSU (Theobald et al., 2005) allows values to be accumulated upstream or downstream along the network. It also allows the stream segments upstream or downstream from a given point to be identified. "Select Upstream Features" was used identify streams upstream of a source intake.

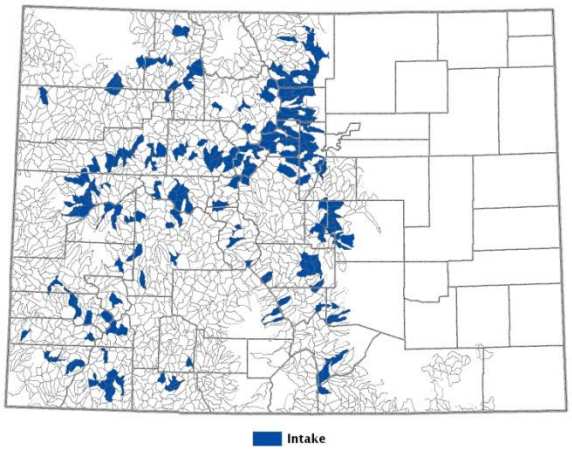
  A "Select By Location" then was used on the selected upstream streams to determine the associated reservoirs (NHDPlus waterbodies). "Select By Location" was used to identify the HUC12s containing the reservoirs

- Transbasin Diversions – No single dataset was available to locate the withdrawal points for transbasin diversions. The locational information was derived through internet searches on each transbasin diversion.

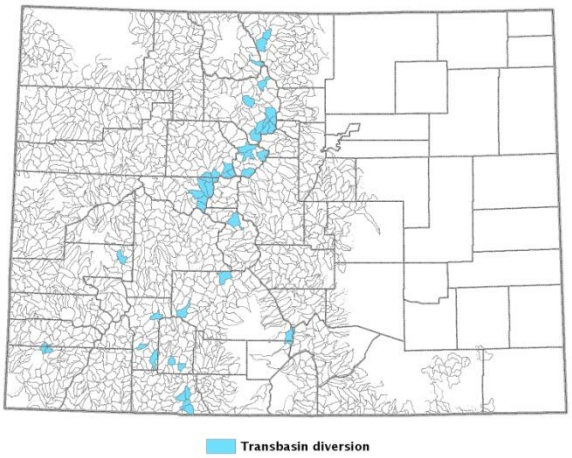
- 5 Miles Upstream – Erosion in the area upstream of a source intake, reservoir, or transbasin diversion also could have a significant impact on drinking water supply. Five miles was selected as a fixed distance to look upstream because of a municipal ordinance that authorizes municipalities to maintain and protect the watershed within 5 miles of any infrastructure.

A tool within FLoWS ("Select Upstream Cumulative") allows the user to set the cumulative distance from a point on the stream network. By setting the distance to 5 miles, all stream reaches within 5 miles of a source intake, upstream reservoir or withdrawal point for a transbasin diversion were identified and the associated HUC12s were determined by using the "Select By Location" tool within ArcGIS.

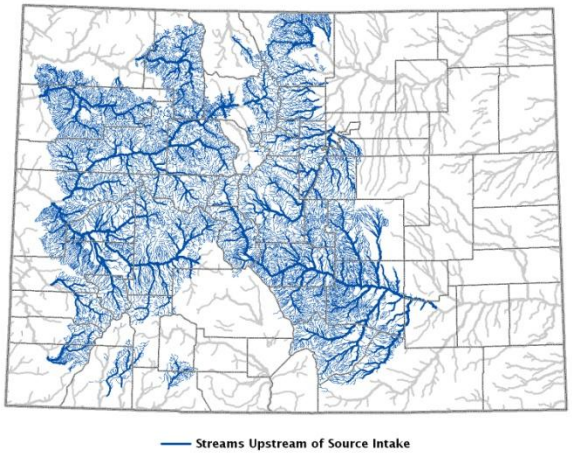
Forested HUC12s Containing Source Intakes



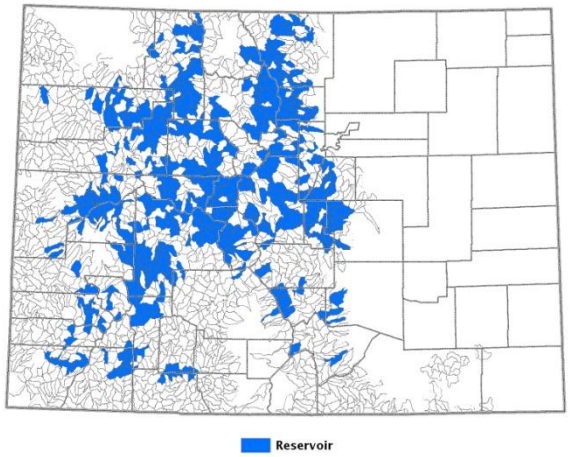
Forested HUC12s Containing Withdrawal Points for Transbasin Diversions



Streams Upstream of a Source Intake

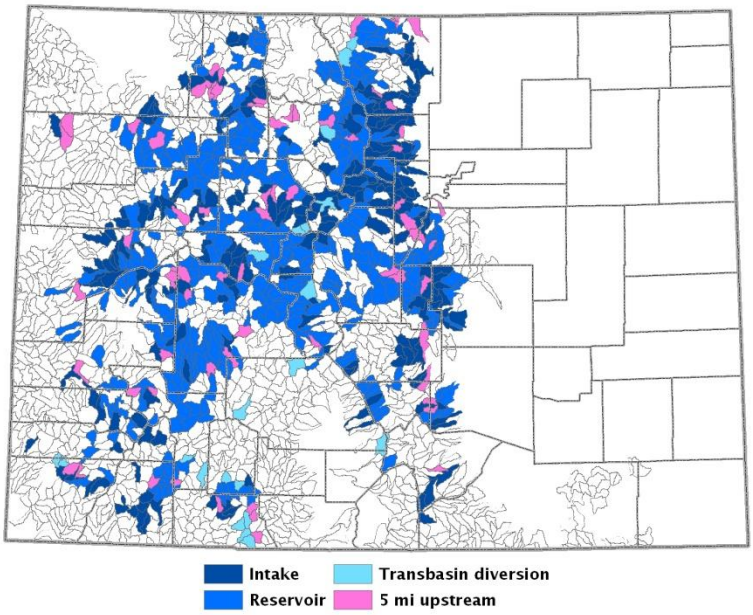


Forested HUC12s Containing Reservoirs Upstream of Source Intakes



- Important Watersheds for Drinking Water – The full set of watersheds identified by the process are shown below in the following order: intakes, upstream reservoirs, transbasin diversion and HUC12s within 5 miles of these structures.

Important Watersheds for Drinking Water



Soil Erosion

Post-fire Soil Erosion Model Development

Miller et al. (2006, 2007) developed a model to predict potential post-fire erosion for LANDFIRE zones 23 and 28, which cover most of the forest in Colorado, using software called GeoWEPP (the Geo-spatial interface for the Water Erosion Prediction Project). WEPP is a process-based model that predicts erosion after a fire. The model used vegetation types and simulated weather conditions as input to the first-order fire-effects model (FOFEM) to predict the amount of bare soil that would result if a fire occurred. The percent of bare soil, soil type, topography and climate then were used to predict the resulting erosion on a hillside. See Miller et al. publications for a full description of the development of the erosion model.

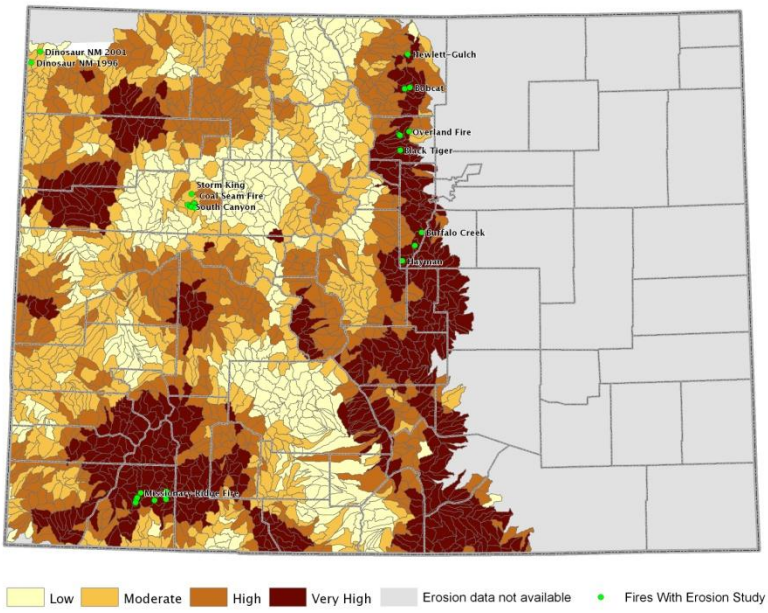
Erosion studies at recent fires

Several post-fire erosion studies have been completed at the sites of recent fires in Colorado (see Moody and Martin, 2009; Gartner, 2005; Gartner et al., 2008). The sites of the erosion studies, all of which had significant erosion, were used to set thresholds for the predicted post-fire erosion values. The predicted erosion amounts from the Miller et al. model were categorized into seven quantiles.

Ranking

The data were reclassified according to: Low (1st quantile), Moderate (2nd and 3rd quantiles), High (4th and 5th quantiles), and Very High (6th and 7th quantiles). Sites where post-fire erosion has been measured generally fell into the Moderate, High, or Very High potential erosion categories, indicating that the model is doing a reasonable job of identifying those areas that might experience post-fire erosion.

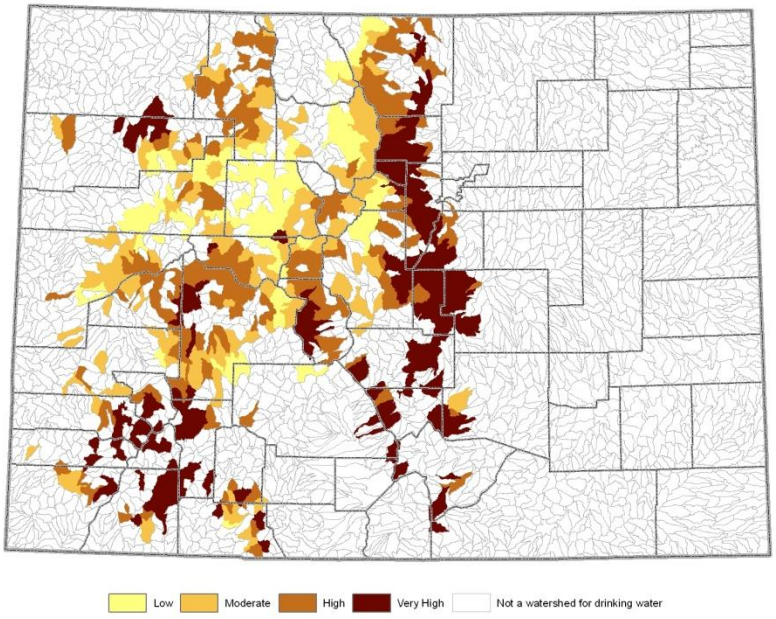
Potential Post-fire Erosion Categories and Actual Post-fire Erosion Studies



Potential Post-fire Erosion Risk in Important Watersheds for Drinking Water

The final data layer was created by a spatial overlay of the categorized potential post-fire erosion risk with the important watersheds for drinking water.

Potential Post-fire Erosion in Important Watersheds for Drinking Water



Data Sources

HUC12s / 6th-level watersheds - United States Geological Survey (USGS), Colorado Water Science Center, HUC12s (1:24,000), http://datagateway.nrcs.usda.gov/

Source Intakes – Colorado Department of Public Health and Environment, 2001, Source Water Assessment Phase.

NHDPlus waterbodies (for reservoirs) – U.S. Environmental Protection Agency (USEPA) and the U.S. Geological Survey (USGS), 2005, Waterbodies shapefile, http://www.horizon-systems.com/nhdplus.

Transbasin diversions - Colorado Statewide Measures report, The Nature Conservancy, in preparation, 2009.

Colorado stream network – The Nature Conservancy (TNC) and Colorado State University (CSU), 2009.

Erosion risk – Colorado State University, 2005 (see reference to Miller et al. paper), data distributed by author.

Fire studies – Coordinates of fire studies taken from papers referenced below (Moody and Martin, 2009; Gartner, 2005; Gartner et al. 2008).

References

Municipal ordinance for 5 miles upstream of source intake
Colorado Statutes/TITLE 31 GOVERNMENT - MUNICIPAL/POWERS AND FUNCTIONS OF CITIES AND TOWNS/ARTICLE 15 EXERCISE OF MUNICIPAL POWERS/PART 7 PUBLIC PROPERTY AND IMPROVEMENTS/31-15-707. Municipal utilities.

Colorado stream network
Theobald, D. M., J. Norman, E. Peterson, and S. Ferraz, 2005. Functional Linkage of Watersheds and Streams (FLoWS): Network-based ArcGIS tools to analyze freshwater ecosystems, Natural Resource Ecology Lab/Colorado State University, http://www.nrel.colostate.edu/projects/starmap/download/flows /FLoWS_ESRI_2005_paper.pdf.

Colorado Statewide Measures Report, The Nature Conservancy, in preparation, 2009.

Potential Post-fire Erosion Risk
Miller, M. E. Ph.D. Thesis, University at Buffalo, Remote Sensing and Hydrological Modeling of Burn Scars. Feb. 2007.

Miller, M. E. and L. H. MacDonald, 2006, Final report: Predicting Post-fire Forest Erosion in the Western U.S. Submitted to the U.S. environmental Protection Agency, June 2006. 42 p.

Erosion Studies for Recent Fires
Moody, J. A., and D. A. Martin, 2009. Synthesis of sediment yields after wildland fire in different rainfall regimes in the western United States, *International Journal of Wildland Fire*, 18, 96-115.

Gartner, J. E., 2005. Relations between wildfire related debris-flow volumes and basin morphology, burn severity, material properties and triggering storm rainfall. Thesis submitted in partial fulfillment of the degree of Masters of Arts, Department of Geography, University of Colorado, 76 p.

Gartner, J. E., S. H. Cannon, P. M. Santi, and V. G. Dewolfe, 2008. Empirical models to predict the volumes of debris flows generated by recently burned basins in the western U.S., Geomorphology, 96: 339-354, doi: 0.1016/j.geomorph.2007.02.033.

Members of the Front Range Fuels Treatment Partnership Roundtable Data Refinement Work Group and others kindly provided input to this analysis:

Carl Chambers, USFS; John Duggan, Colorado Dept. of Public Health and Environment; Skip Edel, CSFS; Dave Hessel, CSFS (work group co-chair); Jeff Kitchens, BLM; Jan Koenig, TNC; Paige Lewis, TNC; Deborah Martin, USGS (work group co-chair); Mike McHugh, Aurora Water; Brad Piehl, JW Associates, Inc.; Chris Trease, Colorado River Water Conservation District; Layne Wyatt, Northwest Colorado Council of Governments-Water Quality/Quantity Committee.

Wildfire Risk to Communities

Wildland-urban interface data layers for the United States for both 2000 and 2030 were developed by Theobald and Romme. To assess the wildfire risk to communities, susceptibility to wildfire (WFSI) and the intensity of wildfire if it were to occur (WFII) were examined.

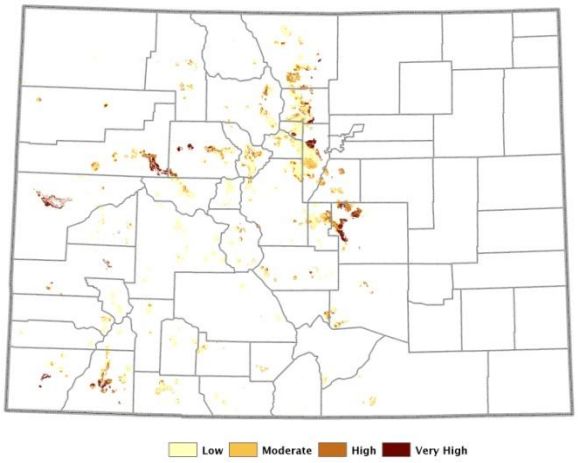
Methods

All input data layers used to create the "Wildfire Risk to Communities" data layer (WUI, WFSI and WFII) are described elsewhere in this section. The wildfire risk within the WUI data layers for 2000 and 2030 was created by clipping the wildfire risk data to the boundaries of the WUI.

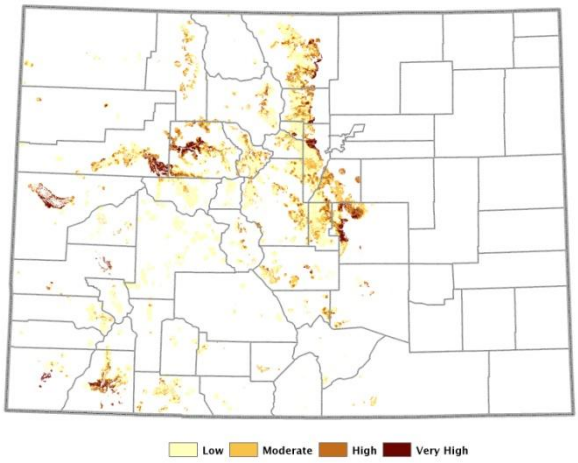
Ranking

The same rankings established for the individual wildfire risk layers were used in the "Wildfire Risk to Communities" data.

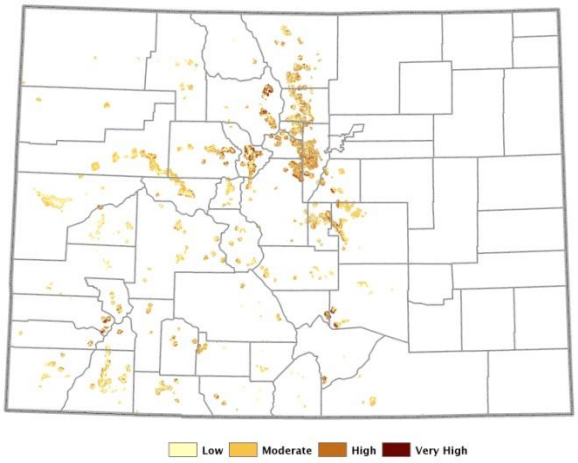
Wildfire Susceptibility in the 2000 WUI



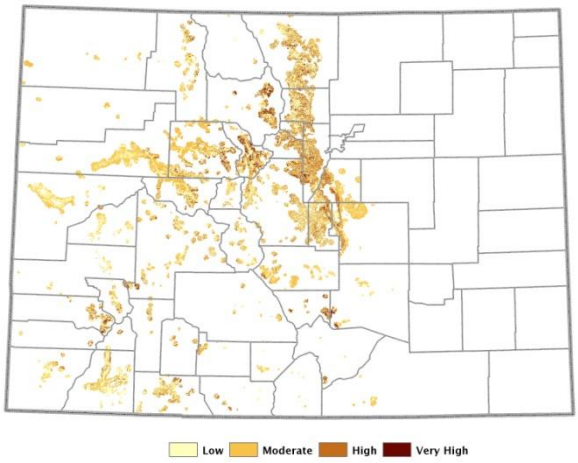
Wildfire Susceptibility in the 2030 WUI



Wildfire Intensity in the 2000 WUI



Wildfire Intensity in the 2030 WUI



Data Sources

See descriptions elsewhere in this section.

Wildland-Urban Interface

The wildland-urban interface (WUI) was developed for the entire United States by Theobald and Romme in 2007 and is fully described in their paper. For the assessment, Theobald generated new WUI data based on the LANDFIRE vegetation types used in the assessment. The new data provides information on the 0.5-, 1- and 2-mile community protection zones for both 2000 and 2030.

Methods (by Theobald & Romme, CSU)

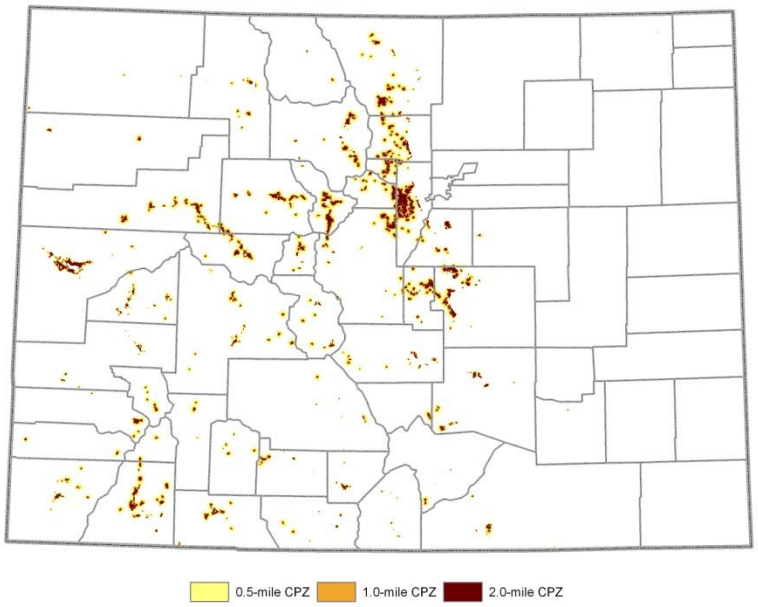
The dataset mapped the intersection of a) wildland-urban interface and b) high-severity vegetation types. First, the WUI was defined as those areas with a housing density of 5 acres or less per housing unit (corresponds to a population density of 250 people per square mile). These areas needed to be in a cluster of at least 10 ha of 1 ha cells at that density.

Second, the WUI was buffered out a distance of 0.5, 1.0 and 2.0 miles to form a community protection zone (CPZ). A cost-weighted method was used to allow the shape and distance of the CPZ to conform to local conditions (vegetation types), rather than being a simple, uniform buffer.

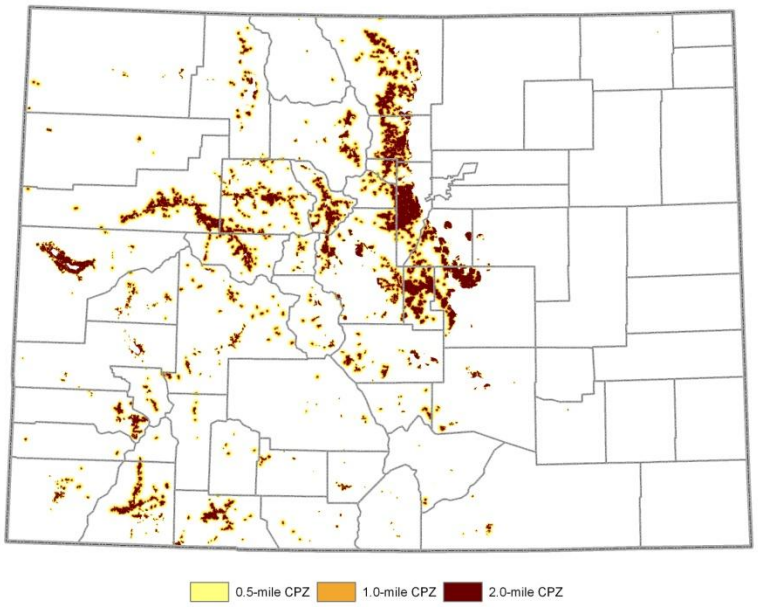
Ranking

Currently, the data is ranked as Very High if it is in a WUI/2-mile CPZ and None otherwise. The data may be ranked differentially for each CPZ buffer distance depending on the analysis. For example, treatments inside the 0.5-mile CPZ could be ranked as a higher priority than treatments inside the 2-mile CPZ.

Wildland-Urban Interface (WUI) with Three Community Protection Zone Buffers for 2000



Wildland-Urban Interface (WUI) with Three Community Protection Zone Buffers for 2030



Data Sources

WUI - http://www.nrel.colostate.edu/~davet/ US wildland-urban interface (WUI) areas in 2000 and 2030, based on LANDFIRE vegetation types, 2009.

References

Theobald, D.M. and W. Romme. 2007. Expansion of the U.S. Wildland-Urban Interface, *Landscape and Urban Planning* 83: 340-354.

Important Habitat for Imperiled Species

The purpose of the imperiled species value layer is to identify forest landscapes that represent or significantly contribute to viable habitats, contain high species richness, endemism and/or that represent core habitat for focal conservation species (i.e., species of concern, threatened and endangered species, or keystone species that are representative of a healthy ecosystem).

The result of the spatial analysis is a continuous surface that is a cumulative representation of individual inputs from various sources. It is focused on forested areas within the state, but extends up to 100m beyond areas identified as forested (as determined by LANDFIRE current vegetation) for smoothness of appearance at the statewide scale.

Each input was given a rank between 0-10 based on conservation value of that input. Cumulative values range from 0- 85, where 0 = no known importance and 85 = extremely important for conservation of wildlife species and maintenance of biodiversity within forested areas. Any area with a value greater than or equal to 15 generally should be considered a priority area.

Methods (by CNHP)

Inputs included CNHP element occurrences (EOs), observation points and Potential Conservation Areas (PCAs), CDOW observation points and species use areas, TNC Conservation Areas, and a riparian model from TNC. See Table D4 for species and communities used. Inputs were scored as follows:-

CNHP EOs scores based on S-rank (0-10 scale)

S-Rank	**Score**
S1	10
S2	9
S3	6
S4	4
S5	2

For birds with different S-ranks for breeding and non-breeding, the higher (more imperiled) rank was used. In all other cases where there are combined ranks (e.g., S1S2) scores were rounded up to the higher rank. This S-rank score was then modified by EO Rank (score range still 0-10, but score may be raised or lowered within this range depending on EO Rank).

EO Rank	Modifier
A-B	+2
C, E	0
H, F	-1
D	-2
X	-3

CNHP PCAs scores based on Biodiversity Significance Rank (B-Rank).

B-Rank	Score
B1	10
B2	9
B3	6
B4	4
B5	2

Scores then were modified by whether they were drawn for a Target. If a PCA was not specifically drawn for a target, at least 50 percent of its area must occur within a forest (as determined by LANDFIRE current vegetation) in order to be included.

Criteria	Modifier
No target	0
1 target	+2
>1 target	+3

Note that Purgatoire Canyon PCA was down-ranked from a B2 to a B5 for the purposes of this project because Purgatoire was originally drawn for gray vireo and given a rank of B5. During the southeast Colorado inventory, the triploid checkered whiptail was found there, and the PCA was redrawn and upgraded to B2. However, the whiptail is not a target species and Purgatoire is not that important for vireo, so this site was scored on its old rank.

CNHP observation points and CDOW data were scored based on S-rank, with no modifiers. The scores are lower than those used for EOs because these are observation data and, therefore, generally less precise.

S-Ranks	Score
S1	8
S2	7
S3	5
S2	3
S5	1

TNC Conservation Area scores based on target status

Status	Score
Conservation area w/ target	7
Conservation area w/ no target but 25% forest	4

Scores then were modified by +1 if the conservation area was designated as a priority conservation area in its respective ecoregional plan. Conservation areas marked as Provisional were removed.

Modeled riparian areas provided by TNC were edited to remove known areas of tamarisk and then given a score of 4.

CNHP EOs with F (failed to find) or X (extirpated) EO Ranks that don't contribute to the analysis were deleted. All trout and boreal toad records were kept, regardless of EO Rank, as delineating potential habitat/likely areas for re-colonization. Any H, F or X record for which this is the only instance of the target also were retained. Of the remaining Target EOs, those that have a PCA drawn for them were replaced by the PCA as the target polygon.

Topology of the input datasets was corrected as necessary. Multipart features were exploded, redundant data, targets represented in more than one input dataset or with overlapping polygons in the same dataset, were reviewed and any overlap was removed to eliminate double-counting of the same target. Because TNC Conservation Areas from several ecoregional plans were used, resulting in some overlapping areas from different plans, the maximum score (as opposed to a sum) was used wherever overlap occurred. Scores from all unique targets (species, natural communities, PCAs, TNC Conservation Areas and modeled riparian areas) then were summed and the resulting values converted into a raster. This raster was then clipped to be within 100m of forest (as mapped by LANDFIRE current vegetation).

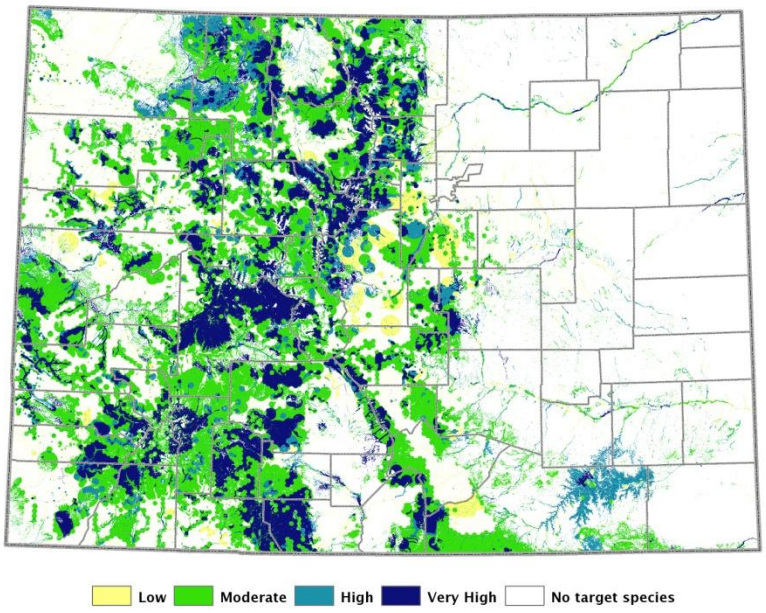
The summed scores range in value from 0 to 85, with a mean value of 4.5 (sd = 5.4).

Ranking

The summed scores were ranked according to the following criteria:

Score	Rank
1-4	Low
5-10	Moderate
10-14	High
14-85	Very High

Important Habitat for Imperiled Species



Data Sources

Colorado Natural Heritage Program. 2009. Biodiversity Tracking and Conservation System (BIOTICS). Colorado State University, Fort Collins, Colo.

Colorado Division of Wildlife. 2009. Target Wildlife GIS datasets.

The Nature Conservancy. 2009. Ecoregional Conservation Areas within Colorado GIS dataset.

The Nature Conservancy. 2009. Modeled Riparian Areas within Colorado GIS dataset.

USDA Forest Service. 2006. LANDFIRE Current Vegetation for Colorado GIS dataset. Available online at http://gisdata.usgs.net/website/landfire.

Table D4. Target Imperiled Species	
Common Name	SRANK
Boreal Toad (Southern Rocky Mountain Population)	S1
Canyon Treefrog	S2
Northern Leopard Frog	S3
Wood Frog	S3
Northern Goshawk	S3B
Boreal Owl	S2
Southwestern Willow Flycatcher	SNA
Prairie Falcon	S4B,S4N
American Peregrine Falcon	S2B
Greater Sandhill Crane	S2B, S4N
Bald Eagle	S1B,S3N
Lewis's Woodpecker	S4
Osprey	S3B
Mexican Spotted Owl	S1B,SUN
Columbian sharp-tailed grouse	S2
Gray Vireo	S2B
Bluehead Sucker	S4
Flannelmouth Sucker	S3
Mountain Sucker	S2?
Rio Grande Sucker	S1
Lake Chub	S1
Arkansas Darter	S2
Iowa Darter	S3
Plains Orangethroat Darter	S3
Humpback Chub	S1
Bonytail Chub	SX
Rio Grande Chub	S1?
Roundtail Chub	S2
Brassy Minnow	S3
Plains Minnow	SH
Orangespotted Sunfish	S5
Common Shiner	S2
Stonecat	S1
Colorado River Cutthroat Trout	S3
Colorado River Cutthroat Trout	S3
Greenback Cutthroat Trout	S2
Greenback Cutthroat Trout	S2
Rio Grande Cutthroat Trout	S3
Rio Grande Cutthroat Trout	S3
Suckermouth Minnow	S2
Northern Redbelly Dace	S1
Southern Redbelly Dace	S1
Flathead Chub	S3
Colorado Pikeminnow	S1

Razorback Sucker	S1
A Stonefly	S2
Moss's Elfin	S2S3
A Stonefly	S1
Pawnee Montane Skipper	S1
Spotted Bat	S2
River Otter	S3S4
Lynx	S1
Fringed Myotis	S3
Townsend's Big-eared Bat Subsp	S2
Dwarf Shrew	S2
Botta's Pocket Gopher Subsp	S1
Iron Fen	S2
Montane Riparian Forests	S2
Mixed Montane Forests	S3
Montane Riparian Forest	S3
Montane Riparian Forests	S3
Subalpine Riparian/Wetland Forest	S3
Coniferous Wetland Forests	S3
-	SU
Narrowleaf Cottonwood Riparian Forests	S1
Narrowleaf Cottonwood Riparian Forests	S2
Boxelder/River Birch	S1
Montane Riparian Deciduous Forest	S2
Montane Riparian Deciduous Forest	S2
Thinleaf Alder-Mixed Willow Species	S3
Montane Riparian Shrubland	S3
Thinleaf Alder-Red-Osier Dogwood Riparian Shrubland	S3
Montane Riparian Shrublands	S3
Thinleaf Alder/Mesic Forb Riparian Shrubland	S3
Montane Riparian Shrubland	S3
Hanging Gardens	S2S3
Subalpine Riparian Shrubland	S3
Lower Montane Riparian Shrublands	S1S2
Foothills Riparian Shrubland	S2
Lower Montane Riparian Shrublands	S2
Wet Meadow-Perched Wetland	S3
Buxbaum's Sedge Wet Meadow	SU
Quaking Fen	SU
Montane Wetland	S1
Montane Wetland	S1S2
Montane Wetland	S2?
Wet Meadows	S3
Montane Wet Meadows	S3
Clustered Sedge Wetland	S2
Wet Meadow	S2

Wet Meadow	S3
Montane Wetland	S1
Spring Wetland	S3
Foothills Riparian Shrubland	S3
Foothills Riparian Shrubland	S2
Montane Riparian Shrubland	S3S4
Riparian Woodland	S2
Coniferous Wetland Forests	S2
Montane Riparian Forests	S3
Montane Riparian Woodland	S2
Montane Riparian Forest	S2
Montane Riparian Forest	S2?
Montane Riparian Forest	SU
Montane Riparian Forest	S2S3
Montane Riparian Forests	S3
Montane Riparian Forest	S2
Montane Riparian Forest	S3
Montane Riparian Forest	S3
Cottonwood Riparian Forest	S3
Narrowleaf Cottonwood Riparian Forests	S2
Narrowleaf Cottonwood/Common Chokecherry	S1
Narrowleaf Cottonwood/Skunkbrush	S3
Narrowleaf Cottonwood/Mixed Willows Montane Riparian Forest	S3
Foothills Riparian Woodland	S2
Narrowleaf Cottonwood Riparian Forests	S3
	S1
Narrowleaf Cottonwood/Snowberry Montane Riparian Forest	S2
Montane Riparian Woodland	S2
Plains Cottonwood Riparian Woodland	S3
Plains Cottonwood Riparian Woodland	S1
Plains Cottonwood Riparian Woodland	S1
Plains Cottonwood/Western Wheatgrass-Vine Mesquite	S2
Plains Cottonwood / Alkali Sacaton	S2
Plains Cottonwood/Sand Dropseed	S1S2
Plains Cottonwood Riparian Woodland	S2
Fremont's Cottonwood Riparian Forests	S2
Fremonts Cottonwood Riparian Forests	S1S2
Montane Riparian Forests	S2
Montane Riparian Forests	S3
	S2
Montane Riparian Woodland	S2S3
Montane Riparian Forests	S3
	SU
Montane Riparian Forest	S3

Lower Montane Riparian Forests	S2
Peachleaf Willow Alliance	S1
Lower Montane Willow Carrs	S3
Drummond Willow/Aquatic Sedge	S2
Montane Willow Carr	S3
Alpine Wetlands	S2
Alpine Wetlands	S2
Beaked Sedge Perched Wetland	S3
Alpine Wetlands	S1
Sphagnum Moss	S2
Sphagnum Moss	S1
Sphagnum Moss	SNR
Longnose Leopard Lizard	S1
Mesa Verde Aletes	S1
Golden Columbine	S1
Debeque Milkvetch	S2
Horseshoe Milkvetch	S1
Hamilton Milkvetch	S1
San Rafael Milkvetch	S1
Schmoll Milkvetch	S1
Narrowleaf Grapefern	S1
Small-winged Sedge	S2
Gypsum Valley Cateye	S1S2
Mesa Verde Stickseed	S1
Canadian River Spiny Aster	S1
Rabbit Ears Gilia	S2
Good-neighbor Bladderpod	S2
Payson Lupine	S2
Dolores River Skeletonplant	S1
Arkansas Canyon Stickleaf	S2
Degener Beardtongue	S2
Plateau Penstemon	S2
Ute Ladies' Tresses	S2
Juniper Tumble Mustard	S2

PLUS

CNHP PCAs drawn for a target OR containing at least 50% forest

TNC Conservation Areas

Important Habitat for Economically Important Species

The economically important species in forests were determined at a meeting that included the Colorado Division of Wildlife and the Colorado Natural Heritage Program. The agreed-upon species were black bear, bighorn sheep, elk, moose and mule deer. Gold-medal streams also were included.

Methods

The following data layers for the target species were determined to be the most relevant to the analyses:

Black Bear
- Fall Concentration
- Summer Concentration

Bighorn Sheep
- Migration Corridors
- Production Area
- Severe Winter Range
- Winter Concentration Area

Elk
- Migration Corridors
- Production Area
- Severe Winter Range
- Winter Concentration Area

Moose
- Migration Patterns
- Concentration Area
- Summer Range

Mule Deer
- Critical Winter Range
- Migration Corridors
- Winter Concentration Area

Turkey
- Production Area
- Roost Sites
- Winter Concentration Area

Gold medal streams

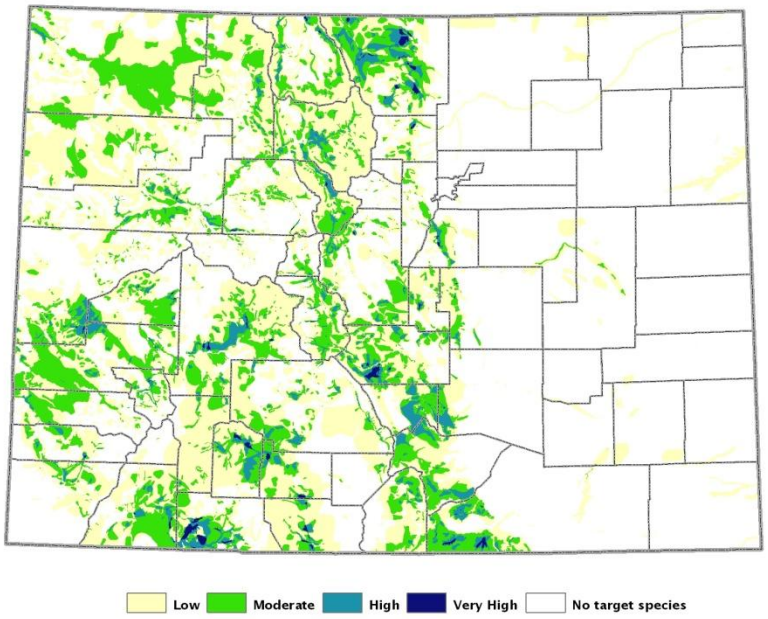
For each species, rasters were created for each data layer (e.g., a raster of fall concentration and a raster of summer concentration for black bear) assigning a value of 1 to any area used by the species. The rasters were added and any value > 1 was reclassed to 1. The species rasters then were added to obtain a species richness (number of species using a particular area).

Ranking

The species richness raster was ranked according to the following scheme:

Low – 1 species; Moderate – 2 species; High – 3 species; and Very High – 4 to 5 species occupy the area.

Important Habitat for Economically Important Species



Data Sources

Species data - Natural Diversity Information Source (NDIS), 2008, http://ndis.nrel.colostate.edu/.

Density of Recreational Opportunities

The recreation layer represents density of recreation opportunities. The layer incorporates publicly accessible lands access over state lands to hunting units, campgrounds, hiking trails, national and state parks, ski areas, and fishing, rafting and boating opportunities on rivers and accessible water bodies. Each individual layer is weighted equally, and as such, the final recreation layer displays the density of recreation opportunities rather than differences in actual use. No statewide data on visitor use was available; therefore, this factor was not incorporated into the analysis.

Methods

We calculated the diversity of recreation opportunities as a cumulative (simple and kernel) probability density estimate. Polygon data was coded as 1 if present (see equation 1). A moving window analysis using equation 2 was used to account for fuzzy estimate of spatial influence for point and line data. The CUBIST software was used for the calculations.

Eq. 1 Simple Density, where; *x*=length or area[*x* |1|], α=weight, λ=area

$$F(x) = \frac{\sum_{i=n}^{i} (x_i \alpha_i)}{\lambda}$$

Eq. 2 Kernel Density

$$F(x) = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \left[\int_{-\infty}^{x} f(t)dt \right]$$

Density is calculated for the following recreation targets:

Type	**Method Notes**	**Density Function**
Publicly accessible lands	Publicly accessible lands using COMaP v.7 coded as 1. No data is set for all other lands using a setnull statement.	Simple
Hunting	Expert knowledge using COMaP v.7 and State Trust Lands in the CDOW public access program. Densities coded as 1.	Simple
Fishing, rafting, and boating	National Hydrography Dataset (NHD) network (large rivers) and accessible water bodies. Grids merged post-hoc.	Simple
Camping	Kernel density estimate (1 km) of BLM, USFS and NPS campgrounds using units as weight	Kernel

Type	Method Notes	Density Function
	field.	
Hiking trails	Simple density estimate (1-km) of BLM, USFS and NPS trails.	Simple
National and State Parks	COMaP v7 polygons densities coded as 1.	Simple
Ski areas	Kernel density (1-km) estimate using "area" as a weight field for ski areas point locations from USFS.	Kernel

The final recreation data is the normalized cumulative density of all recreation targets (equation 3).

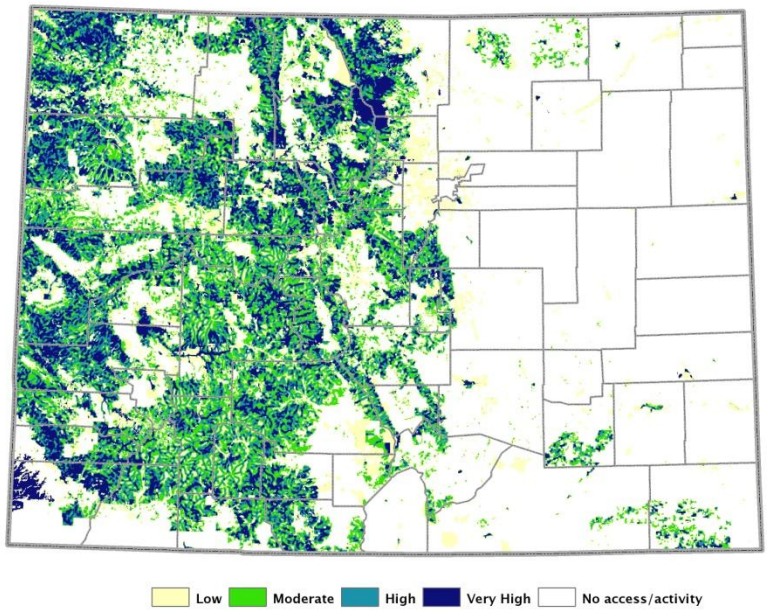
Eq. 3

$$\sum_{i=n}^{i}(F(x)_i - \mu(F(x)_i))/(\sigma^2(F(x)_i))$$

Ranking

The data ranges from 0 to 1 and was ranked into four categories using quantiles.

Density of Recreational Opportunities



Data Sources

RuleQuest Research - CUBIST software, http://www.rulequest.com/.

BLM trails and campgrounds (2009): Individual field offices where available – Glenwood Springs, Grand Junction, Gunnison, Kremmling, Little Snake, San Juan Public Lands Center, Uncompahgre and White River.

NPS trails and campgrounds: http://www.nps.gov/gis/data_info/.

USFS trails, ski areas and campgrounds: USDA Forest Service Rocky Mountain Region Geospatial Services and http://www.fs.fed.us/r2/gis/datasets_unit.shtml.

State Trust Lands in the Public Access Program (2009): State Land Board.

COMaP - Theobald, D.M., G. Wilcox, S.E. Linn, N. Peterson, and M. Lineal. 2008. Colorado Ownership, Management, and Protection v7 database. Human Dimensions of Natural Resources and Natural Resource Ecology Lab, Colorado State University, Fort Collins, Colo. 15 September. www.nrel.colostate.edu/projects/comap .

Methods - Jeffrey Evans, The Nature Conservancy, 2009.

References

Silverman, B.W. *Density Estimation for Statistics and Data Analysis*. New York: Chapman and Hall, 1986.

Projected Change in Housing Density

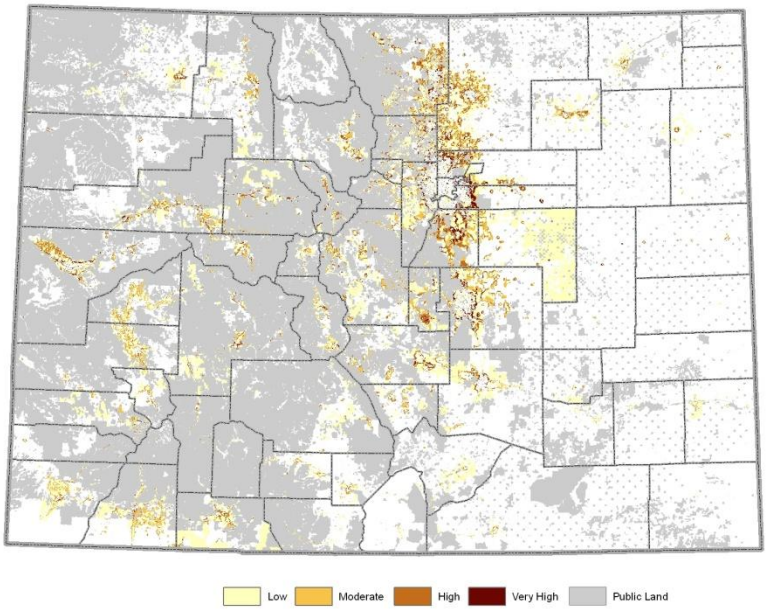
Classes of housing density were recently updated by D. Theobald for the years 2000, 2010, 2020 and 2030.

Ranking

These classes range from rural (1) to high-density urban (9 and 10). The Change in Housing Density data layer is the difference in the class for 2030 and the class for 2000. The data is then ranked by the number of classes changed: 1-2 low; 3-4 moderate; 5-6 high; 7-9 very high.

The change in the number of classes does not directly correspond to the impact of the change. A change from rural to exurban could have much more impact than a change from exurban to suburban. See the section on Degree of Human Modification for a more in-depth treatment of the impacts of changes in housing density.

Projected Change in Housing Density Classes from 2000 to 2030



Data source

Housing density classes – Theobald, D., 2008, produced from SERGoM v3 for the US Forests on the Edge (FOTE) project, www.nrel.colostate.edu/ftp/theobald.

Change in the Degree of Human Modification from 2000 to 2030

A new dataset recently became available that assesses the functional impact of changes in housing density. A change in housing density from rural to exurban could have significantly more impact to wildlife than a change from suburban to urban, even though the change in number of housing density classes is equal (see the Change In Housing Density section).

Methods (taken from information provided by D. Theobald, CSU)

The human modification rasters are values 0 to 1000 (integerized from a 0.0 to 1.0 scale [by multiplying by 1000], 0.0 is not human modified or "natural," and 1.0 is completely modified or "urban/built-up") . These data are a conversion of housing density to the footprint of human development built on Ian Leinwand's thesis work (2009).

To conduct the overlay analysis, we converted the estimated housing density at each location into two measures of impact on wildlife habitat that capture estimated amount of human modification of habitat by human development. The first is the amount of land cover that is modified by humans, or *human modification of cover* (*HMc*). This is an estimate of the visible "footprint" or spatial impact of development that causes modification to land cover types, including and around structures and roads. Note that this measure quantifies modifications associated with the housing unit and the general transportation and utility infrastructure needed by residential development. As such, it provides a general estimate of the effects of housing density and roads (and utility corridors, etc.).

The second metric is an estimate of both the direct (HMc) and effective or functional aspects that are due to both visible modifications to cover, as well as proximal effects associated with human activities such as light, noise, sound, pets, etc. These effects typically decline as a function of distance away from housing units, roads and other associated infrastructure. This effect is referred to as the *human modification function* (*HMf*). We used a distance of 100m radius from each housing unit structure, which others have concluded to be representative of general ecological effects.

We used estimates of *HMc* and *HMf* (Table D5) that were developed from interpretation of high-resolution aerial photography from more than 300 plots or "chips" that were randomly located throughout the public-private land interface in the southern Rockies ecoregion. Although some regional variation in effects of land use on habitat exists, these estimates provide useful measures of effects and are fairly robust given common development patterns. Future research, however, could pursue developing regionally specific estimates.

Table D5. Mean and standard deviation of the area (in hectares) of human modification per residential unit for rural, exurban and suburban residential density classes (Leinwand 2009).

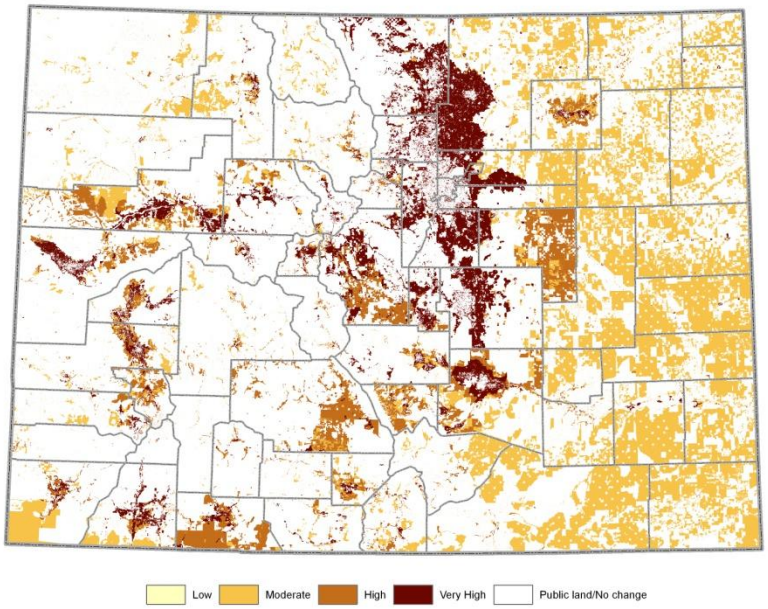
	Human modification *cover*			Human modification *functional*		
Class of housing density	50% (median)	10%	90%	50% (median)	10%	90%

Rural	0.79	0.28	2.72	4.65	2.16	10.46
Exurban	0.25	0.09	1.19	2.65	1.21	4.59
Suburban/ Urban	0.13	0.06	0.35	0.33	0.13	0.55

Ranking

The functional human modification rasters for 2000 and 2030 were used in the assessment. The change in functional human modification was classified into quartiles.

Change in the Functional Impact of Human Modification from 2000 to 2030



References

Leinwand, I. 2009. Land use patterns and trends in the Southern Rocky Mountain Ecoregion at the public-private interface. M.S. Thesis. Colorado State University.

http://cogcc.state.co.us/infosys/Maps/gismain.cfm.

Air Quality

The air quality dataset was obtained from the Air Pollution Control Division of the Colorado Department of Public Health and Environment. The following information was provided by Colleen Johnson of the Smoke Management Control Program at the division.

National Ambient Air Quality Standards (NAAQS) have been established for six criteria pollutants. These pollutants are monitored at various locations around the state. In addition, several other non-criteria air pollutants for which there currently are no National Ambient Air Quality Standards are monitored. The six criteria air pollutants are carbon monoxide, ozone, sulfur dioxide, nitrogen dioxide, lead and particulate matter. The standards are established to protect the most sensitive members of society. More information about monitoring data and sites can be found in the division's Annual Data Report (http://www.colorado.gov/airquality/documents/2007AnnualDataReport.pdf).

The state is classified into a number of categories because of the standards. The categories are attainment/unclassifiable, maintenance/attainment and non-attainment. Many areas of the state are unclassified (monitoring does not occur everywhere). There are a number of communities in the attainment category. These are the communities where APCD is monitoring or in the past has monitored various pollutants, and the ambient levels are/were below the standards. Most of the state is attainment/unclassified. Unclassified areas are considered to be in attainment of the NAAQS.

If the monitored levels in a community do not attain the NAAQS, the area will be designated non-attainment. There are non-attainment areas for specific pollutants. When ambient air quality monitoring exceeds the NAAQS, a community will develop and implement a State Implementation Plan (SIP) to address the air quality. If the strategies implemented through the SIP are successful in bringing the area back into attainment of the standard, the area will be redesignated (by EPA) as maintenance/attainment.

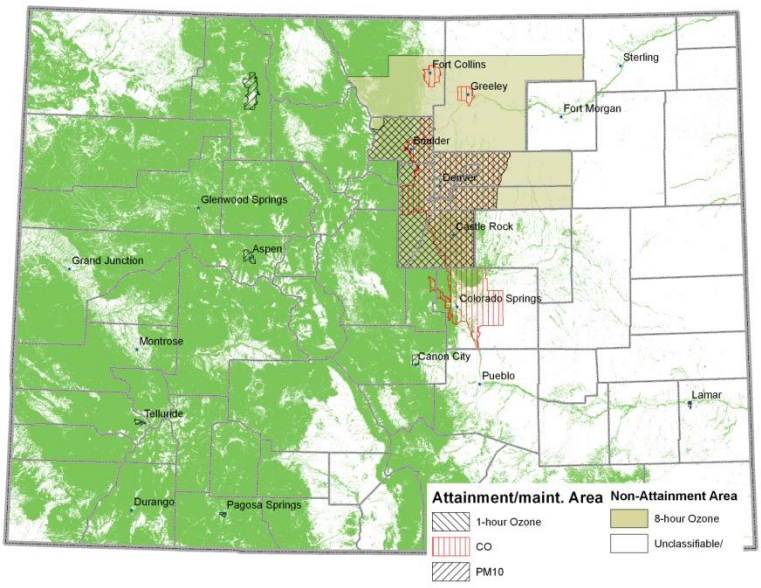
Colorado has improved poor air quality in areas of the state where violations of the national standards were recorded and has preserved those improvements over time. In 2002, Colorado accomplished a milestone by achieving compliance with all federal air quality standards and having the U.S. Environmental Protection Agency (EPA) designate all areas of Colorado in compliance. Since that time, areas of the Front Range, specifically the Denver metropolitan, Greeley and Fort Collins areas, have fallen out of compliance with the national 8-hour standard for ozone. At the same time, EPA has lowered the national standard for ozone, making the challenge to maintain compliance that much greater. Colorado will need the combined efforts of state and local governments, business and industry, as well as the citizens of the state to meet the challenge of reducing ozone pollution.

There are a number of maintenance/attainment areas for various pollutants (particulate matter, carbon monoxide and ozone) around the state. These areas historically were non-attainment areas, but are now re-designated as maintenance/attainment. While current air quality is better in these areas, the control strategies implemented and maintained by the communities are contributing factors.

The ozone designations are a little confusing. In the Front Range area, there is a maintenance/attainment area for the 1-hour ozone standard. However, this same area currently is in non-attainment of the 8-hour ozone NAAQS. These communities will be developing a plan to reduce sources of air pollutants that contribute to ozone development. This area already has initiated reduction strategies to attain the 1-hour ozone standard, but additional challenges lie ahead.

Wildland fire projects in maintenance or non-attainment areas may have certain restrictions as part of a community's plan (SIP) to reduce sources of these criteria pollutants. The pollutants of concern are primarily particulate matter and ozone. As land managers and owners look for more opportunities to burn outside of traditional prescribed burning windows, the ozone non-attainment area has become more important.

Air Quality



Data Sources

Air quality designation boundaries - Smoke Management Program, Colorado Air Pollution Control Division, 2009. Thanks to Colleen Johnson for integrating the data into a very usable format.

References

Metadata reference - http://www.cdphe.state.co.us/regulations/airregs/100114aqccambientairquality.pdf.

Colorado regulations - http://www.gpoaccess.gov/cfr/.

Invasives

The Colorado Department of Agriculture tracks noxious weeds across the state to the level of the quarter-quad (approximately 7,500 acres). Species on List A of the CDA noxious weed list are designated for eradication. The goal for those species on List B is to stop their spread. For the assessment, 5 species from List A and 17 species from List B were selected as relevant to forests. See Table D6 for details.

Quarter-quads that Contain List A or List B Species

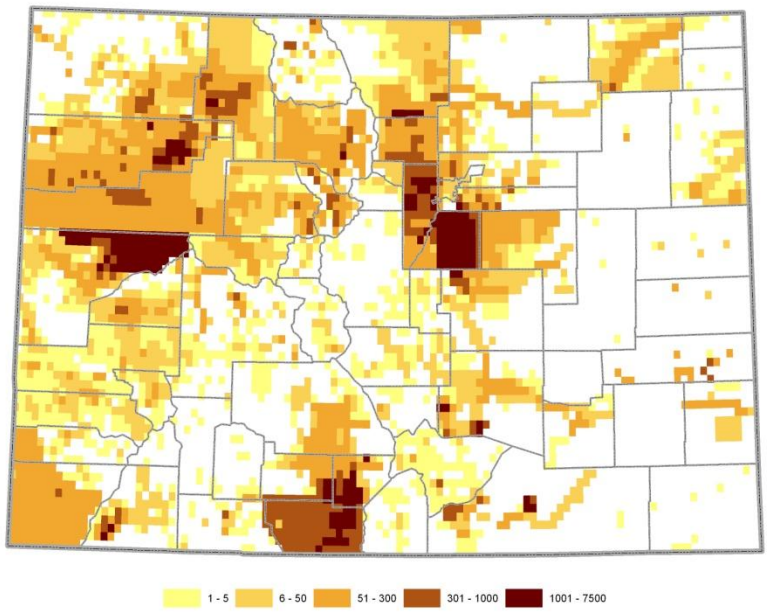


Table D6. Colorado Noxious Weed List for Statewide Forest Assessment

List A weed species

Meadow knapweed (Centaurea pratensis)
Myrtle spurge (Euphorbia myrsinites)
Cypress spurge (Euphorbia cyparissias)
Mediterranean sage (Salvia aethiopis)
Yellow starthistle (Centaurea solstitialis)

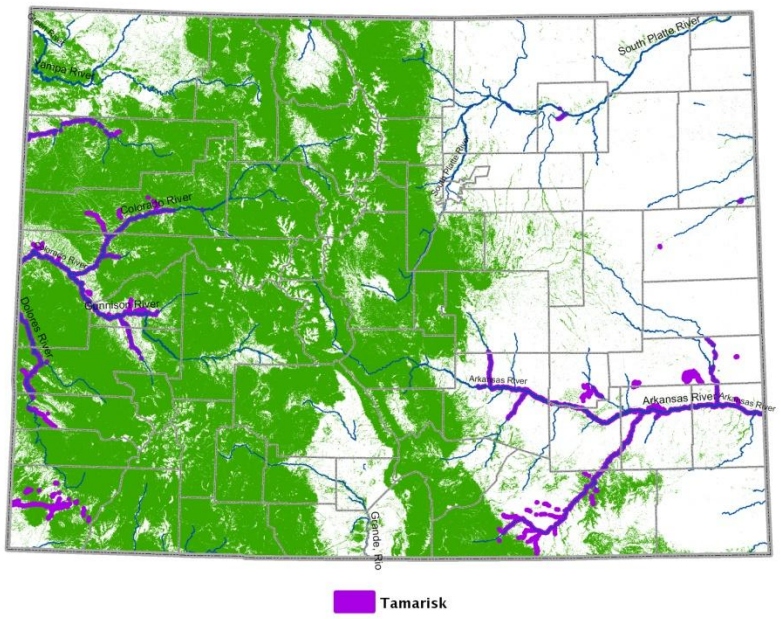
List B weed species

Black henbane (Hyoscyamus niger)
Bull thistle (Cirsium vulgare)
Dalmatian toadflax, broad-leaved (Linaria dalmatica)
Dame's rocket (Hesperis matronalis)
Diffuse knapweed (Centaurea diffusa)
Hoary cress (Cardaria draba)
Houndstongue (Cynoglossum officinale)
Leafy spurge (Euphorbia esula)
Oxeye daisy (Chrysanthemum leucanthemum)

Perennial pepperweed (Lepidium latifolium)
Plumeless thistle (Carduus acanthoides)
Russian knapweed (Acroptilon repens)
Russian-olive (Elaeagnus angustifolia)
Salt cedar (Tamarix chinensis, T.parviflora, and T. ramosissima)
Scotch thistle (Onopordum acanthium)
Spotted knapweed (Centaurea maculosa)
Yellow toadflax (Linaria vulgaris)

The Tamarisk Coalition recently conducted an extensive survey of tamarisk across the state.

Tamarisk



Data Sources

Colorado Department of Agriculture, http://www.colorado.gov/cs/Satellite/Agriculture-Main/CDAG/1167928184069.
Tamarisk line data – Colorado Tamarisk Mapping & Inventory Project, Tamarisk Coalition, 2006-2007, http://www.tamariskcoalition.org/tamariskcoalition.

Lands that Meet Forest Legacy Criteria

"The Forest Legacy Program (FLP) authorizes the USDA Forest Service or state governments to purchase permanent conservation easements on private forest lands to prevent those lands from being converted to non-forest uses. The forest lands that contain important scenic, cultural, recreation resources, fish and wildlife habitats, water resources and other ecological values that will support continued traditional forest uses receive priority." (Taken from the Colorado State-Wide Forest Legacy Assessment of Need, Five-Year Review, 2006). We used data from the assessment and the methodology from the Forest Legacy document to determine the lands that meet the criteria for Forest Legacy based on the assessment data.

Methods

The data used by the 2006 assessment and the 2009 Colorado Statewide Forest Resource Assessment are described below.

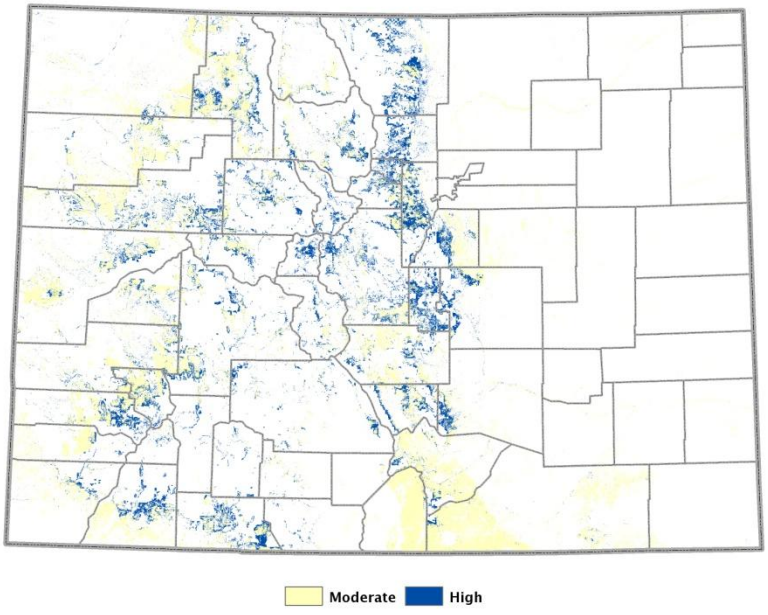
1. Primary Forest Conversion Map – areas in Colorado that are in danger of conversion from traditional forest uses.
    a. 2006 analysis - used land ownership, vegetation and housing density change from Theobald, filtered for private land and categorized by no change, moderate change, high change. Data were overlaid with Red Zone.
    b. Forest assessment - used Change in Degree of Human Modification, categorized by low, moderate, high. The High and Very High categories used in the assessment were merged for the analysis. The mask for private lands in the forest was used after the data layers were summed.
2. Wildlife Habitat Protection
    a. 2006 analysis - used 30 species from NDIS and ranked by areas with highest density of species.
    b. Forest assessment - combined important habitat for imperiled species and ecologically important species (equal weight). The High and Very High categories were merged for the analysis.
3. Growth / Sprawl Control
    a. 2006 analysis - used Theobald housing density change map.
    b. Forest assessment - covered by use of change in degree of human modification in 1.
4. Water Quality / Quantity Protection
    a. 2006 analysis - used 303(d) streams.
    b. Forest assessment - used the Important Watersheds for Drinking Water data layer. The High and Very High categories were merged for the analysis.
5. Wetland and Riparian Area Protection
    a. 2006 analysis - used significant riparian communities in GAP data.
    b. Forest assessment – used riparian forest types.
6. Wildfire Control Issues
    a. 2006 analysis - used CSFS Red Zone map.

b. Forest assessment - combined the two wildfire risk layers, WFSI and WFII (equal-weight). The High and Very High categories were merged for the analysis.

7. Private Property Rights
    a. 2006 analysis - no data identified.
8. Flora / Fauna Species Diversity
    a. 2006 analysis - used Potential Conservation Areas from CNHP.
    b. Forest assessment - addressed by wildlife layers above.
9. Forest Timber Products
    a. 2006 analysis - used GAP vegetation data and assigned values based on forest types.
    b. Forest assessment - recreated using the same timber values for each forest type as defined in the assessment.
10. Large Continuous Forest
    a. 2006 analysis - used federal land-ownership map and buffered in one-third mile increments up to 1 mile.
    b. Forest assessment – used the same method as the 2006 analysis.
11. Lifestyle Protection for Landowner
    a. No data identified.

These data layers were summed and then classified into 5 quantiles. The top two quantiles were ranked as High and the bottom three as Moderate.

Lands that Meet the Forest Legacy Criteria



Data Sources

All data sources are documented elsewhere in the Data Sources and Methods section.

References

Western Environmental and Ecology (under contract with the Colorado State Forest Service), 2006, *Colorado State-Wide Forest Legacy Assessment of Need, Five-Year Review.*