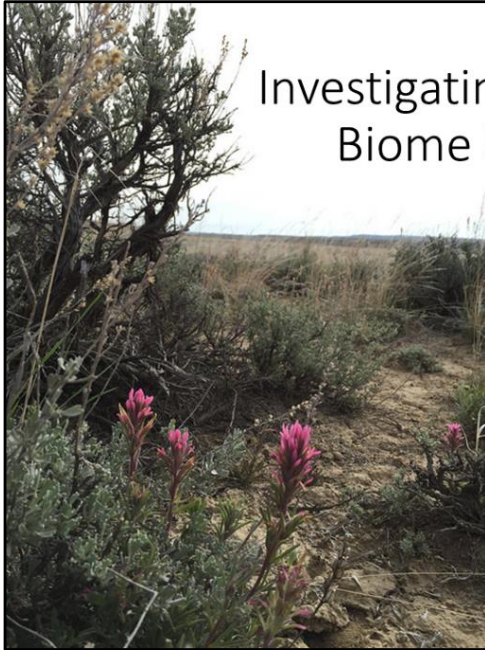
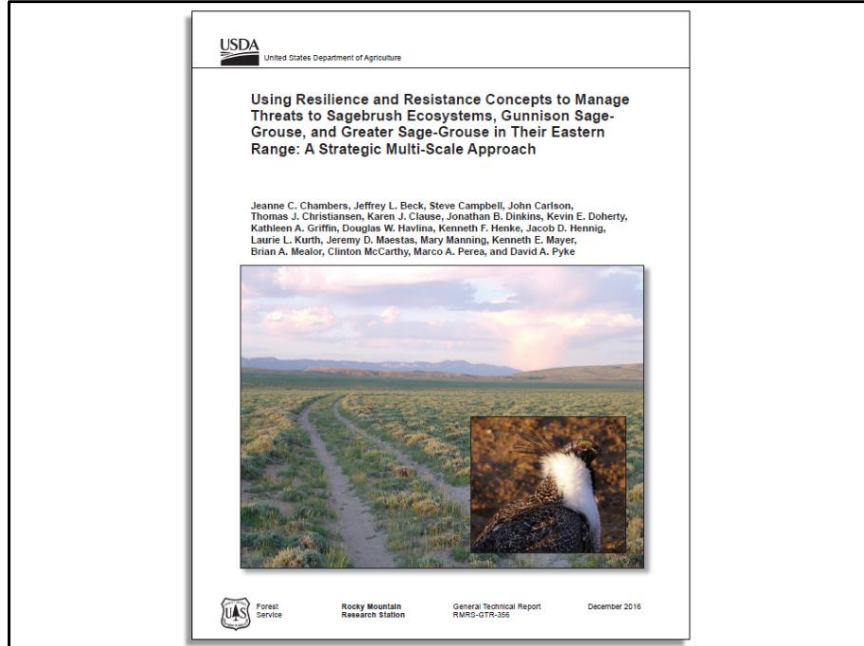


# Investigating the Sagebrush Biome Using SMRRT



7 April, 2017



This presentation uses the broad process (SMRRT) described in Chambers et al 2016 report ([https://www.fs.fed.us/rm/pubs/rmrs\\_gtr356.pdf](https://www.fs.fed.us/rm/pubs/rmrs_gtr356.pdf)). The difference is that the analyses described here are not specific to a single species such as the Greater Sage-grouse but describe the broader sagebrush biome. We use varying extents (geographic coverage) to show where data sets are available and we explore multiple data sets where they are available. These analyses and data sets are consistent with Chambers et al 2017 (Chambers et al 2017 Science framework for conservation and restoration of the sagebrush biome: Linking the Department of the Interior's Integrated Rangeland Fire Management Strategy to long-term strategic conservation actions. Part 1. Science basis and applications. Gen. Tech. Rep. RMRS-GTR-360. Fort Collins, CO: U.S Department of Agriculture, Forest Service, Rocky Mountain Research Station. 213 p. <https://www.treesearch.fs.fed.us/pubs/53983> )

Using the SMRRT Science Framework, investigate Sagebrush biome and threats in BLM CO Districts

### **Location and Data Sets**

- Where are areas of sagebrush?
  - Data sets: LandFire, Homer/USGS grass shrub
- Where are Resistant and Resilient (R&R) areas?
  - What is R&R?
- How does R&R vary across the sagebrush biome?
  - May provide information on how areas respond to treatment, and likely recovery or conversion to undesirable states

We obtained the data sets cited in Chambers et al 2016 from the ScienceBase website:

<https://www.sciencebase.gov/catalog/item/576bf69ce4b07657d1a26ea2>

Several of these data sets are specific to sage-grouse and not useful for the sagebrush biome because too many gaps exist; we deal with this by returning to original data sets from which these are derived or by seeking other data sets that depict similar data and are science-based.

The next 3 slides indicate how we used the Science Framework within the confines of these analyses and serve as an outline for the presentation.

Using the SMRRT Science Framework, identify Predominant Threats to the Sagebrush Biome

- **Where are areas of cheatgrass?**
  - Data sets: LandFire, Pacific NW National Lab (Larson/PNNL)/FWS, Homer/USGS (not yet)
- **Where are areas of pinyon juniper (PJ)?**
  - Data sets: Falkowski, Chambers, Rehfeldt
- **Where are developed areas?**
  - Data sets: USGS Landscape Intactness, Development Footprint
- **What is the spatial distribution of fire risk?**
  - Data sets: Crist, Short

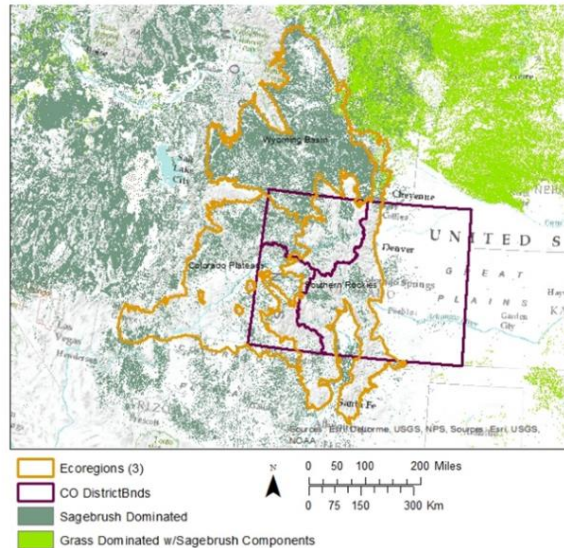
See the more detailed slides for references and data descriptions.

Using the SMRRT Science Framework, identify Sagebrush Interactions with Predominant Threats and Change Agents

- How does the R&R vary in areas where PJ is likely to expand into sagebrush?
- Are areas of sagebrush fragmented by development (DV)?
- Where might WY Big Sagebrush grow in 2050?
- How does R&R vary in areas dominated by sagebrush and invaded by cheatgrass?
- Where will Wyoming Big Sagebrush grow in 2050?
- How does fire risk vary in sagebrush and PJ expansion areas?
- How will future changes affect the sagebrush biome? E.g. development, climate change
- What about grazing – this is mentioned as an option for management and treatment, not as a CA?

This is a preliminary list of questions identified at the NOC; we invite further questions, suggestions, and discussion.

## Where are areas of sagebrush?



This sagebrush data set is derived from LandFire EVT and BpS ecological systems. The table listing these is on slide 22 and is taken directly from the **Greater Sage-grouse Monitoring Framework: Table 4** ([https://eplanning.blm.gov/epl-front-office/projects/lup/21152/48421/52584/GRSG-FINAL-Monitoring\\_Framework\\_20140530.pdf](https://eplanning.blm.gov/epl-front-office/projects/lup/21152/48421/52584/GRSG-FINAL-Monitoring_Framework_20140530.pdf)).

We will be able to use the USGS (Collin Homer) Grass Shrub product when it is released.

In LandFire data each raster cell represents the **dominant** land cover for the area of the cell. In the Grass/Shrub product, the fractional component of each cell is given for each layer. That is for the shrub component, a cell value of 0.20 means that 20% of that cell area on the ground is shrub.

## What is Resilience & Resistance?

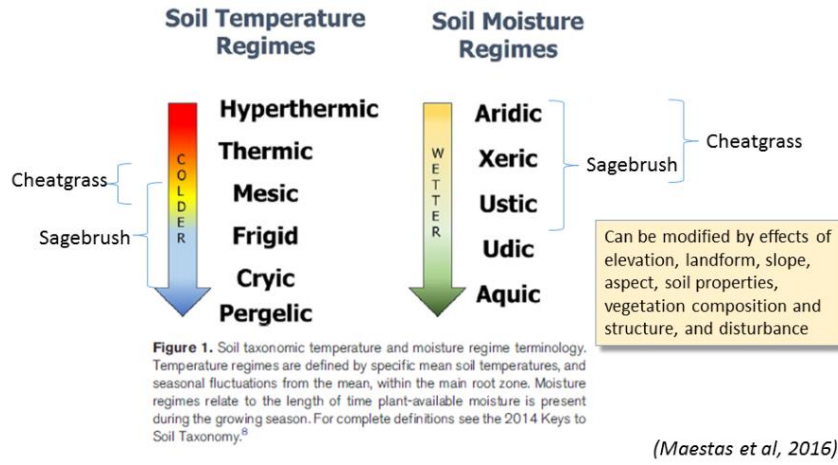
- **Resilience** refers to the ability of ecosystems to reorganize or recover after disturbances like wildfire
- **Resistance** is the capacity of an ecosystem to remain largely unchanged despite disturbances or pressure from invasive species, like cheatgrass
- Resilience and resistance concepts help managers better understand key drivers of ecosystem change, identify relative risks of crossing thresholds to undesired states, and design appropriate management actions to promote desired ecosystem trajectories

*(Maestas et al, 2016)*

The R&R concept is written up in a paper by Maestas et al, 2016:  
<http://www.bioone.org/doi/full/10.1016/j.rala.2016.02.002>

## Where are Resistant and Resilient (R&R) Areas?

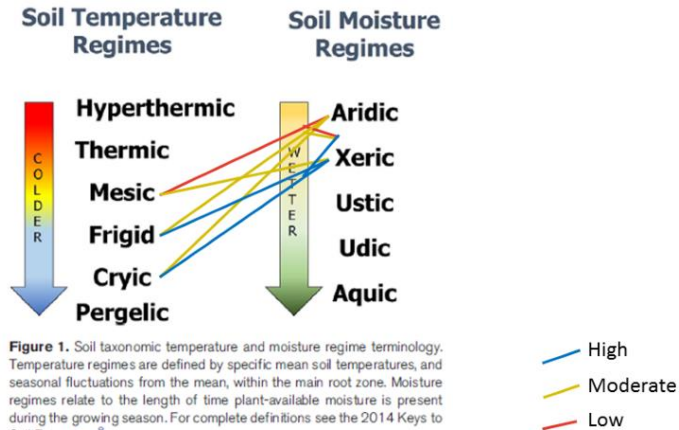
-- Optimal Soil Characteristics for Sagebrush and Cheatgrass



Cheatgrass thrives in soils that are slightly warmer and drier than the optimal conditions for sagebrush, but there is still much overlap in Mesic and Aridic/Xeric soils.

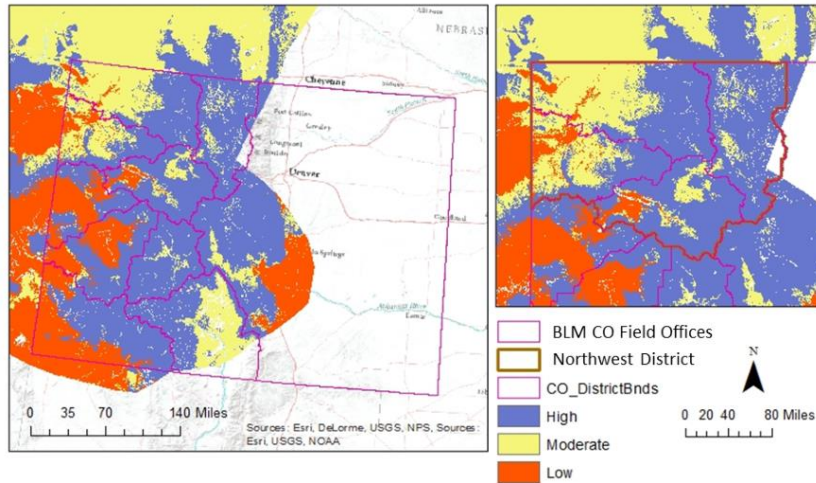
## R&R Soil Characteristics: Sagebrush Optimal Conditions

(Maestas et al, 2016)

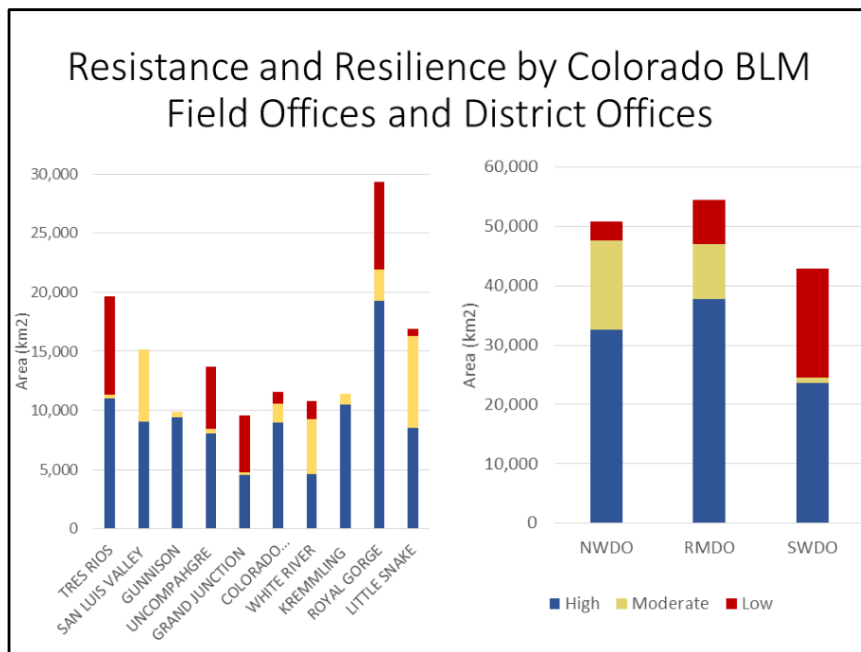


This figure shows how the R&R mapping is classified for sagebrush using Low (red), Moderate (yellow), and High (blue) classes. Relate this to the R&R map on the next slide. Each R&R class is a combination of a soil temperature and moisture regime. For example, Low R&R (red areas on the following map) have Mesic, Aridic soils.

## Where are Resistant and Resilient (R&R) areas?

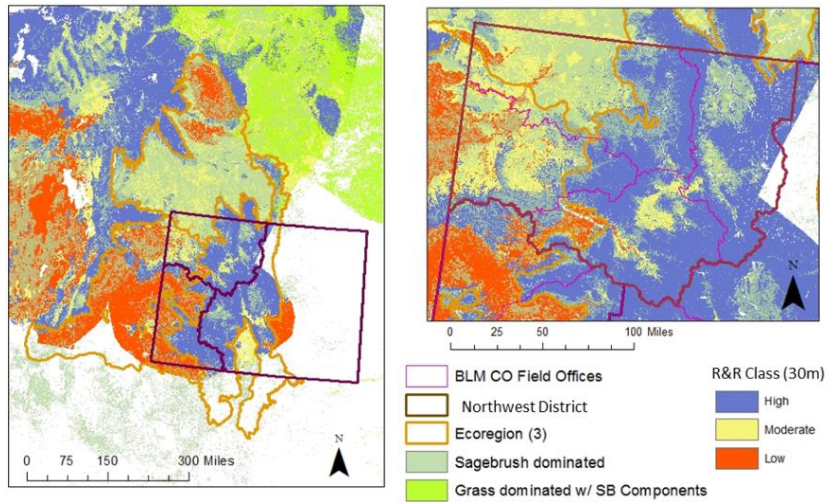


The R&R data set is mapped to the SG Management Zones hence the odd boundary and large unmapped area in CO.

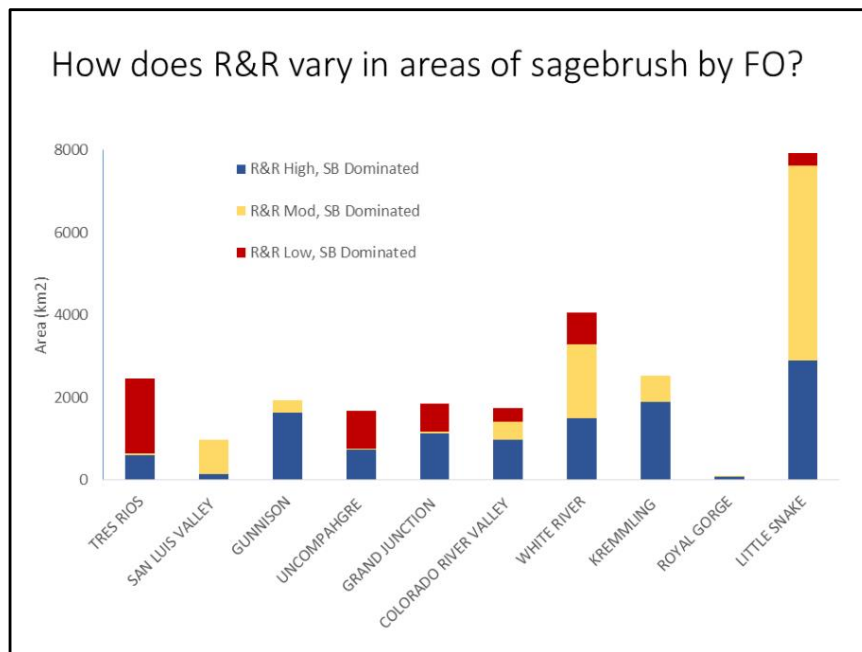


R&R is not mapped in open water or wetland areas; unmapped areas are not shown here.

How does R&R vary across the sagebrush biome?



Sagebrush is overlaid across R&R to determine how the R&R class varies in areas of sagebrush. Is sagebrush equally distributed across R&R classes or does it favor High or Moderate R&R?



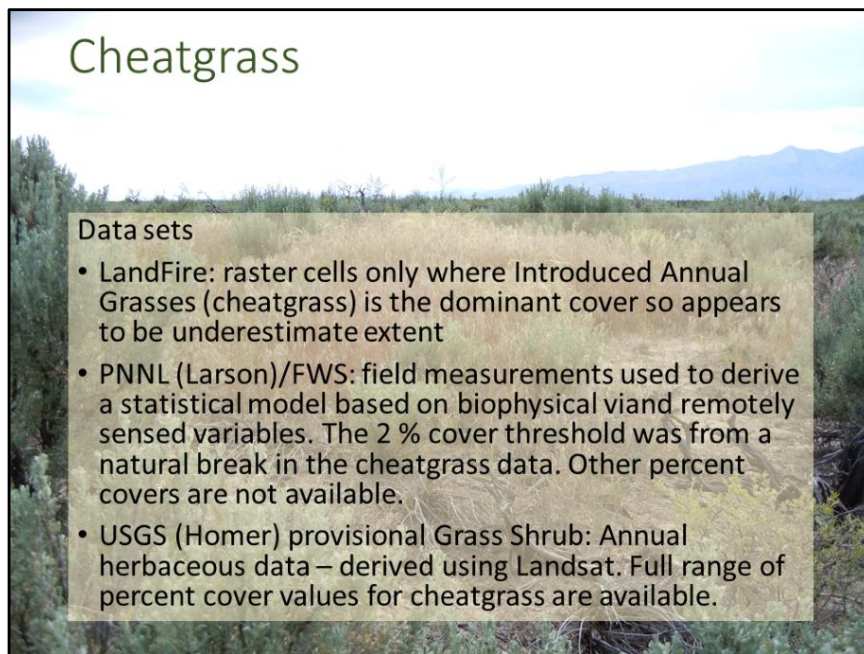
Except for Tres Rios and Uncompahgre, sagebrush mainly grows in areas of high and moderate R&R.

## Predominant Threats, Change Agents, and Sagebrush Interactions

- Cheatgrass
- Pinyon-Juniper
- Development
- Fire
- Climate Change



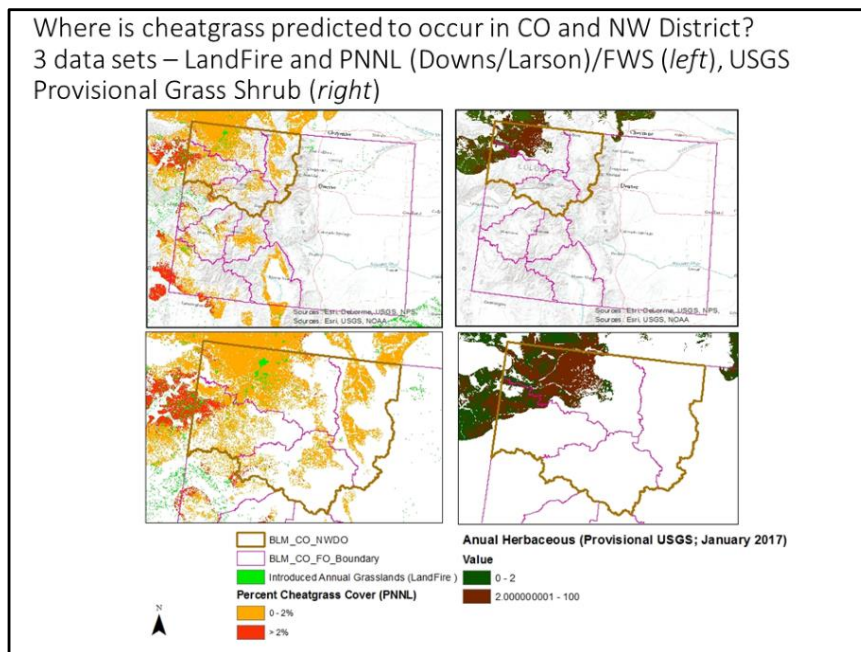
Do we need to consider other threats? Or separate development into components?  
For example, should we examine oil and gas development separately?



The PNNL data are modeled only for SG historic range. Masked areas include cultivated agriculture, pasture/hay, non-target cover types, urban/DV areas, and water. During the presentation, someone said they were reluctant to use the PNNL cheatgrass data because “it is for the PNW” - it is not. The random sampling of field data to build the model was stratified by lat/long – this is simplistic (IMHO) and could have been improved by stratifying by biophysical variables such as elevation or precipitation or perhaps by the soil temperature and moisture classes that underlie the R&R classes.

I checked with Janelle Downs (PNNL): the spatial accuracy for WYB and COP is not reported in the Downs et al report and is not available. The overall accuracy is about 71%. Downs set the cheatgrass threshold at 2% cover, based on available data and model fit. In a frequency plot of cheatgrass field measurement, the majority of sites showed cheatgrass at levels less than 2%; just a few measurements showed cheatgrass > 2% cover. The model could not determine additional classes given the lack of data points.

The provisional grass-shrub data (Collin Homer, USGS) are not yet released – it might be worth finding out more about this depending on timeline and needs for the EA?



LandFire (bright green) shows minimal coverage of cheatgrass because it only shows cells where cheatgrass is the dominant cover.

Are there issues with using the provisional grass/shrub data in the EA? We can find out when Homer's final product will be available and plan to revise the analyses based on those data.

PNNL data (Kyle Larson/Janelle Downs). People were concerned about accuracy of these data so I asked about a validation for the eastern SG range; they responded with about 80% accuracy. Note that LandFire data accuracy is also highly varied by species and location, and also has limited validation points. While I haven't looked into LF accuracy specifically for cheatgrass for this area, in another project (in CA) using LF EVT I found that other species validate between 25 – 70%. I don't think that 80% is too low accuracy to be useful. It will be interesting to see later this year when LandFire does a major remap and when the grass shrub product is finally released, how these 3 data sets compare. Sorry I was unable to find more details on this.

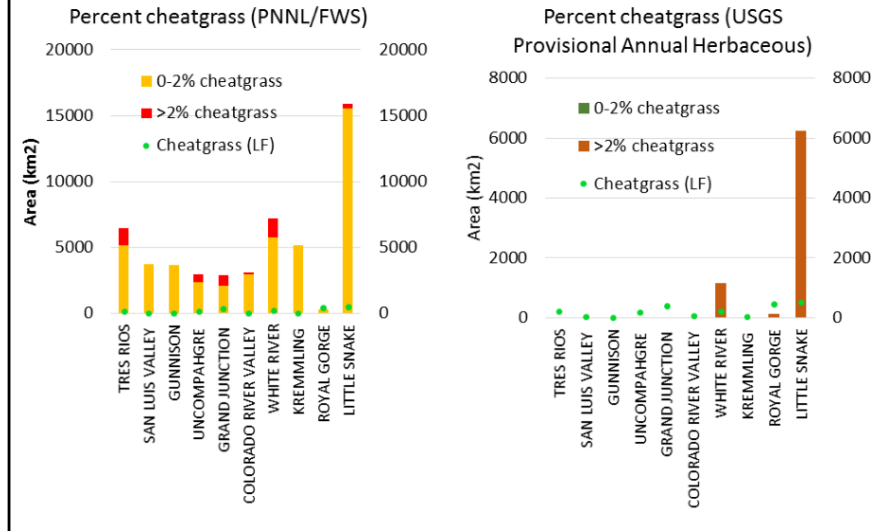
Here is Kyle's actual reply:

"The geographic domain of the model we developed to predict cheatgrass

occurrence was for the historic range of sage grouse, which represents much of the Intermountain West including portions of western Colorado (see Figure 2.1 in the report). The model is based on 6600+ field observations across that domain taken by multiple agencies between 2000 and 2014 as part of other monitoring/research efforts. That being said, we had less field data for the eastern portion the range than west (primarily the Great Basin) and therefore more confidence in the results for areas west of the Rockies. We stratified our sub-sample for model building by latitude/longitude to improve overall representation, although underlying differences in the geographic dispersion of the data are still evident. Classification accuracy of our model in the eastern portion was actually pretty good (~80%), but we had fewer field observations there to validate the model compared to the west.

In summary, the model and data are intended to illustrate range-wide patterns of cheatgrass occurrence and support regional and sub-regional decision making. The results may be less representative at finer scales because they are based on data from across an ecologically diverse range. This interpretation should be applied to any local landscape-scale area within the domain, not just Colorado.”

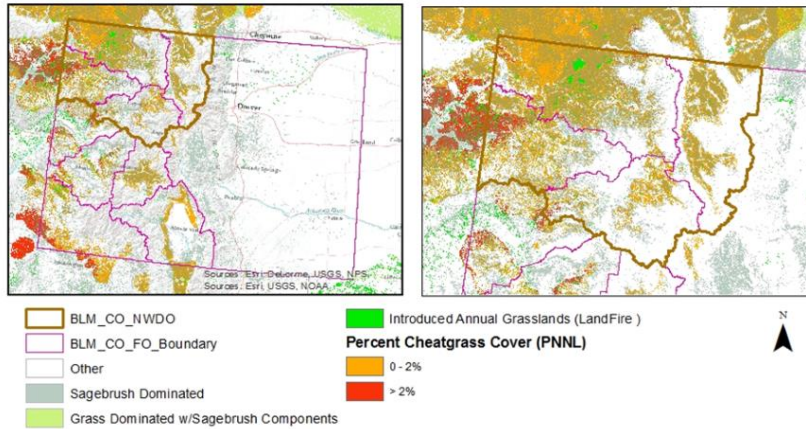
## Summarize cheatgrass by Colorado FO



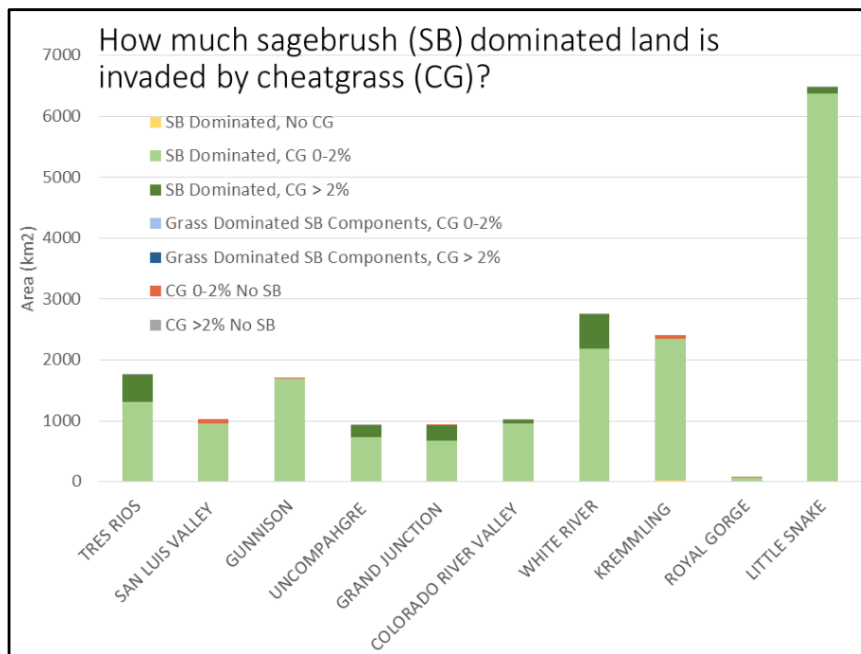
Note the differences in y-axes

LF = LandFire

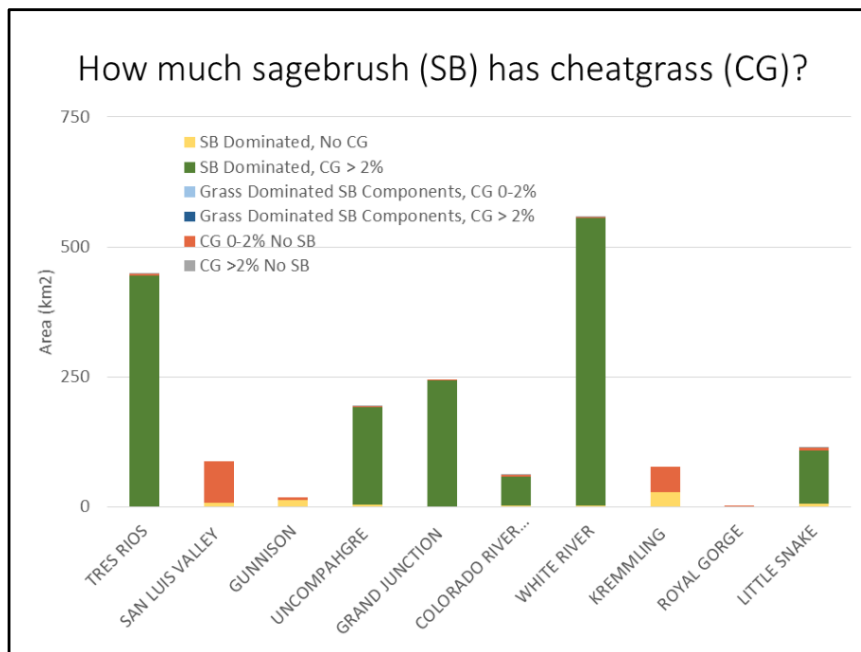
## Where are areas of sagebrush and cheatgrass?



Overlay cheatgrass from PNNL and sagebrush. Where does cheatgrass occur in the sagebrush biome?

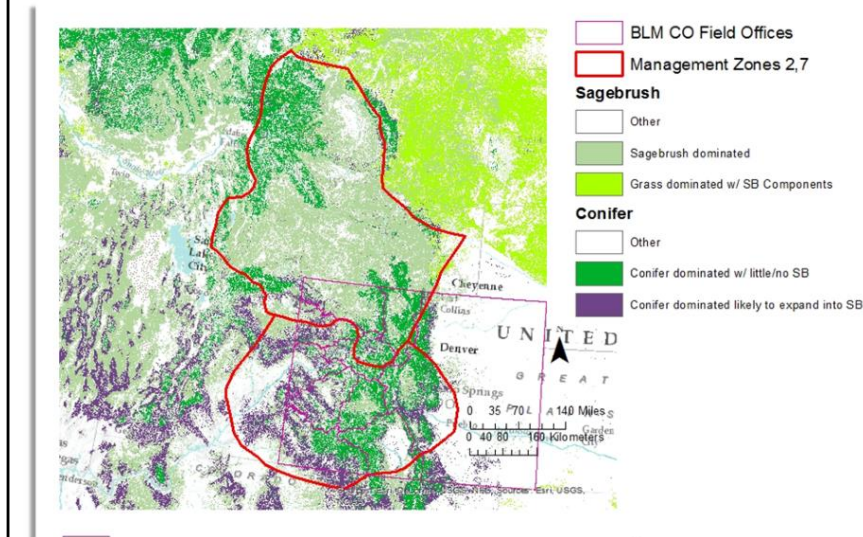


Overlay sagebrush with cheatgrass (PNNL), summarized by Field Office. The dominant class here is sagebrush dominated with 0-2% cheatgrass – I remove this for the next slide to better show the less dominant classes.



Sagebrush overlaid with cheatgrass. Same chart as previous slide but with sagebrush dominated with 0-2% cheatgrass class removed so that we can see other classes in more detail.

## Where are areas of Sagebrush and Conifer?



Sagebrush and Conifer are both derived from LandFire data – see next two slides for the BpS and EVT classes used. Is the conifer class broader than what is needed for this project? Would it be better to limit this to PJ? (The plant communities that make up the “conifer” class are shown on slide 23: should any be dropped for this analysis?)

Ecological systems in BpS and EVT capable of supporting sagebrush vegetation and capable of providing suitable seasonal habitat for Greater Sage-Grouse.

|                                                                          |                                                                  |
|--------------------------------------------------------------------------|------------------------------------------------------------------|
| Colorado Plateau Mixed Low Sagebrush Shrubland                           | Inter-Mountain Basins Semi-Desert Shrub-Steppe                   |
| Columbia Plateau Low Sagebrush Steppe                                    | Northwestern Great Plains Mixed Grass Prairie                    |
| Columbia Plateau Scabland Shrubland                                      | Northwestern Great Plains Shrubland                              |
| Columbia Plateau Steppe and Grassland                                    | Rocky Mountain Gambel Oak-Mixed Montane Shrubland                |
| Great Basin Xeric Mixed Sagebrush Shrubland                              | Rocky Mountain Lower Montane-Foothill Shrubland                  |
| Inter-Mountain Basins Big Sagebrush Shrubland                            | Western Great Plains Floodplain Systems                          |
| Inter-Mountain Basins Big Sagebrush Steppe                               | Western Great Plains Sand Prairie                                |
| Inter-Mountain Basins Curl-Leaf Mountain Mahogany Woodland and Shrubland | Wyoming Basins Dwarf Sagebrush Shrubland and Steppe              |
| Inter-Mountain Basins Mixed Salt Desert scrub                            | Artemisia tridentata ssp. Vaseyana Shrubland Alliance (EVT only) |
| Inter-Mountain Basins Montane Sagebrush Steppe                           | Quercus gambelii Shrubland Alliance (EVT Only)                   |

Source: Greater Sage-grouse Monitoring Framework: Table 4. Used in Chambers et al 2016

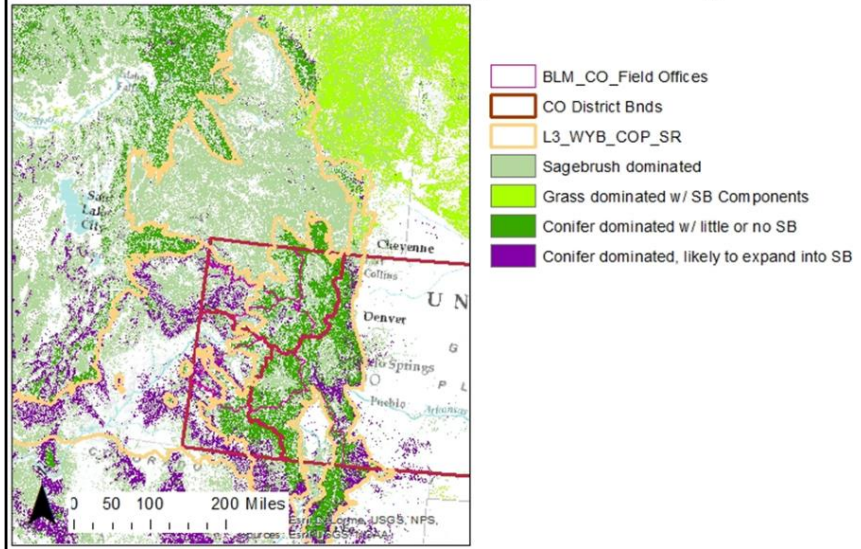
Ecological systems with conifers most likely to encroach into sagebrush vegetation.

|                                                              |
|--------------------------------------------------------------|
| Colorado Plateau Pinyon-Juniper Woodland <i>Pinus edulis</i> |
| Columbia Plateau Western Juniper Woodland and Savanna        |
| East Cascades Oak-Ponderosa Pine Forest and Woodland         |
| Great Basin Pinyon-Juniper Woodland <i>Pinus monophylla</i>  |
| Northern Rocky Mountain Ponderosa Pine Woodland and Savanna  |
| Rocky Mountain Foothill Limber Pine-Juniper Woodland         |
| Rocky Mountain Poor-Site Lodgepole Pine Forest               |
| Southern Rocky Mountain Pinyon-Juniper Woodland              |
| Southern Rocky Mountain Ponderosa Pine Woodland              |

Source: Greater Sage-grouse Monitoring Framework: Table 5. Used in Chambers et al 2016

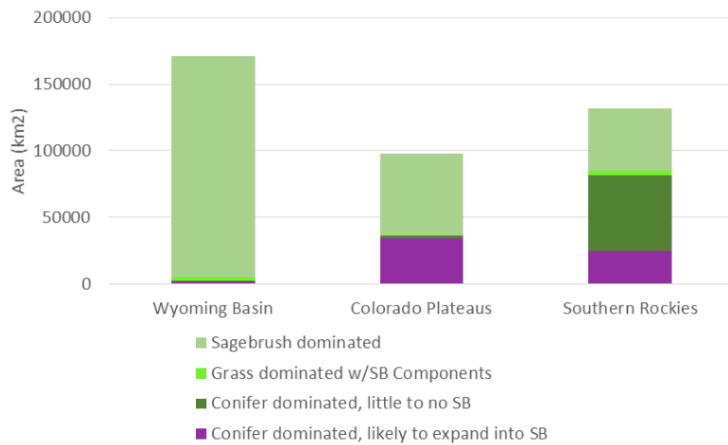
Note that this is all conifers, not just PJ. Which classes should we use for PJ alone (CP PJ Woodland, GB PJ Woodland and SRM PJ Woodland)?

## Conifer and sagebrush by Level 3 Ecoregions



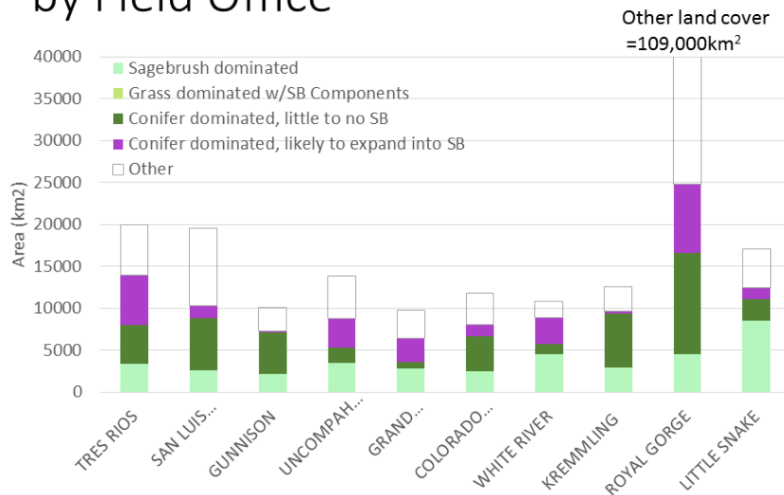
Level 3 ecoregions from EPA = Wyoming Basin (WYB), Colorado Plateau (COP), and Southern Rockies (SR). The NWDO includes parts of these ecoregions, making it a complex area to manage.

## Conifer and sagebrush coverage by Level 3 Ecoregions



SB and conifer derived from LandFire. Because these data sets are derived from LandFire there is no overlap; LandFire shows only the dominant class in each raster cell or pixel.

## Conifer and sagebrush coverage by Field Office



SB and conifer derived from LandFire

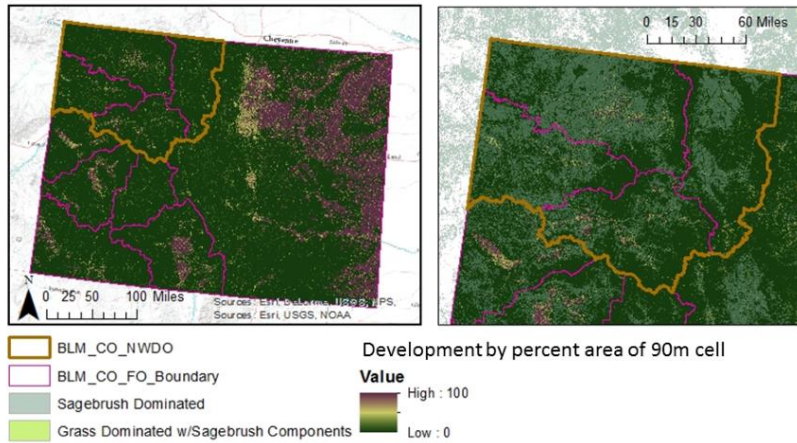
# Development



- Data sources:
  - USGS West-wide Intactness and Development Footprint
    - Percent DV by 90m cell size
    - Includes urban, agricultural, energy/utilities, and transportation
  - BLM NOC Wildlife Lab Disturbance Data Set
    - Vector-based area footprint
    - Excludes agriculture
    - Based on detailed State guidelines. States calculate disturbances for broad scale and project scale. Calculation of disturbances vary by percent disturbance threshold, by definition of the extent used to calculate the disturbance (i.e., various buffers and boundaries), and vary according to the threats considered at difference percent disturbance. Threats are listed in the GrSG Monitoring Framework, Table 2. Local guidelines can be found in RMPs. Where else?

DV = development.

Where are developed areas (*left*) in relation to sagebrush (*right*)?



DV data is the USGS development footprint – at 90m resolution it is a little coarse for this effort. It might be better to dig more into the BLM Wildlife lab data?

### USGS Landscape Intactness Levels Defined by 2.5km and 20km Radii Moving Windows

- Highest = 0 to 1 % at both scales
- Very-high = 0 to 1% at one scale and 1 to 2 % at the other scale
- High = 1 to 2 percent at both scales
- Moderate = 2 to 3 percent at one scale and less than 3 percent at the other scale
- Lowest = greater than 3 percent at either scale.
- What are useful thresholds of development to consider?

Highest landscape intactness = lowest development

Lowest landscape intactness = highest development

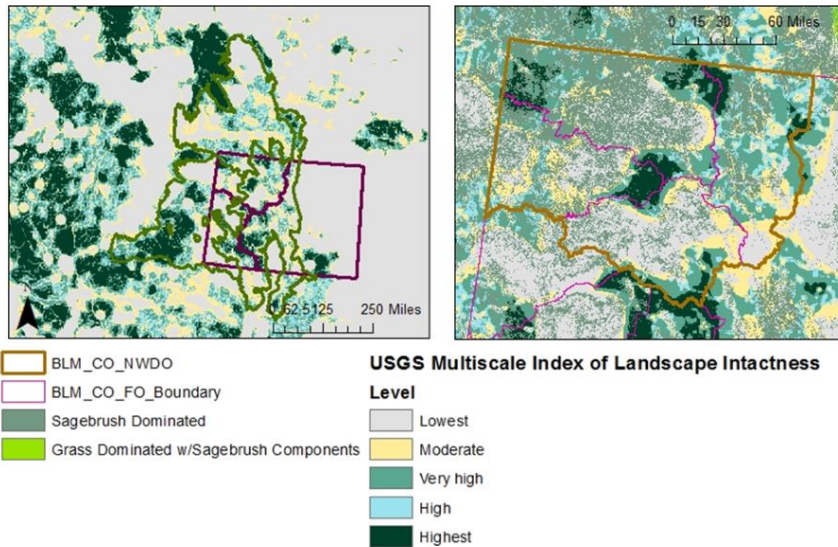
We can provide more info on this if needed but here are links to the report and data sets.

Carter, S.K., Carr, N.B., Miller, K.H., and Wood, D.J.A., eds., 2017, Multiscale guidance and tools for implementing a landscape approach to resource management in the Bureau of Land Management. U.S. Geological Survey Open-File Report 2016–1207: <https://pubs.er.usgs.gov/publication/ofr20161207> (landscape intactness is covered in Chap. 5: “A Multiscale Index of Landscape Intactness for Management of Public Lands”)

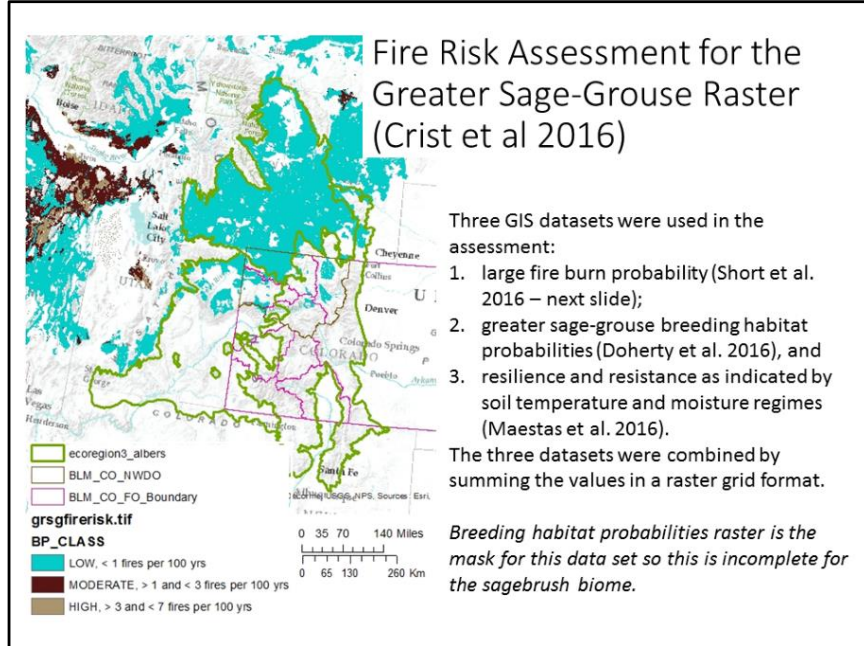
The data release is here:

<https://www.sciencebase.gov/catalog/item/57d8779de4b090824ff9acfb>

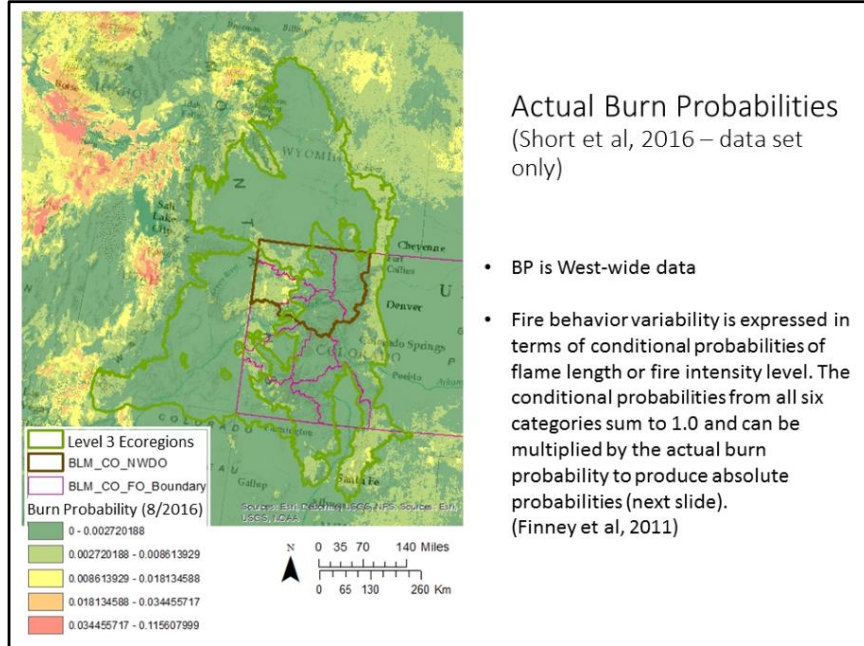
Landscape Intactness (*left*) and Sagebrush overlaid (*right*)







Incomplete for sagebrush biome so I looked at the component data sets – burn probability.

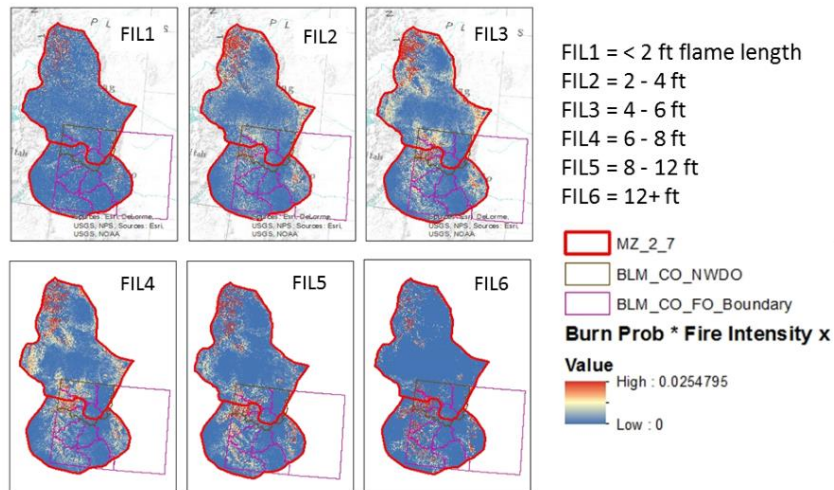


Burn Probabilities are used to derive the Fire Risk Assessment for the Greater Sage-Grouse Raster. Burn probabilities are derived using a logistic regression model based on the historical occurrence of large fires and the Energy Release Component (ERC), a fire danger rating index.

Finney, Mark A.; McHugh, Charles W.; Grenfell, Isaac C.; Riley, Karin L.; and Short, Karen C., "A simulation of probabilistic wildfire risk components for the continental United States" (2011). *USDA Forest Service / UNL Faculty Publications*. Paper 249. <http://digitalcommons.unl.edu/usdafsfacpub/249>

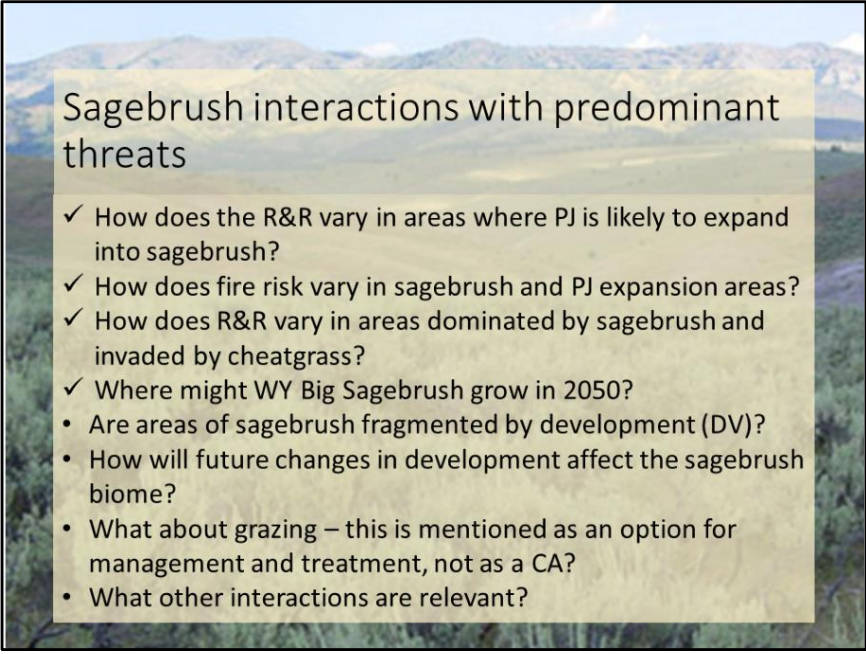
Short, Karen C.; Finney, Mark A.; Scott, Joe H.; Gilbertson-Day, Julie W.; Grenfell, Isaac C. 2016. Spatial dataset of probabilistic wildfire risk components for the conterminous United States. Fort Collins, CO: Forest Service Research Data Archive. <https://doi.org/10.2737/RDS-2016-0034>

Fire Risk = Burn Probabilities X Fire Intensity  
Level (Flame Length) Conditional Probabilities



Fire behavior variability is expressed in terms of conditional probabilities of flame length or fire intensity level. The conditional probabilities from all six categories sum to 1.0 and can be multiplied by the actual burn probability to produce absolute probabilities

Finney, Mark A.; McHugh, Charles W.; Grenfell, Isaac C.; Riley, Karin L.; and Short, Karen C., "A simulation of probabilistic wildfire risk components for the continental United States" (2011). *USDA Forest Service / UNL Faculty Publications*. Paper 249. <http://digitalcommons.unl.edu/usdafsacpub/249>



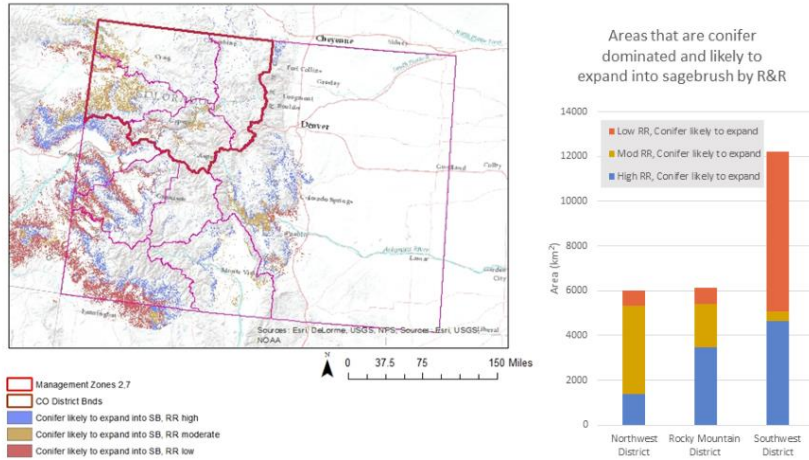
## Sagebrush interactions with predominant threats

- ✓ How does the R&R vary in areas where PJ is likely to expand into sagebrush?
- ✓ How does fire risk vary in sagebrush and PJ expansion areas?
- ✓ How does R&R vary in areas dominated by sagebrush and invaded by cheatgrass?
- ✓ Where might WY Big Sagebrush grow in 2050?
  - Are areas of sagebrush fragmented by development (DV)?
  - How will future changes in development affect the sagebrush biome?
  - What about grazing – this is mentioned as an option for management and treatment, not as a CA?
  - What other interactions are relevant?

We came up with a few possible management questions related to management of threats to the sagebrush biome – what else would you like us to examine?

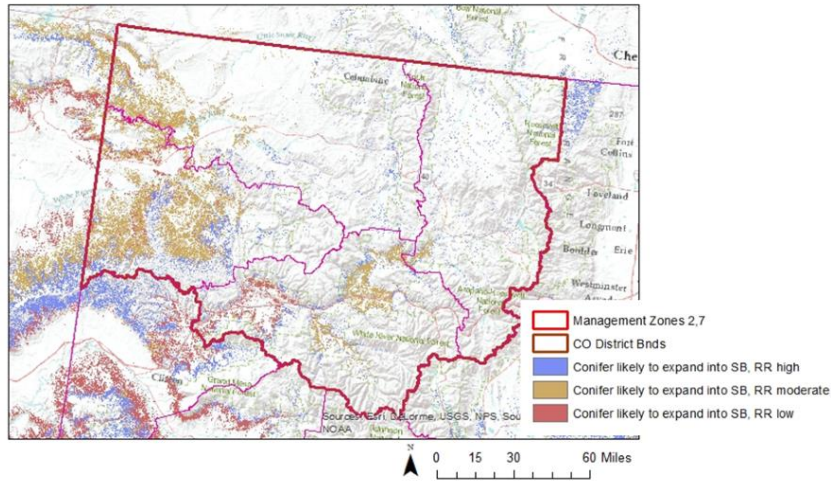
I have worked on the checked questions and will get to the others. Are these helpful?  
How do we need to refine the questions to better meet your needs?

## How does the R&R vary in areas where conifer is likely to expand into sagebrush? Colorado

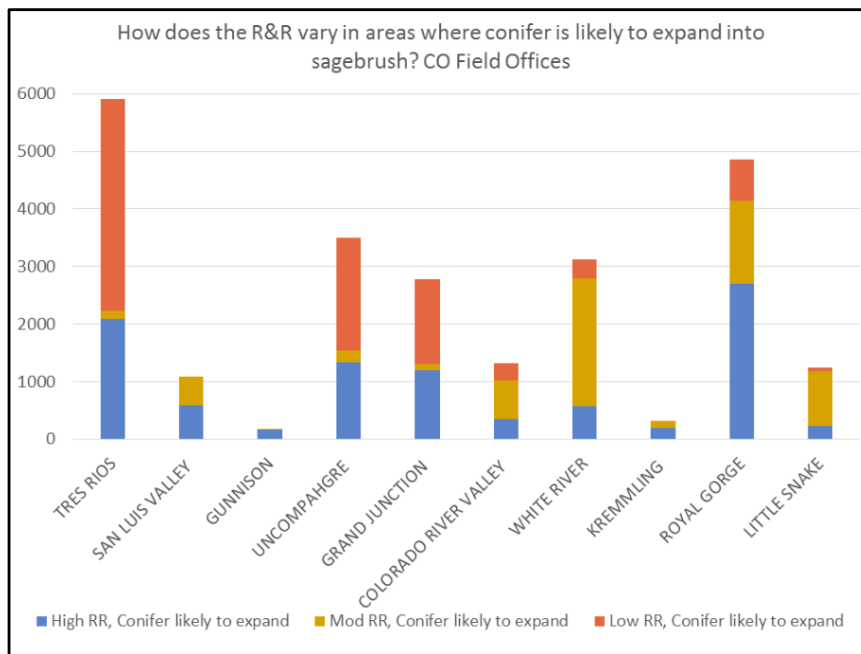


This might help identify areas where SB restoration after conifer removal is more likely to be successful (in areas where SB thrives, that is, in areas of High R&R--blue). Amounts in each class at the District level can put this into perspective for CO. Field verification will be needed for individual projects.

How does the R&R vary in areas where conifer is likely to expand into sagebrush? Northwest District, CO



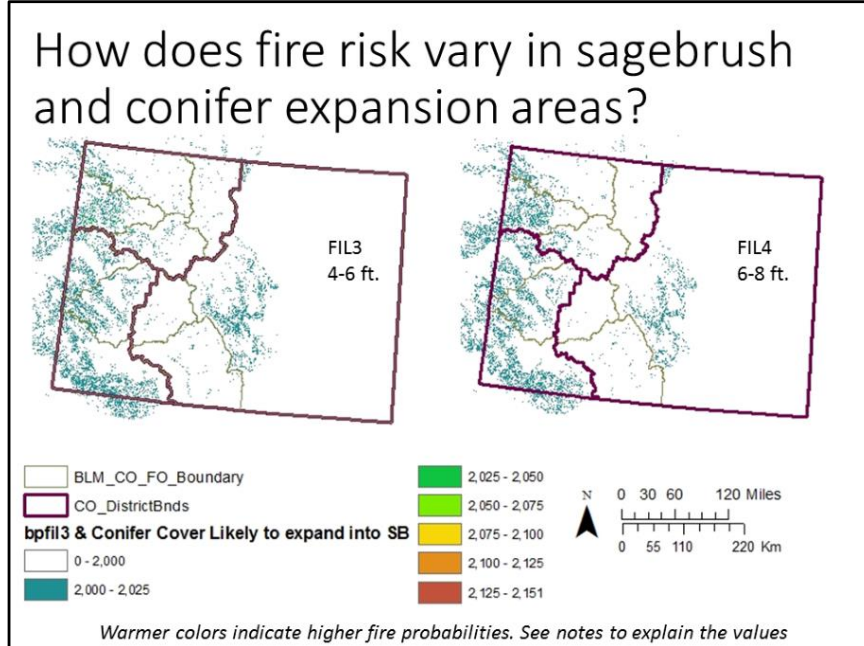
This might help identify areas where SB restoration after conifer removal is more likely to be successful (in areas where SB thrives, that is, in areas of High R&R--blue). Field verification will be needed for individual projects.



Histograms summarizing distribution of R&R classes where conifer expansion is likely among FOs from the preceding map (slide 37)

SB restoration after conifer removal is more likely to be successful in areas where SB thrives (that is, in areas of High R&R--blue). Field verification will be needed for individual projects.

## How does fire risk vary in sagebrush and conifer expansion areas?



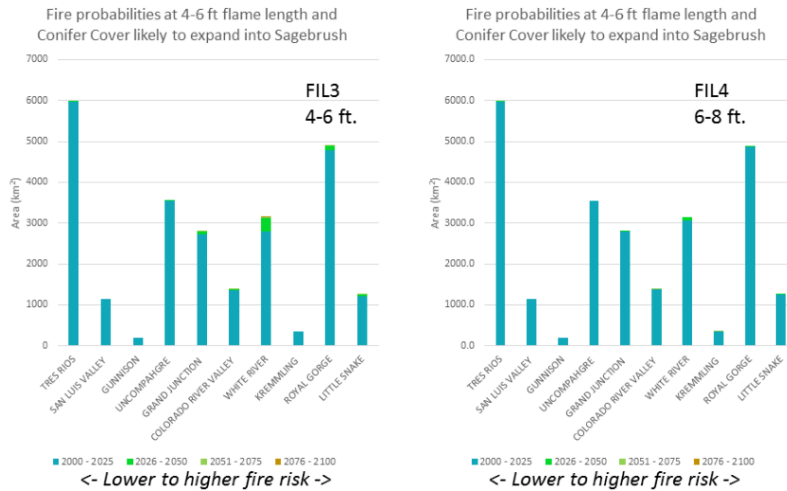
Explanation of raster values:

Conifer cover likely to expand into SB is the 2000 value

Burn Probability Flame Length (BPFIL) is a probability multiplied by 1000

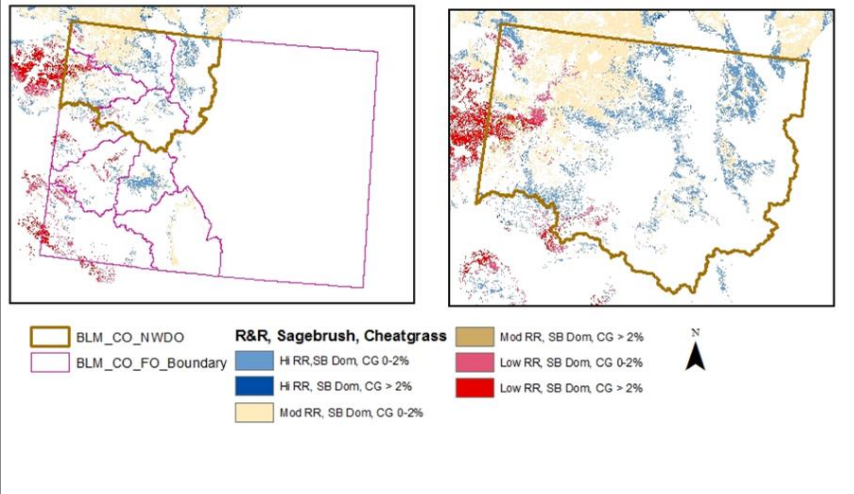
That is for value 2,025. It is an area where conifer is likely to expand (2,000) and the combination of burn probability at a flame length of 4-6 ft (or 6-8 ft) is 0.025

## Identify areas of expanding conifer cover with higher fire risk using FIL3 and FIL4 in CO



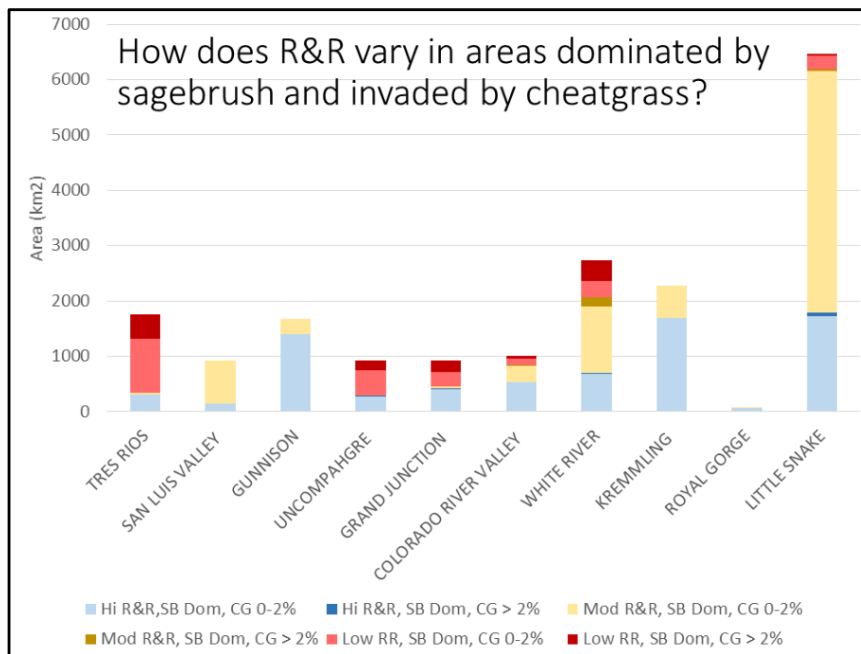
Histograms summarizing distribution of fire probabilities among FOs from the preceding map (slide 39).

How does R&R vary in areas dominated by sagebrush and invaded by cheatgrass?



Areas with high R&R suggest that CG could be treated and SB successfully restored. Field verification will be needed for individual projects.

PNNL Cheatgrass data used in these maps.



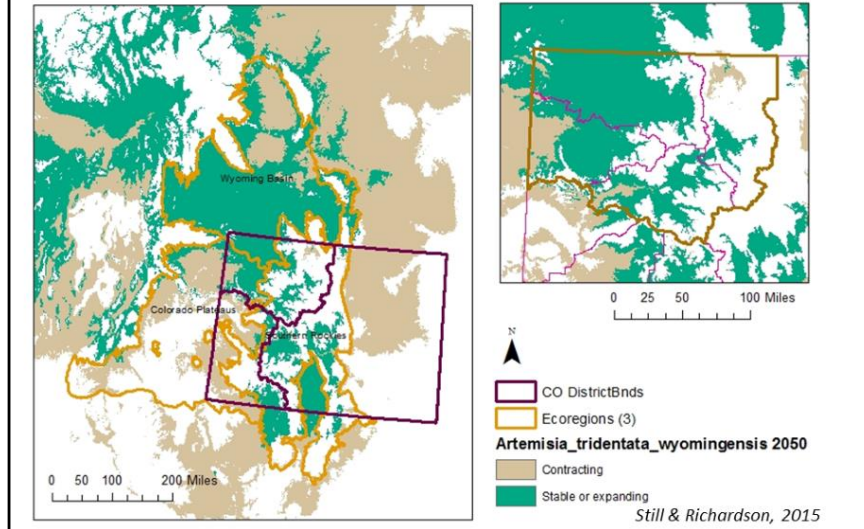
Histograms summarizing distribution of R&R classes in areas dominated by SB and invaded by CG among FOs from the preceding map (slide 41)

Are areas of sagebrush fragmented  
by development (DV)?

Analysis not yet complete

Would this analyses be helpful?

## Where might WY Big Sagebrush grow in 2050?



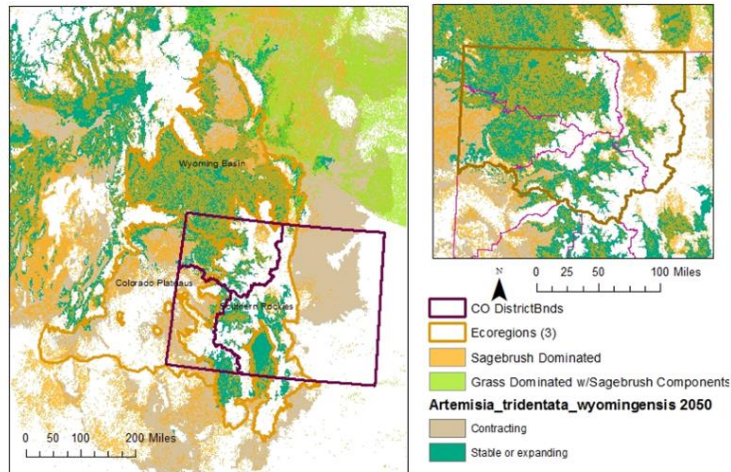
Still and Richardson, 2015. **Projections of Contemporary and Future Climate Niche for Wyoming Big Sagebrush (*Artemisia tridentata* subsp. *wyomingensis*): A Guide for Restoration.** Natural Areas Journal, 35(1):30-43. DOI:

<http://dx.doi.org/10.3375/043.035.0106>

URL: <http://www.bioone.org/doi/full/10.3375/043.035.0106>

Bioclimatic envelope modeling for Wyoming Big Sagebrush. This shows potential, does not account for development or disturbances. Looking at projections for growth and contraction may help identify areas for present day restoration (sagebrush restoration should probably be limited to those areas where the range is stable or expanding; areas where the range is contracting may not be able to support sagebrush in the future).

## Potential Sagebrush changes compared to current LandFire Sagebrush coverage



Overlay of sagebrush projections with current sagebrush cover from LandFire.

How will future development  
affect the sagebrush biome?

Analysis not yet complete

Would this analysis be helpful?

## Climate Change

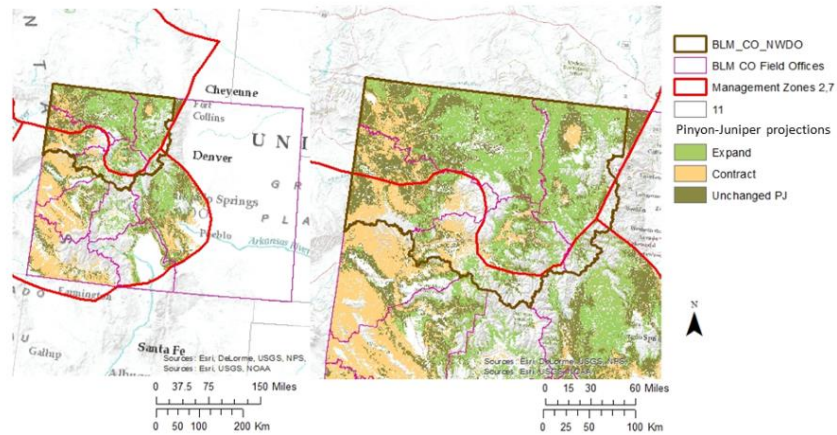
- Used data from **Research on Forest Climate Change: Potential Effects of Global Warming on Forests and Plant Climate Relationships in Western North America and Mexico**
- Rehfeldt et al, 2006 Empirical Analyses of Plant Climate Relationships for the Western US.
- Random Forests multiple regression tree modeling using current climate and projecting using downscaled GCM
- Initially 25 biotic communities and 9 species
- This work is expanded to more species, to US-wide coverage
- The work is updated for assessment reports
  - AR3 – Emissions scenarios: A1B, A2, B1, B2 *for greenhouse gas emissions and was superceded by*
  - AR5 - Representative Concentration Pathways (rcp45, rcp60, rcp85) *for greenhouse gases concentrations*
- Data resolution about 1km

## PJ viability under climate change

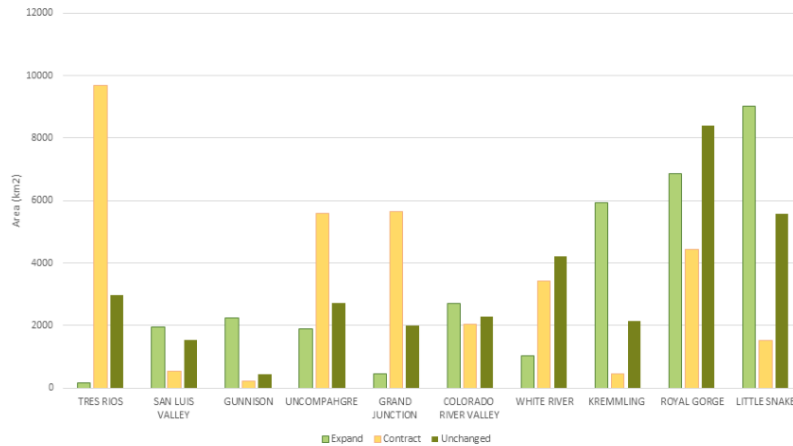
- Species used: Pinyon Pine, Rocky MT Juniper and Utah Juniper
- Current and SRES A2, 2030, CGCM – 2060 and 2090 also available
- Species viability is modeled 0 to 1 where 1 means that the species is most viable under that climate
- **For the 3 PJ species, use the max value of the 3 rasters for current and 2030**

Discussion suggested that it might be more useful to keep these species separate. There is an ongoing project similar to this (talk to Bruce at the SO).

A comparison of Current and Projected (2030) PJ species viability -> Expansion and contraction (excluding areas of more than 5% development)



## Expanding, contracting, and unchanged PJ — currently includes dv'd areas



“includes dv'd areas” = needs to be revised to exclude the areas of >5% development, as map on slide 49

## Summary – Questions - Next Steps

- SMRRT – we used best broad-scale and consistent data sets for sagebrush, R&R, and threats
  - Did we miss any potential threats?
  - Are some threats more important than others, i.e. deserve more focus?
  - Do development threats need to be analyzed separately (e.g., oil and gas)
- What other analyses would be useful?
- Would it be useful to determine thresholds and map/summarize using those?
  - For example: is 2% cheatgrass cover a useful threshold?

Using the SMRRT Science Framework, identify Management Questions specific to Sagebrush biome in CO Districts – these MQs are species specific, how do we make this relevant to the sagebrush biome?

Prioritize areas for management

- Need to develop thresholds for threats (development, cheatgrass, fire)
- Does the area provide suitable habitat and support species populations?
- Can the area be improved by active management?
- If area is at risk due to low R&R but has high conservation value for a focal species, how can it be maintained or improved through management?

## References

Chambers, J.C. et al. 2016. **Using resilience and resistance concepts to manage threats to sagebrush ecosystems, Gunnison sage-grouse, and Greater sage-grouse in their eastern range: A strategic multi-scale approach.** Gen. Tech. Rep. RMRS-GTR-356. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 143 p. [https://www.fs.fed.us/rm/pubs/rmrs\\_gtr356.pdf](https://www.fs.fed.us/rm/pubs/rmrs_gtr356.pdf)

Chambers, J.C. et al. 2017. **Science framework for conservation and restoration of the sagebrush biome: Linking the Department of the Interior's Integrated Rangeland Fire Management Strategy to long-term strategic conservation actions. Part 1. Science basis and applications.** Gen. Tech. Rep. RMRS-GTR-360. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 213 p. <https://www.treeseearch.fs.fed.us/pubs/53983>

Maestas et al, 2016. **Tapping Soil Survey Information for Rapid Assessment of Sagebrush Ecosystem Resilience and Resistance.** *Rangelands*, 38(3):120-128. <http://www.bioone.org/doi/full/10.1016/j.rala.2016.02.002>

Still and Richardson, 2015. **Projections of Contemporary and Future Climate Niche for Wyoming Big Sagebrush (*Artemisia tridentata* subsp. *wyomingensis*): A Guide for Restoration.** *Natural Areas Journal*, 35(1):30-43. DOI: <http://dx.doi.org/10.3375/043.035.0106>

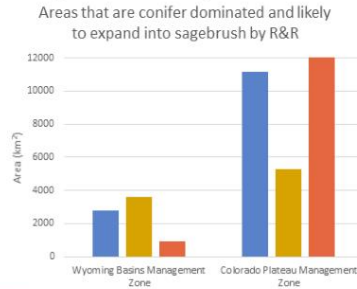
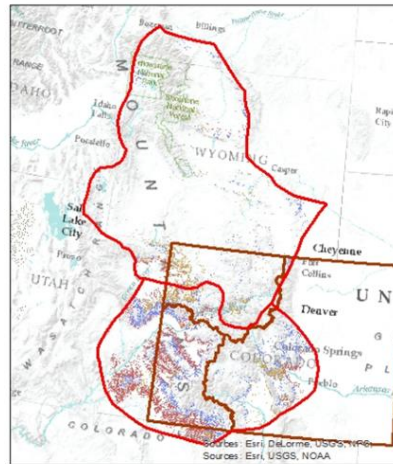
Rehfeldt et al, 2006. **Empirical analyses of plant-climate relationships for the western United States.** *Int. J. Plant sci.* 167(6):1123–1150.

Unused slides

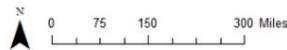
## Data sources

- Chambers et al (2016; Sciencebase: Science Framework for the Conservation and Restoration Strategy)
    - Conifer and Sagebrush: These data sets are derived from LandFire EVT.
    - R&R: data sets are derived from Statsgo and SSURGO (Maestas et al, 2016, Chambers et al 2016)
  - Boundary data sources:
    - BLM (Field Offices, District Offices)
    - Chambers et al, (2016; Sciencebase: Science Framework for the Conservation and Restoration Strategy) – PAC, Management Zones
  - Falkowski et al (2016) Percent conifer cover
  - Cheatgrass:
    - LandFire Introduced Annual Grassland
    - PNNL (Larson) percent cheatgrass thresholded at 2%
    - Provisional USGS (Homer) Annual Herbaceous
- Do we want to look at the LF EVT list for conifers and adjust for only PJ or will using Falkowski be better option?

## Where are areas that are conifer dominated and likely to expand into sagebrush by R&R

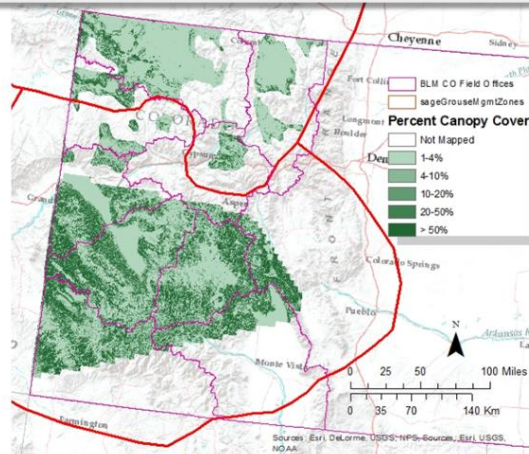


- Management Zones 2.7
- CO District Bnds
- Conifer likely to expand into SB, RR high
- Conifer likely to expand into SB, RR moderate
- Conifer likely to expand into SB, RR low

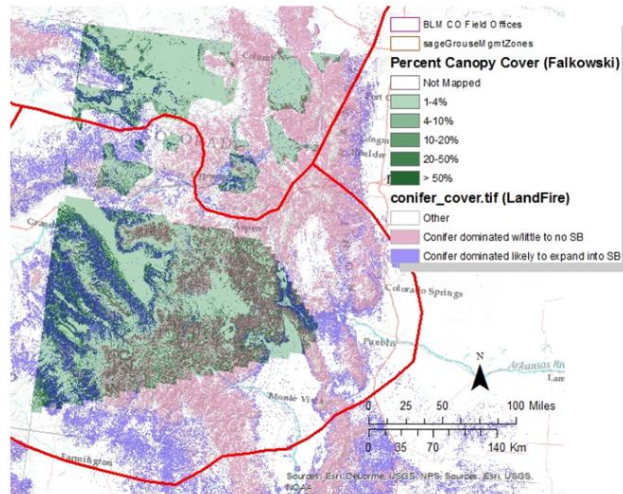


## Percent Canopy Cover (Falkowski et al, 2016)

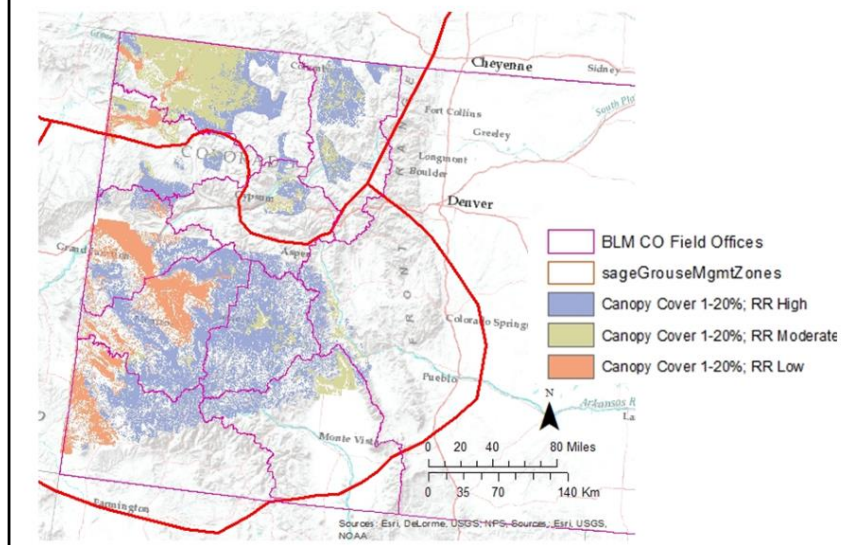
- 1 – 20% cover generally indicates early to mid succession conifer used as a surrogate here for conifer expansion
- Canopy cover is mapped in occupied sage grouse habitat only

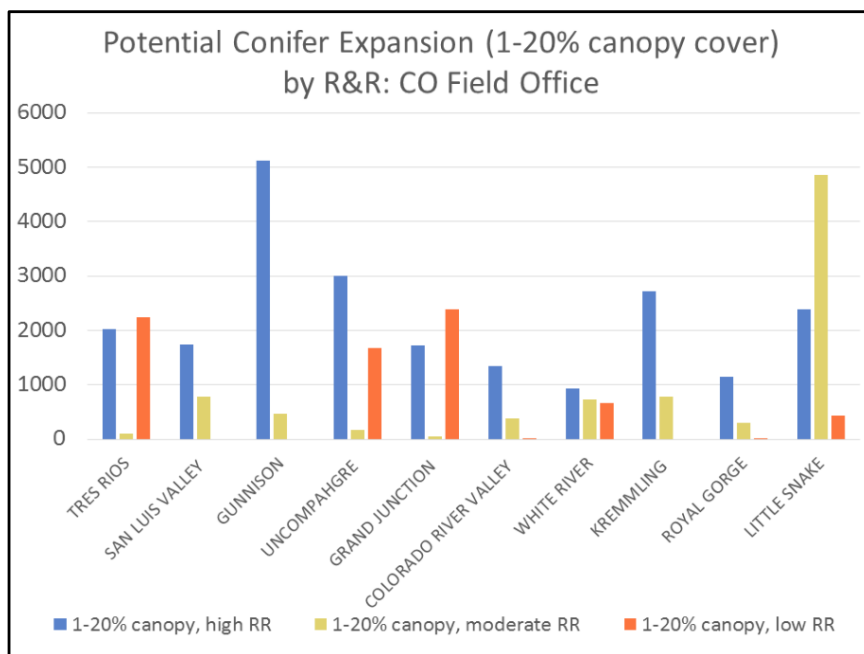


## Compare Falkowski Percent Canopy Cover to LandFire Conifer Canopy Cover (Chambers)

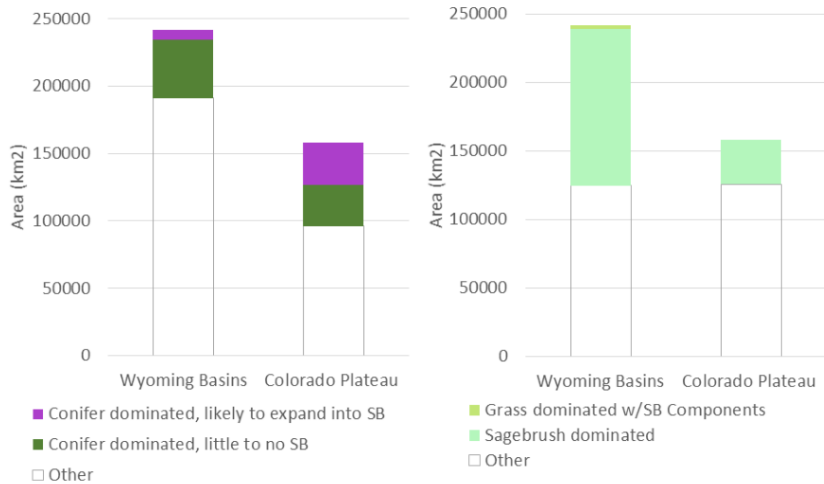


## Percent Canopy Cover by Resistance & Resilience

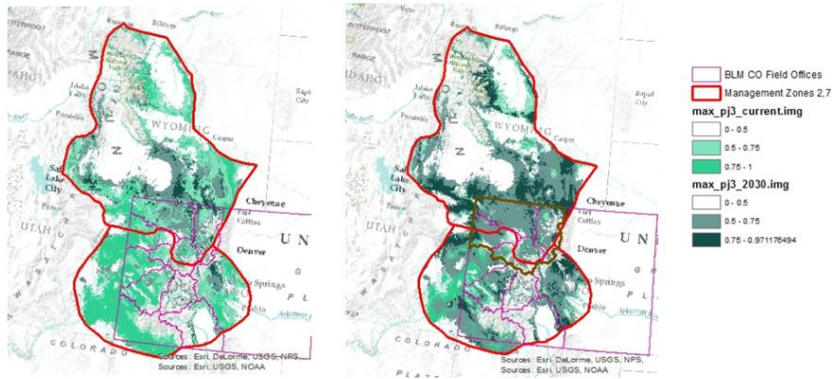




## Conifer and sagebrush coverage by Management Zone



## Pinyon juniper species viability: current and 2030, Management Zones 2 and 7



Current over 2030. Dark green  
areas show *expansion* in 2030.

2030 over Current. Bright green  
areas show *contraction* in 2030.

## Pinyon juniper species viability: current and 2030, NW District



Current over 2030. Dark green areas show *expansion* in 2030.



2030 over Current. Bright green areas show *contraction* in 2030.



## A comparison of Current and Projected (2030) PJ species viability -> Expansion and contraction

