Forest Health Landscape Assessment (San Miguel County, Colorado)

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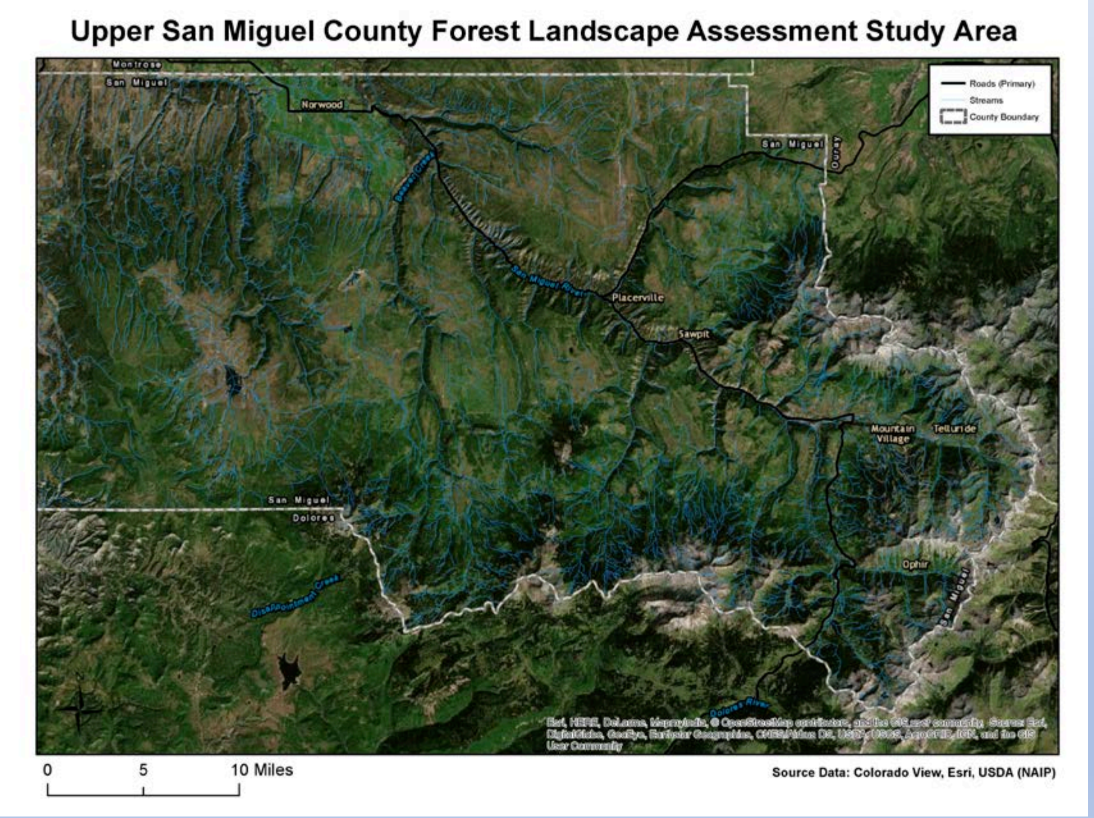
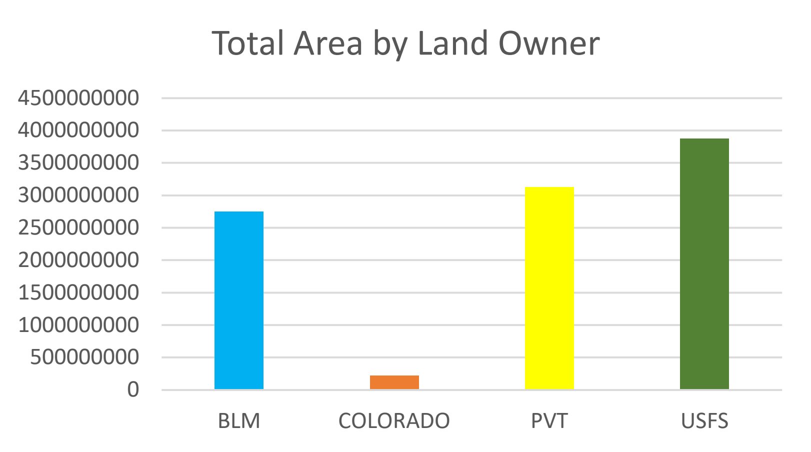
Anticipating Regional Climate Change

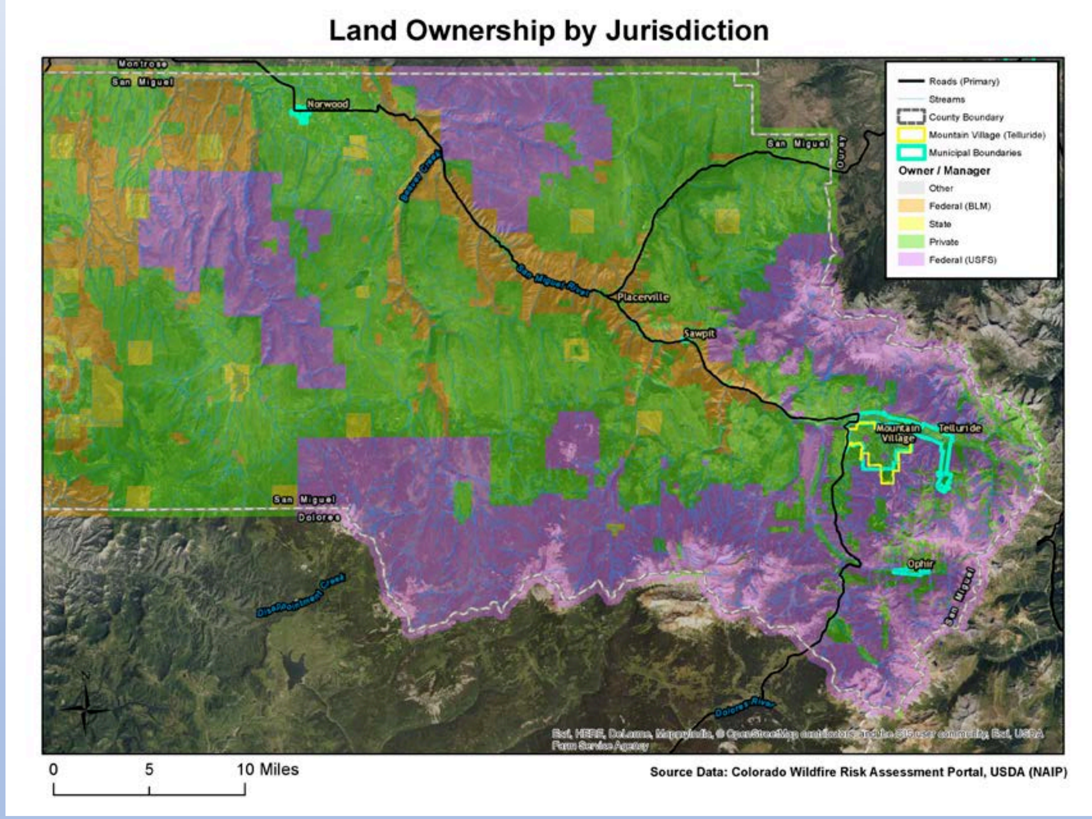
- Concerns in San Miguel County, Colorado, about distribution and extent of future forest cover loss due to climate change-induced die-off, wildfire, etc.:
  - Aesthetic
  - Ecological (e.g. ecosystem services, habitat fragmentation, etc.)
  - Direct impacts on populated areas (e.g. fire, flood, etc.), infrastructures (power, transportation, etc.), recreation (ski resort, trails, etc.)



Stakeholders

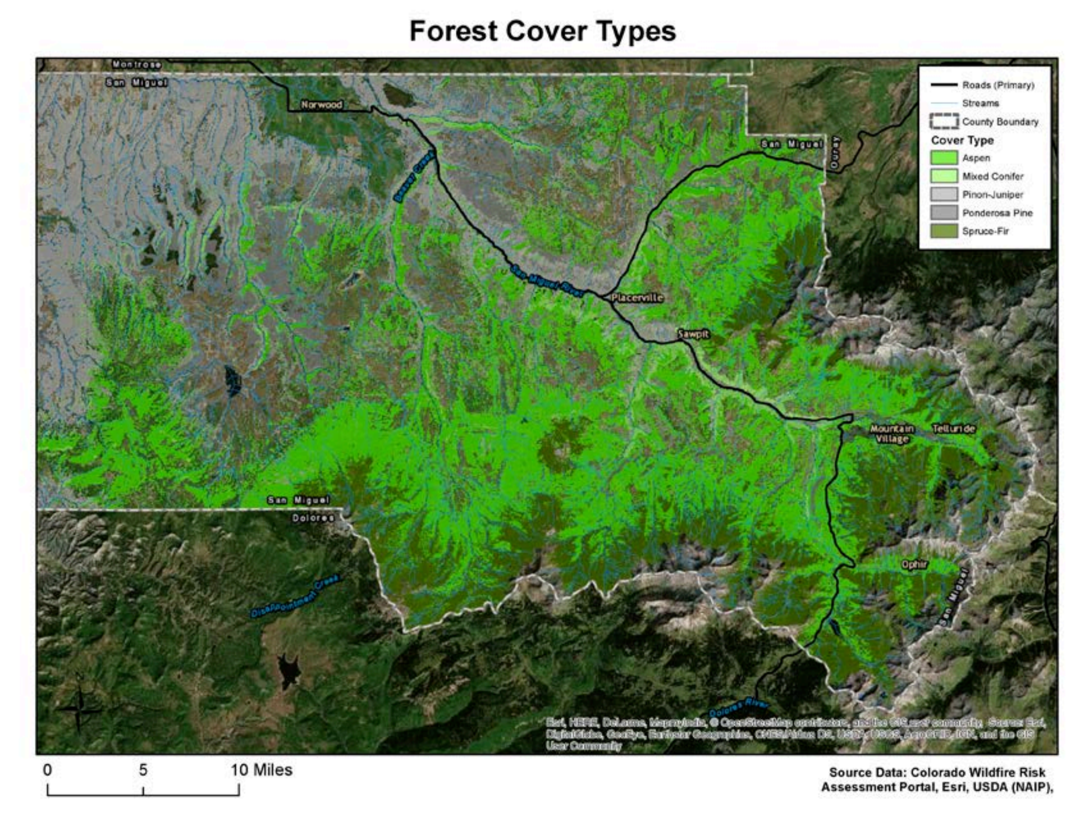
- Array of land managers/owners:
  - State of Colorado (e.g. Department of Wildlife)
  - Federal (BLM and USFS)
  - Other (land trusts and private landowners)





Engaging Outside Expertise

- Dr. Jason Sibold, PhD (Professor of Biogeography, Colorado State University, Fort Collins, CO) engaged as consultant in assessing outlook for forest cover types of concern:
  - Douglas-fir
  - Engelmann Spruce/Subapline Fir
  - Ponderosa Pine
  - Quaking Aspen
- Assessing associated impacts (e.g. wildfire risks)
- Identifying possible mitigation measures

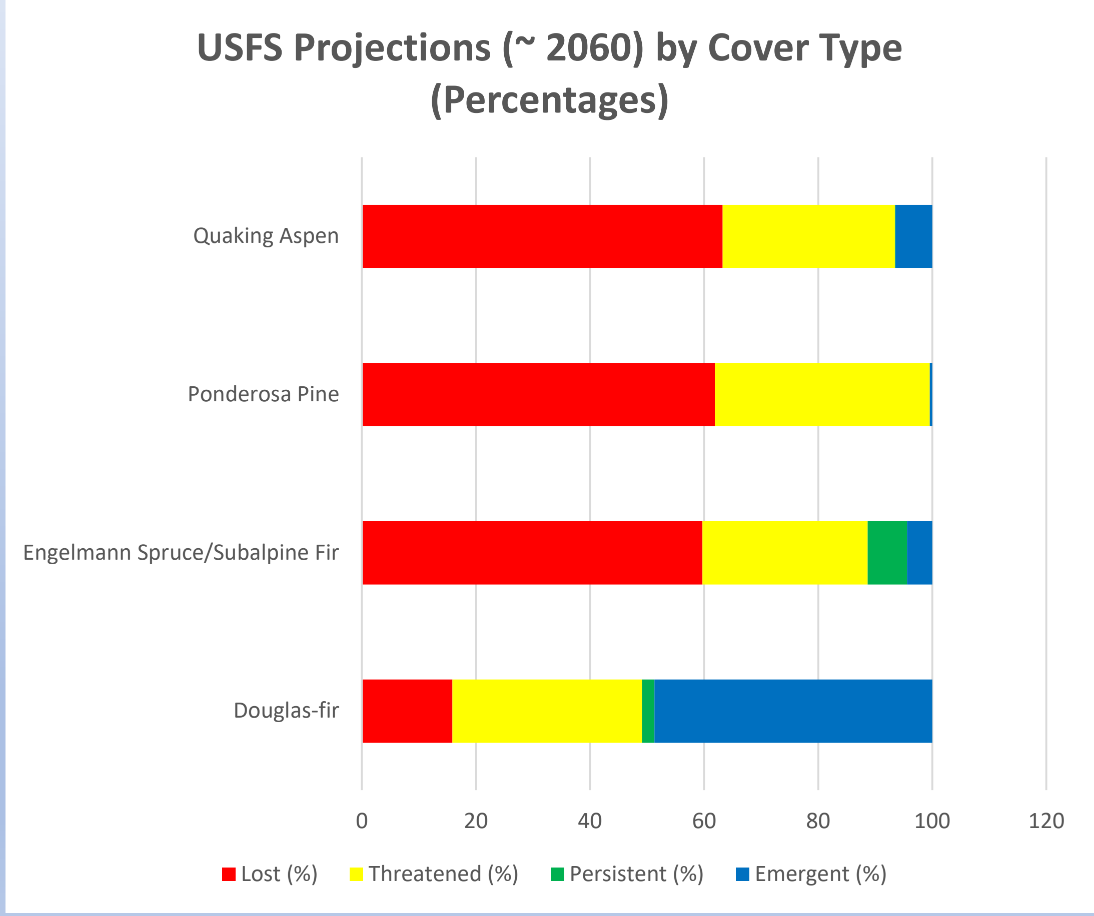


Central Question

- Is the future outlook for San Miguel County as bleak in the aggregate as predicted by USFS models using elevation as proxy for climate change (rising temperatures and shifts in precipitation)?

- OR -

- Are there pockets where alpine forest cover could hang on despite the regional climate warming, where microclimates exist as a function of the terrain itself (i.e. where the dissected mountain topography produces locations of varying suitability ["topo-climate"])?

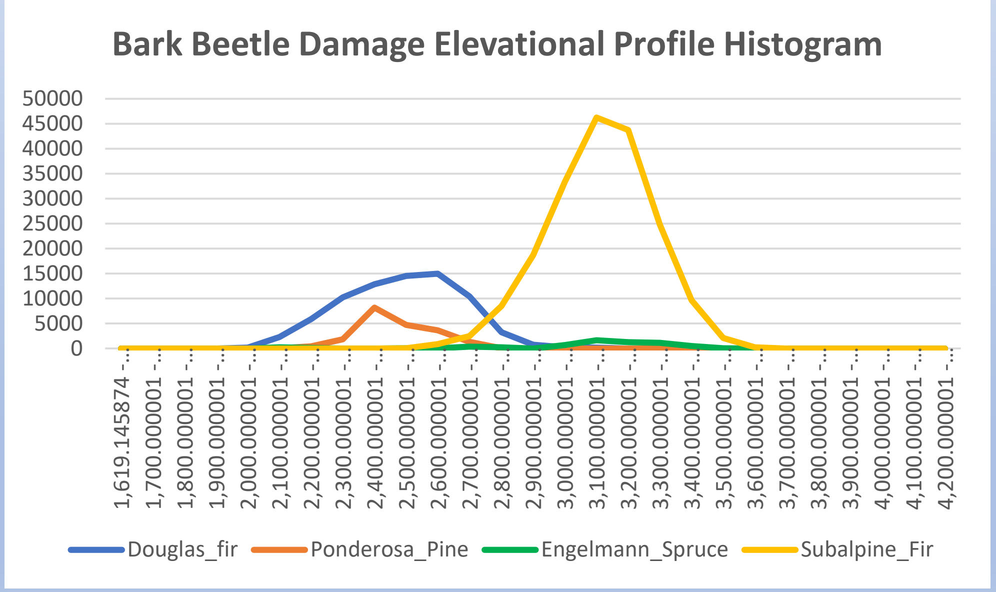


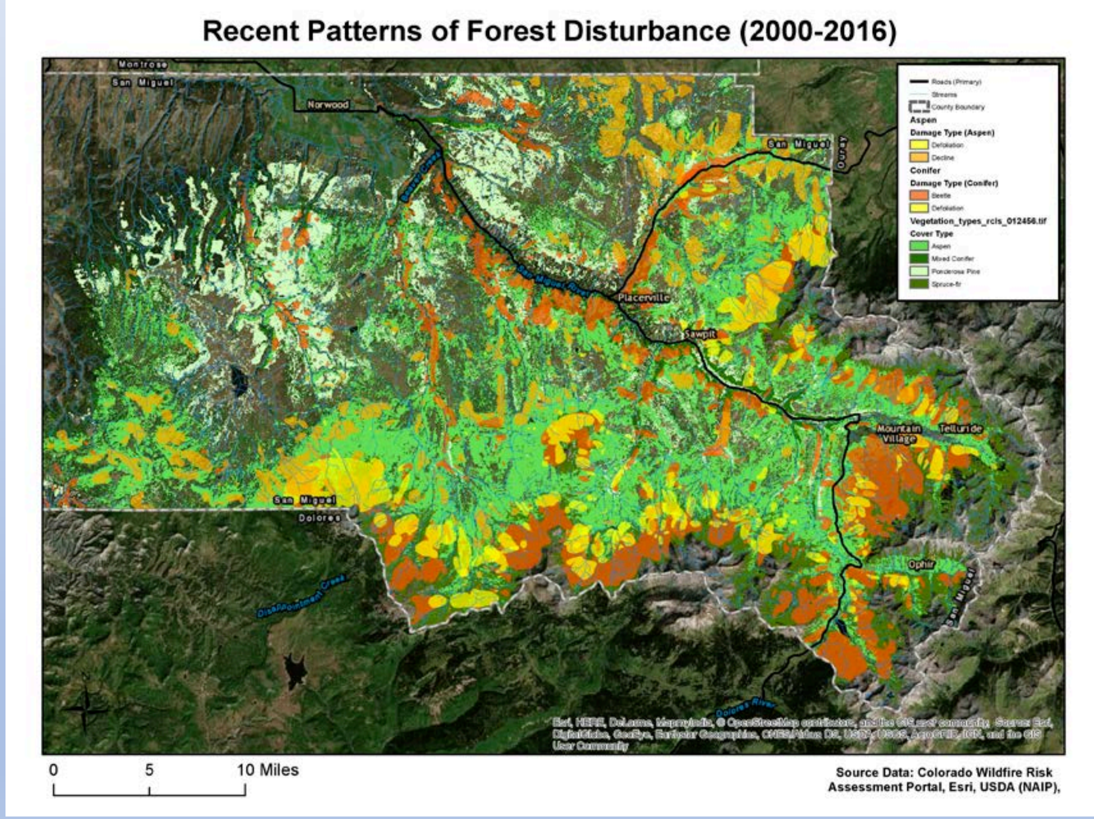
Data Utilized

- Colorado State Forest Service Wildfire Risk Mapping (CO-WRAP website)
- Aerial Survey Data for southwestern Colorado (2000-2016):
    - Observed defoliation/decline (Quaking Aspen)
    - Observed damage by bark beetles (Douglas-fir, Engelman Spruce/Subalpine Fir, Ponderosa Pine)
    - Caveat: variable accuracy (i.e. very approximate polygons)
- USFS Change Projections (Worrall/Marchetti)
- USGS Digital Elevation Model (10-meter resolution)
- Terrain-derived geomorphology (i.e. geomorphometric indices) using the Jeffrey Evans “ArcGIS Gradient Metrics Toolbox”

Aerial Observations (2000-2016)

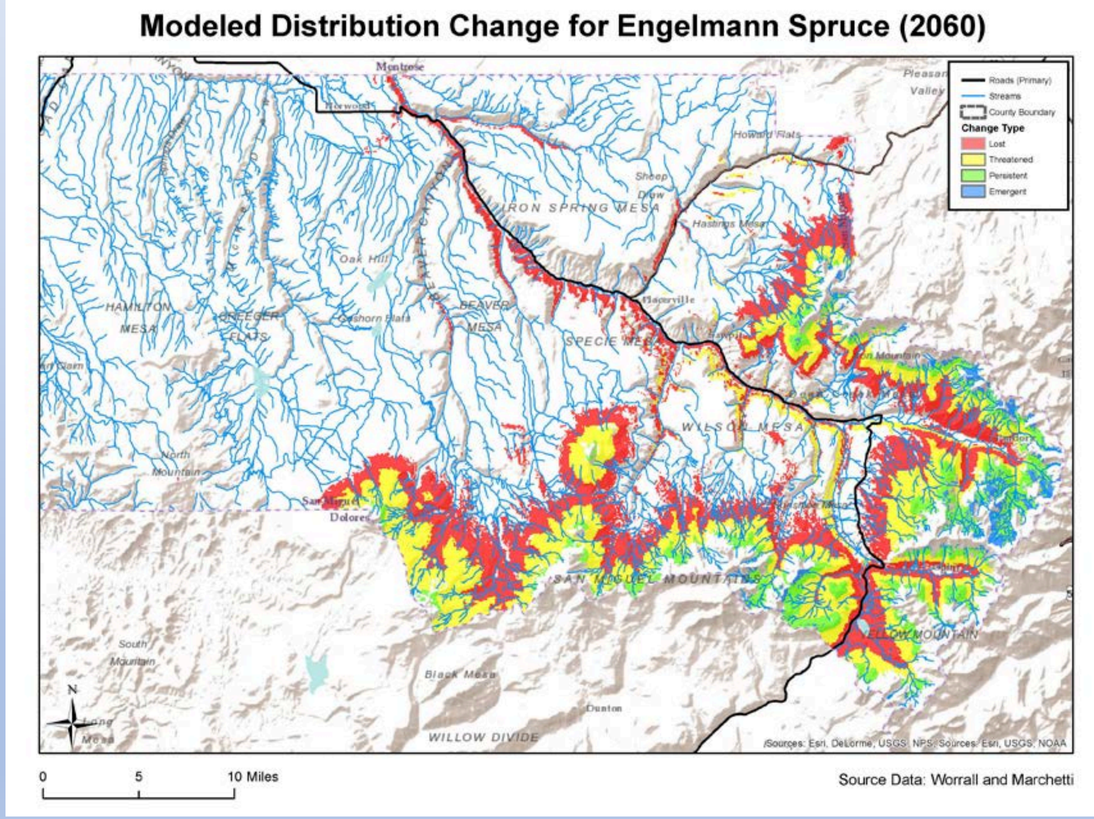
- Aerial surveys flown (USFS/CSFS) show extensive impacts on subalpine forest cover





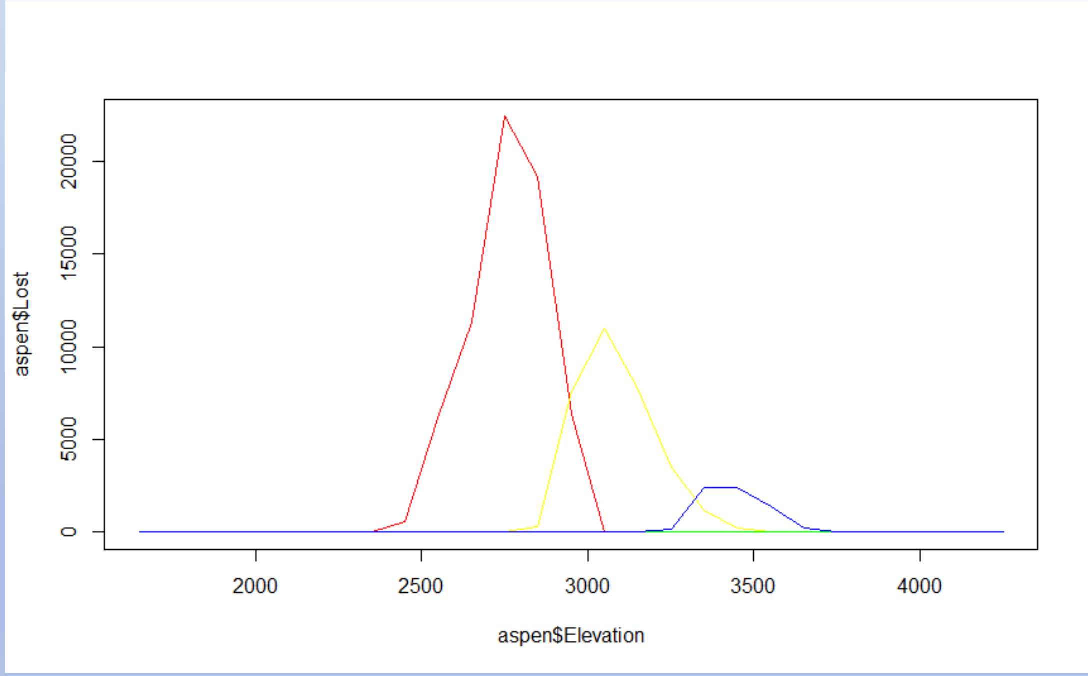
Forest Cover Extent Projections c. 2060

- USFS (Worrall & Marchetti) has projected forest cover extents circa 2060, categorizing existing forested areas as being:
  - Persistent
  - Threatened
  - Lost
  - Emergent

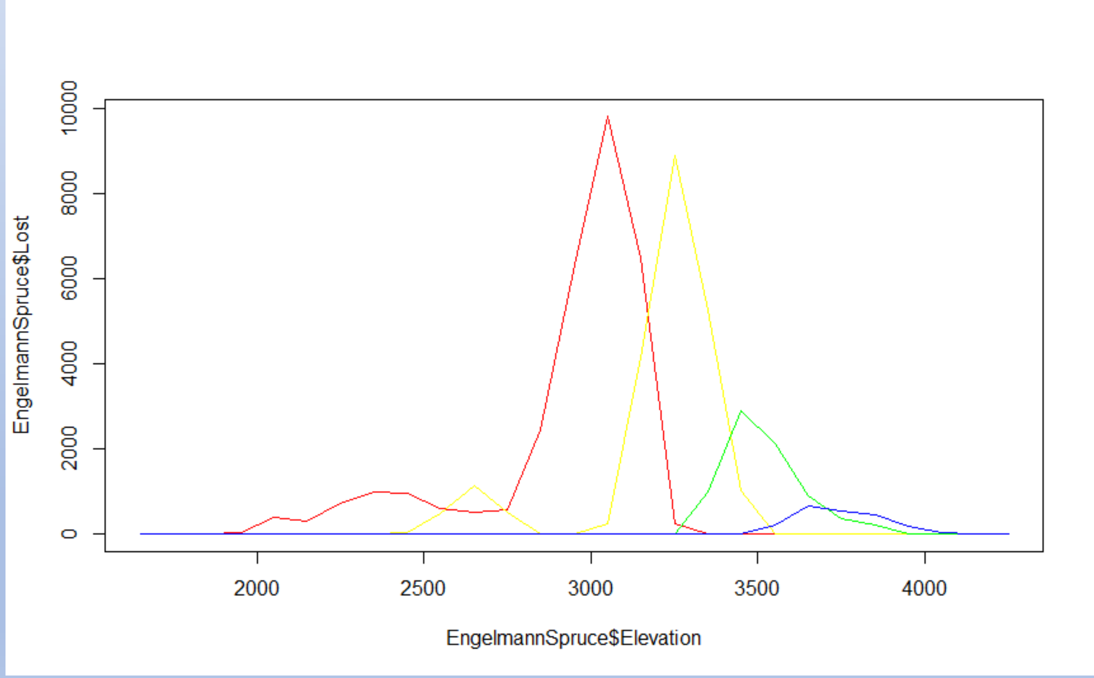


Elevation Histograms

Projected Aspen Cover Change (2060)



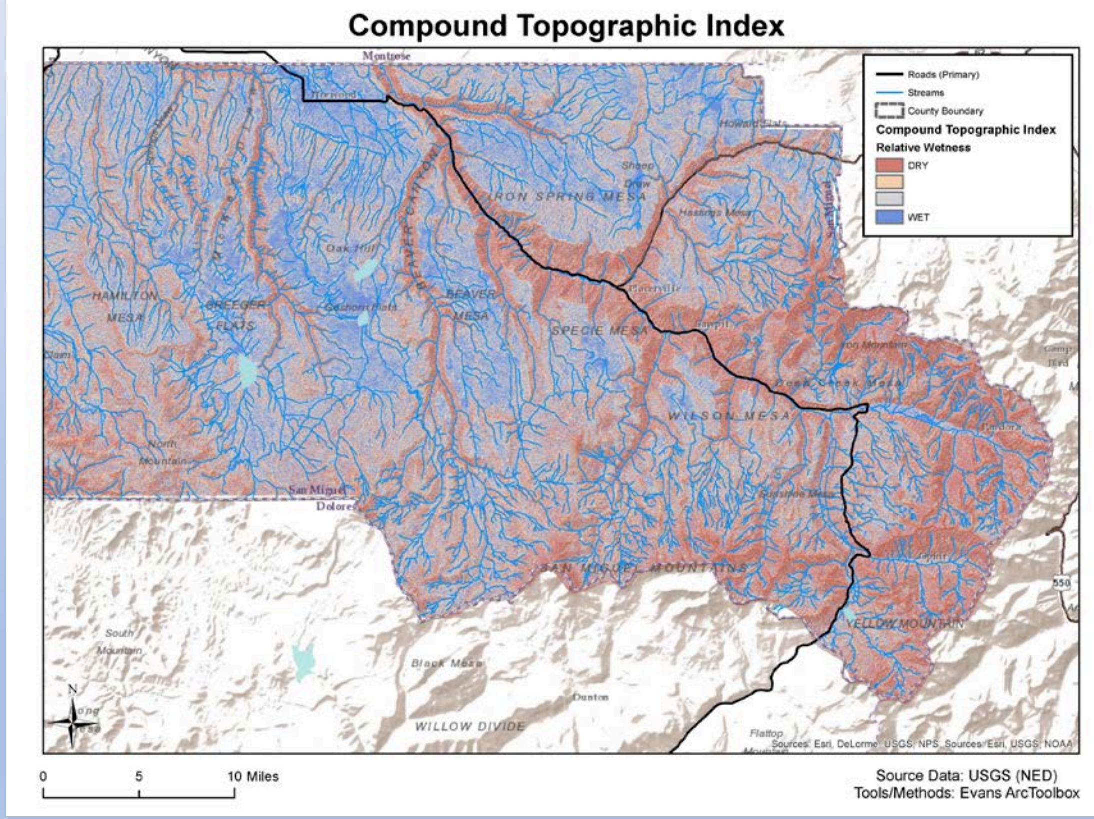
Projected Engelmann Spruce Cover Change (2060)



Methods

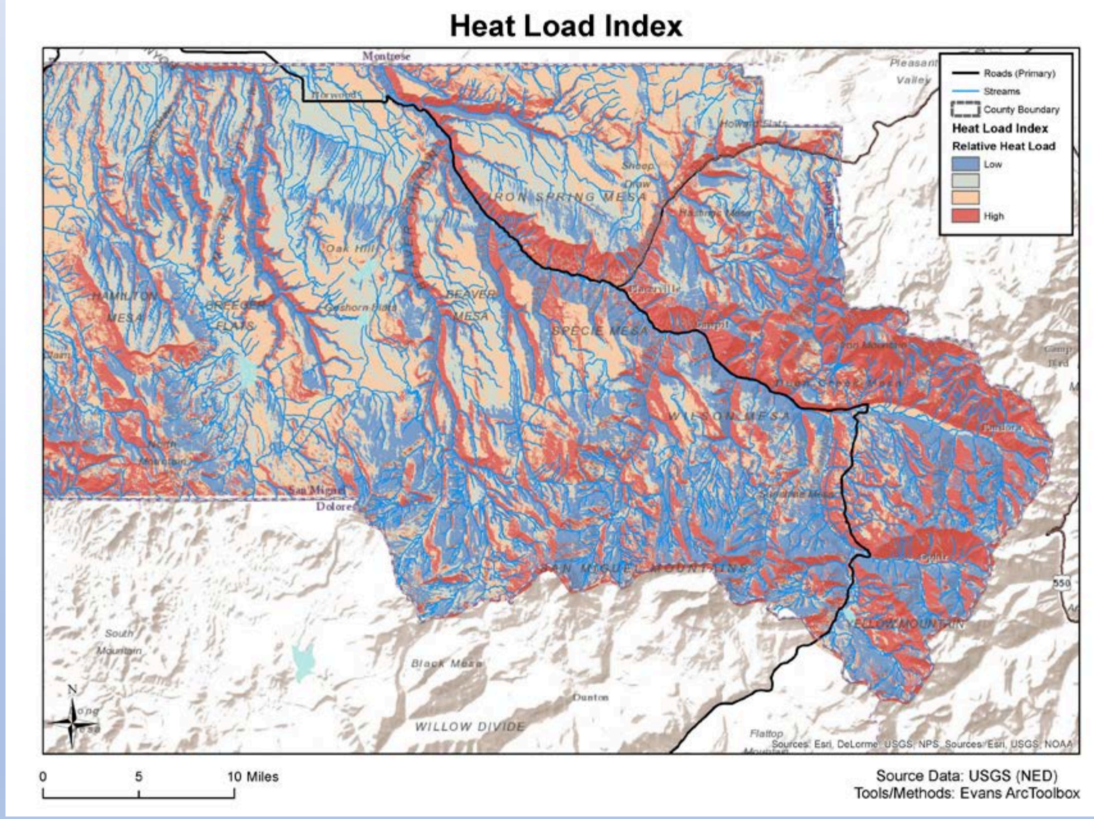
- Merge aerial survey observations of damage/decline (2000-2016)
- Reclassify USFS Projections for 2060 according to suitability:
  - Threatened = Low
  - Persistent/Emergent = High
  - Lost = **Zero** *(i.e. unsuitable)*
- Derive geomorphometric indices from terrain:
  - Compound Topographic Index (CTI), as measure of wetness
  - Heat Load Index (HLI), as measure of heat stress

Estimating Wetness as Function of Terrain



- **Compound Topographic Index (CTI)** - (float) is a steady state wetness index. The CTI is a function of both the slope and the upstream contributing area per unit width orthigonal to the flow direction. The implementation of CTI can be shown as: CTI=ln (As / (tan (beta)) where; As=Area Value calculated as (flow accumulation + 1) * (pixel area in m2) and beta is the slope expressed in radians.
- **References**:
  - Gessler, P.E., I.D. Moore, N.J. McKenzie, and P.J. Ryan. (1995). Soil-landscape modeling and spatial prediction of soil attributes. *International Journal of GIS*. 9(4):421-432.
  - Moore, ID., P.E. Gessler, G.A. Nielsen, and G.A. Petersen (1993) Terrain attributes: estimation methods and scale effects. In *Modeling Change in Environmental Systems*, edited by A.J. Jakeman M.B. Beck and M. McAleer Wiley , London, pp. 189-214.

Estimating Heat as Function of Terrain

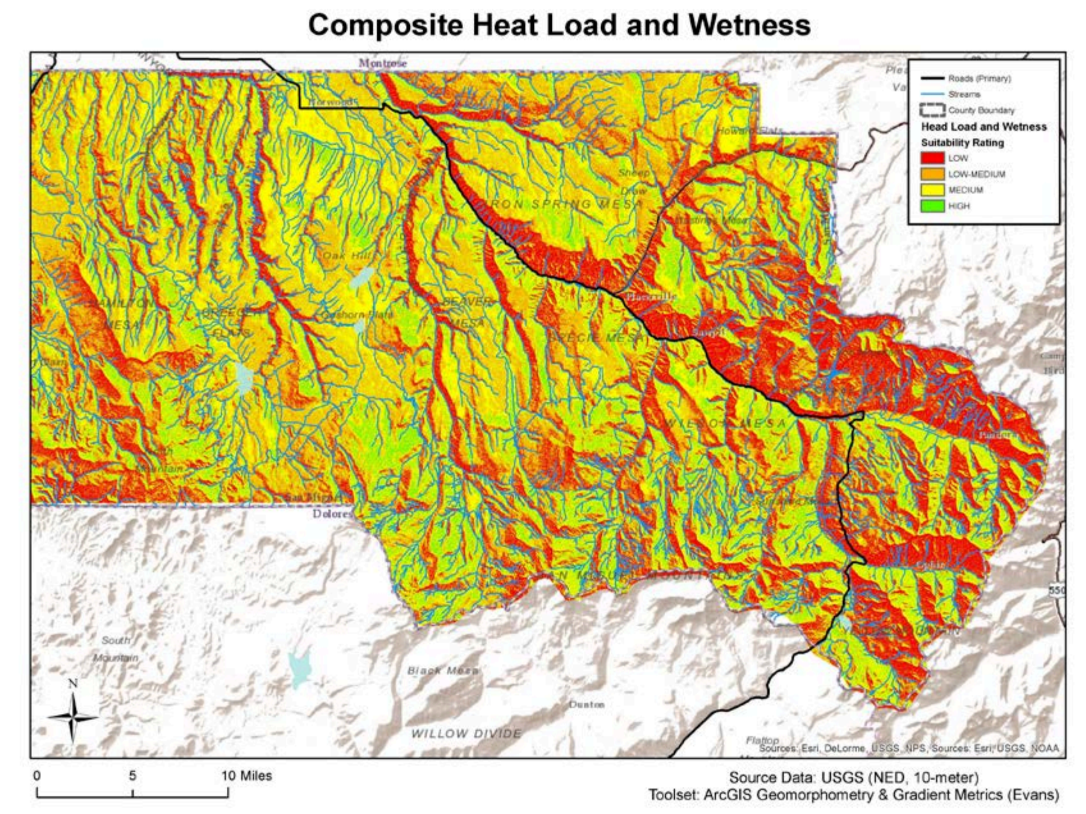


- **Heat load index** - (float) A southwest facing slope should have warmer temperatures than a southeast facing slope, even though the amount of solar radiation they receive is equivalent. The McCune and Keon (2002) method accounts for this by "folding" the aspect so that the highest values are southwest and the lowest values are northeast. *Additionally, this method accounts for* ***steepness of slope****, which is not addressed in most other aspect rescaling equations.*
- **Reference**:

McCune, Bruce and Dylan Keon, 2002. Equations for potential annual direct incident radiation and heat load index. *Journal of Vegetation Science*. 13:603-606.

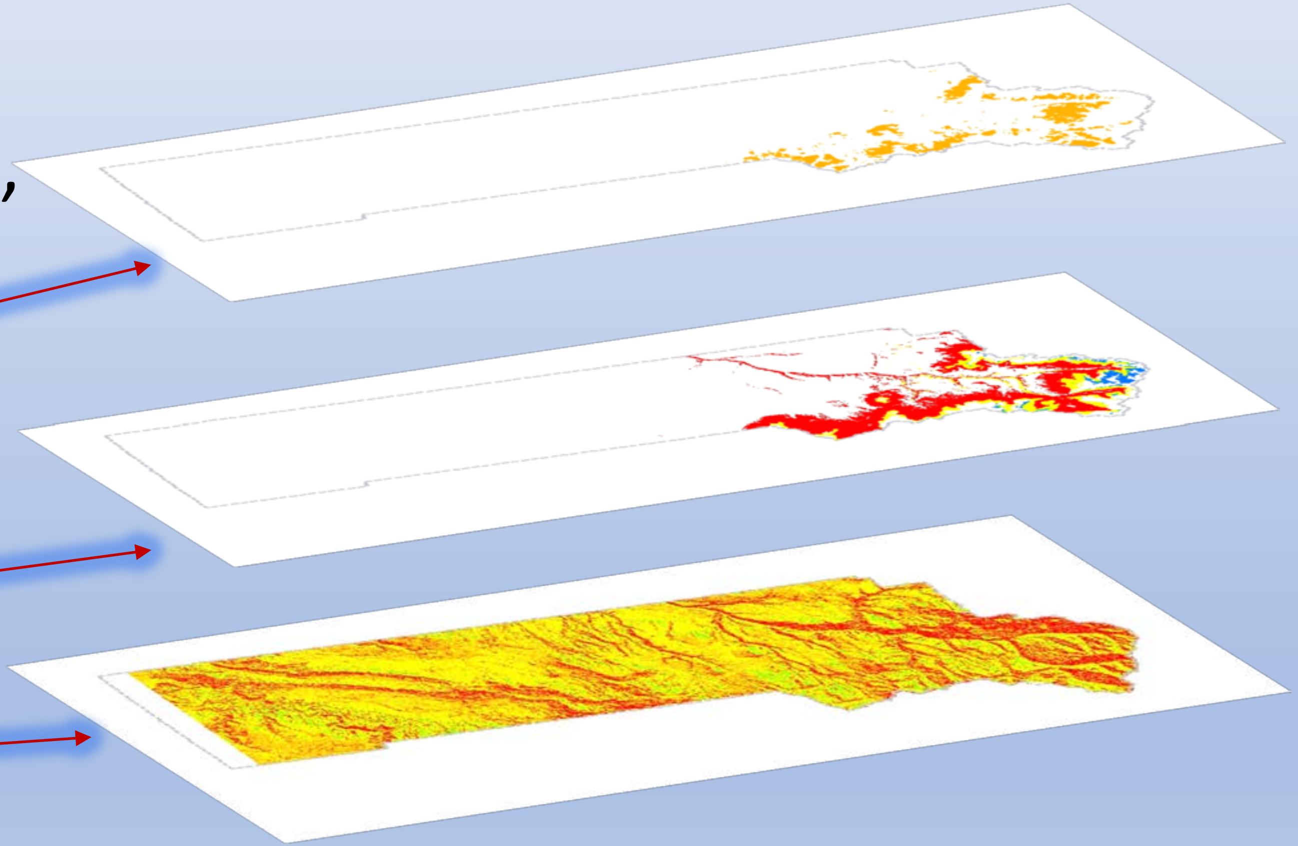
Site Suitability Surface ("Topo-climate")

- Generate suitability surface by combining "CTI + HLI" using weighted overlay process, assigning weights of 30% for CTI and 70% for HLI
- *Heat stress is considered <u>more significant</u> than moisture availability (i.e. heat seen as primary driver of the system)*

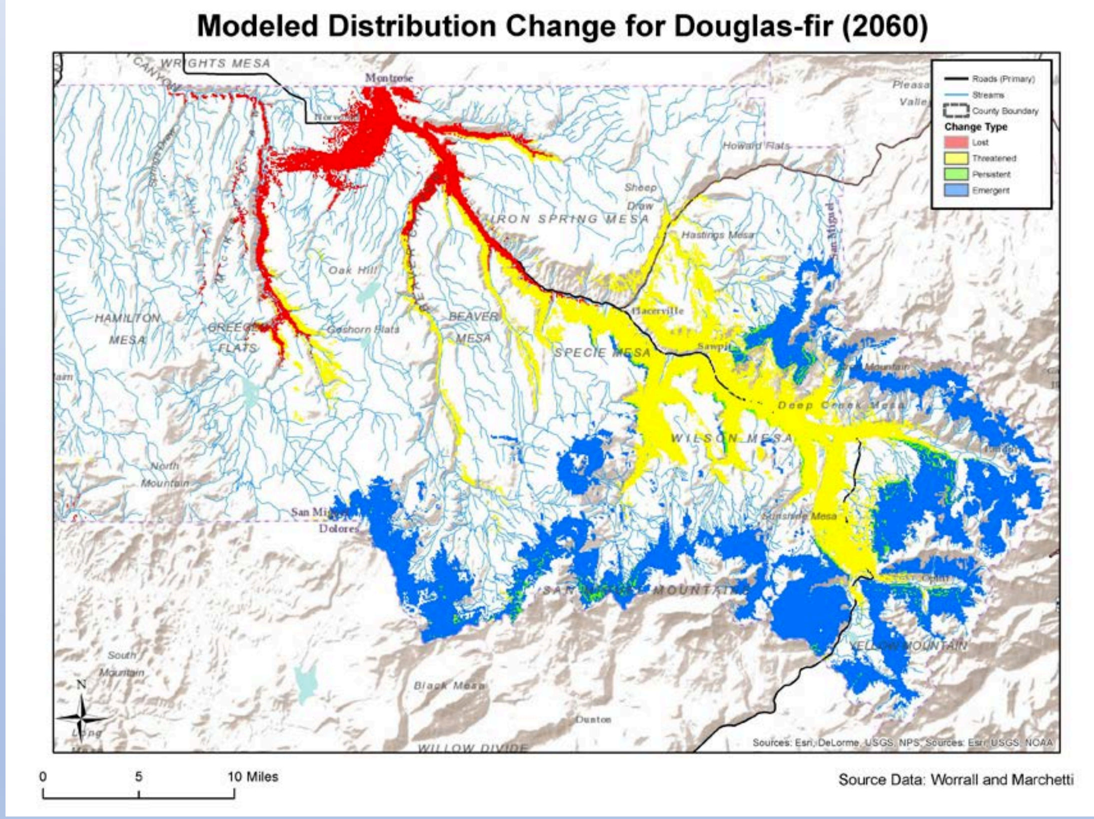


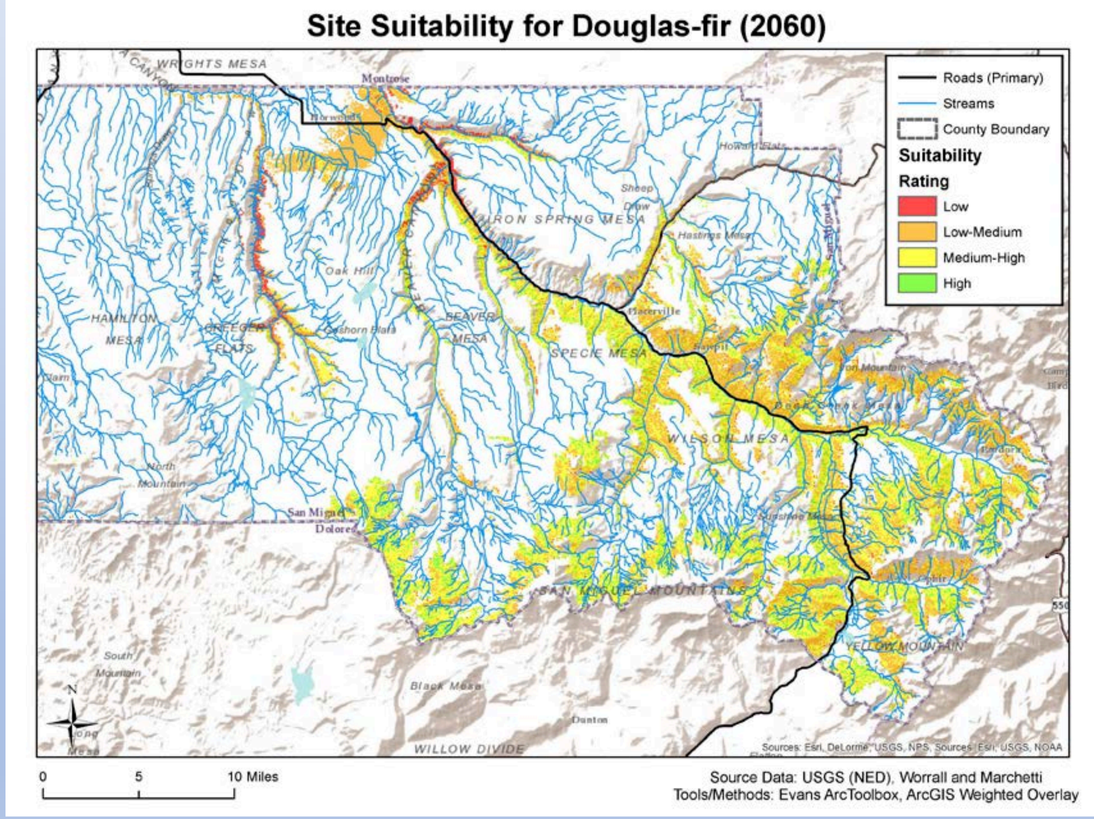
Estimating Site Suitability by Forest Cover Type

- Build site suitability surfaces for each forest cover type using weighted overlay model, inputs parameterized as follows:
  - Observed decline/damage for given forest cover type -> 33%
  - Projected change (Worrall and Marchetti) -> 33%
  - Terrain-derived site suitability (CTI+HLI) -> 34%

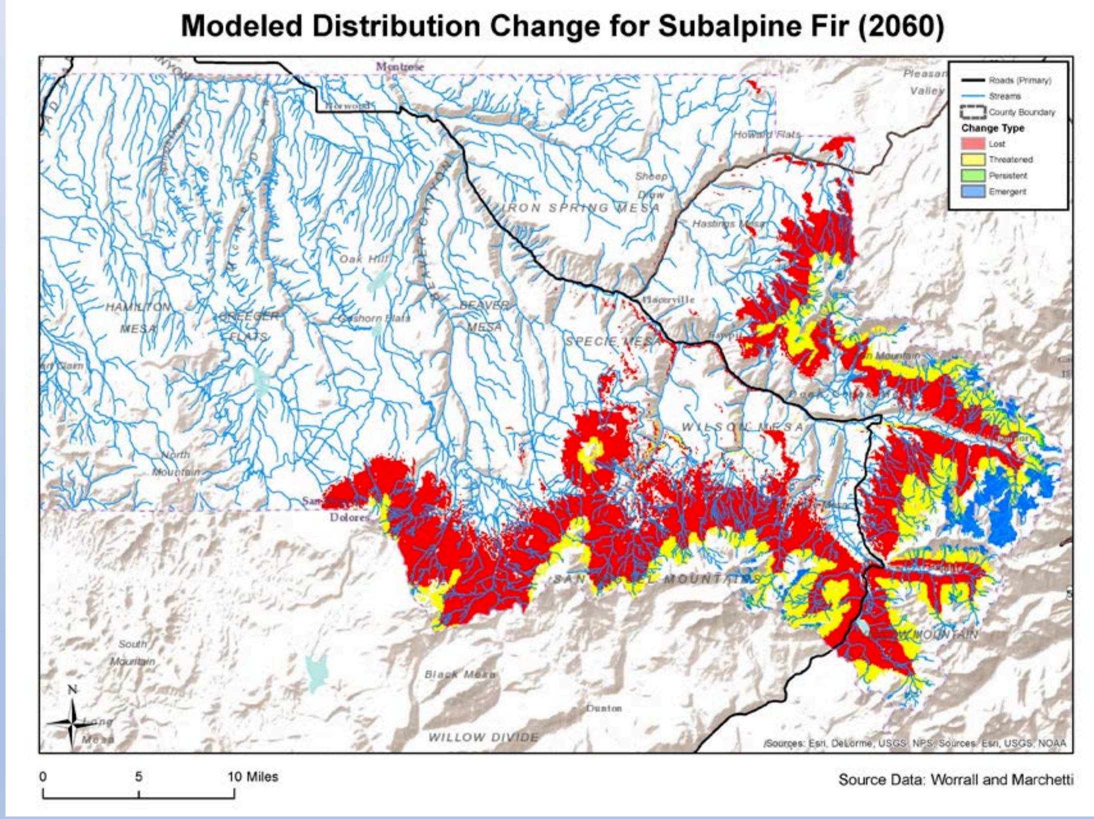


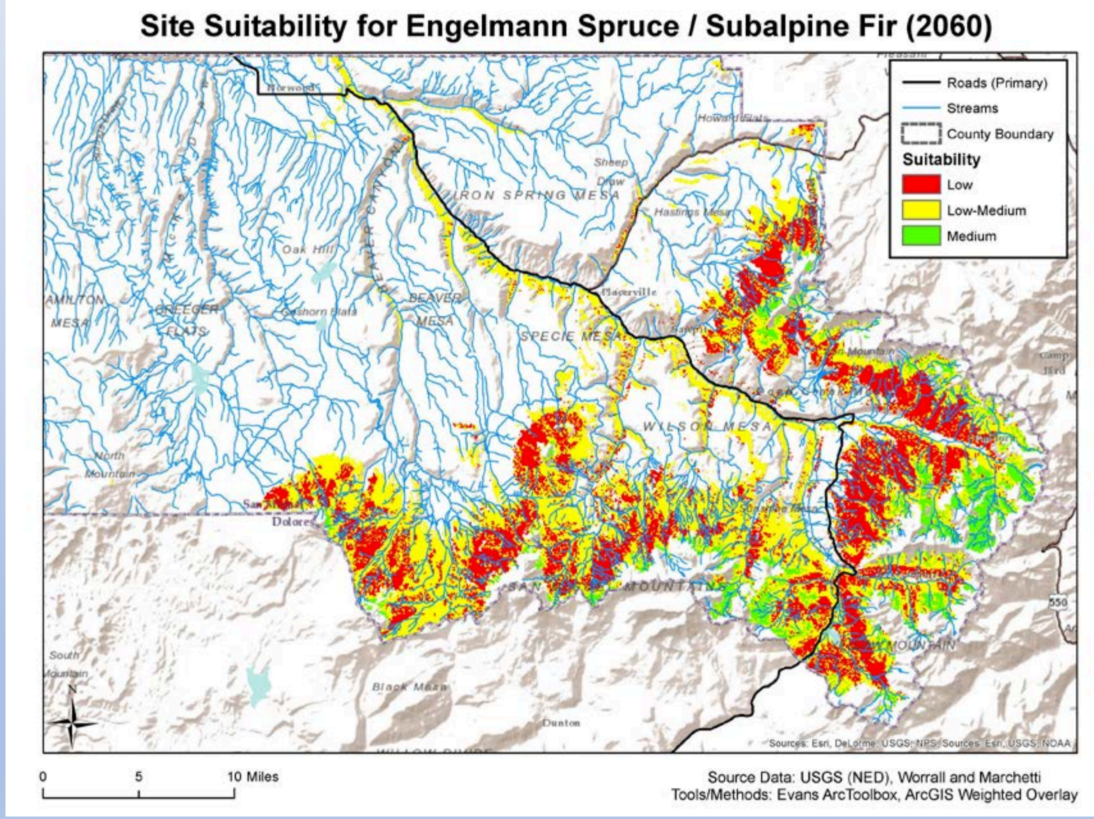
Weighted Overlay Suitability (Douglas-fir)



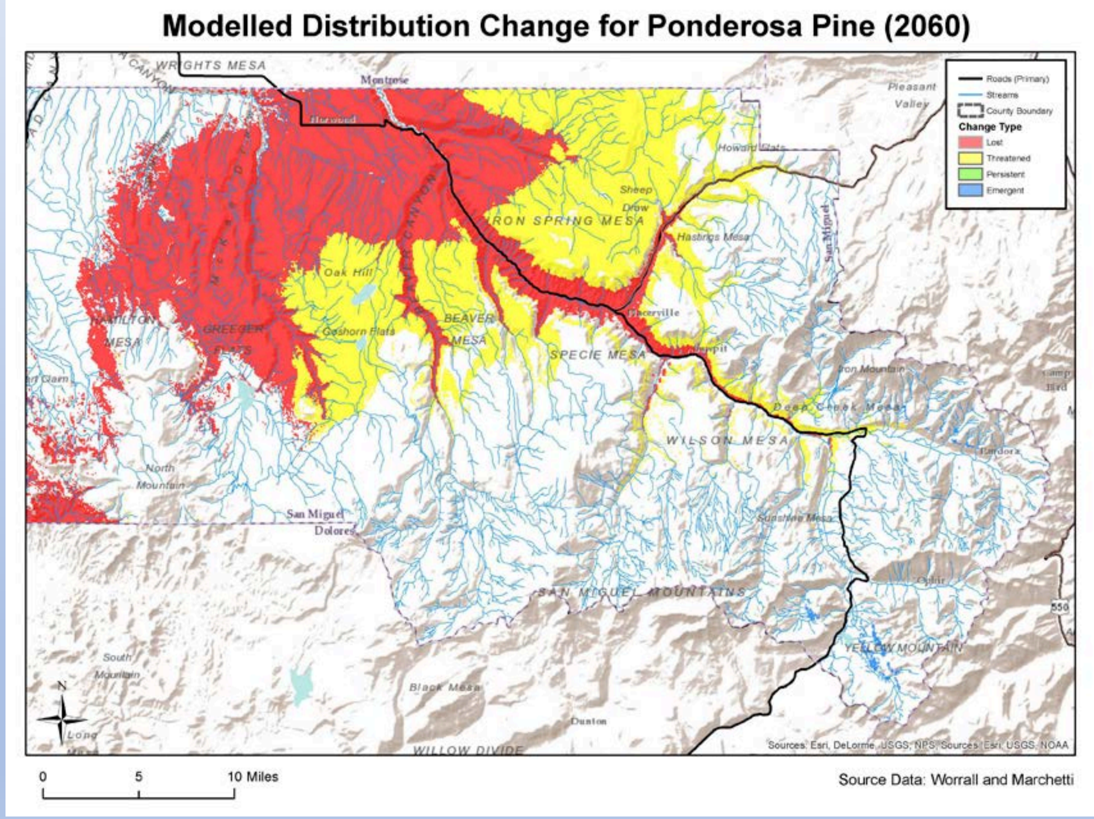


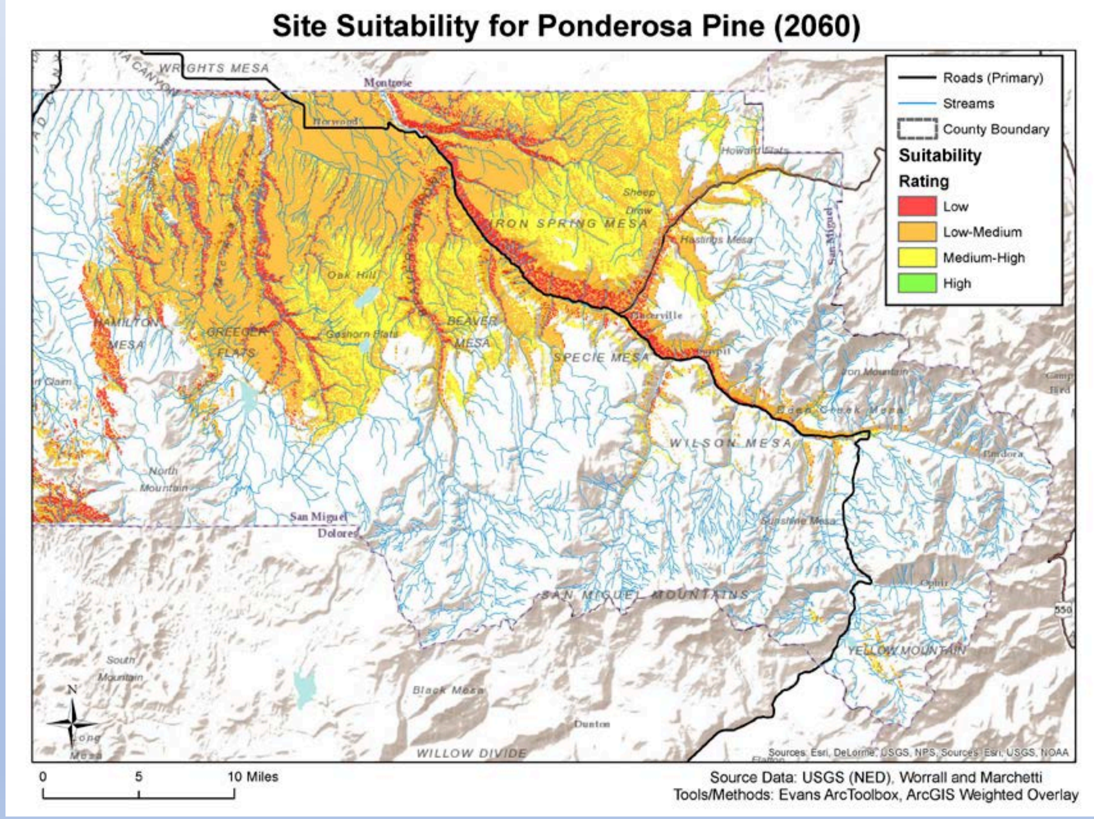
Weighted Overlay Suitability (Englemann Spruce/Subalpine Fir)



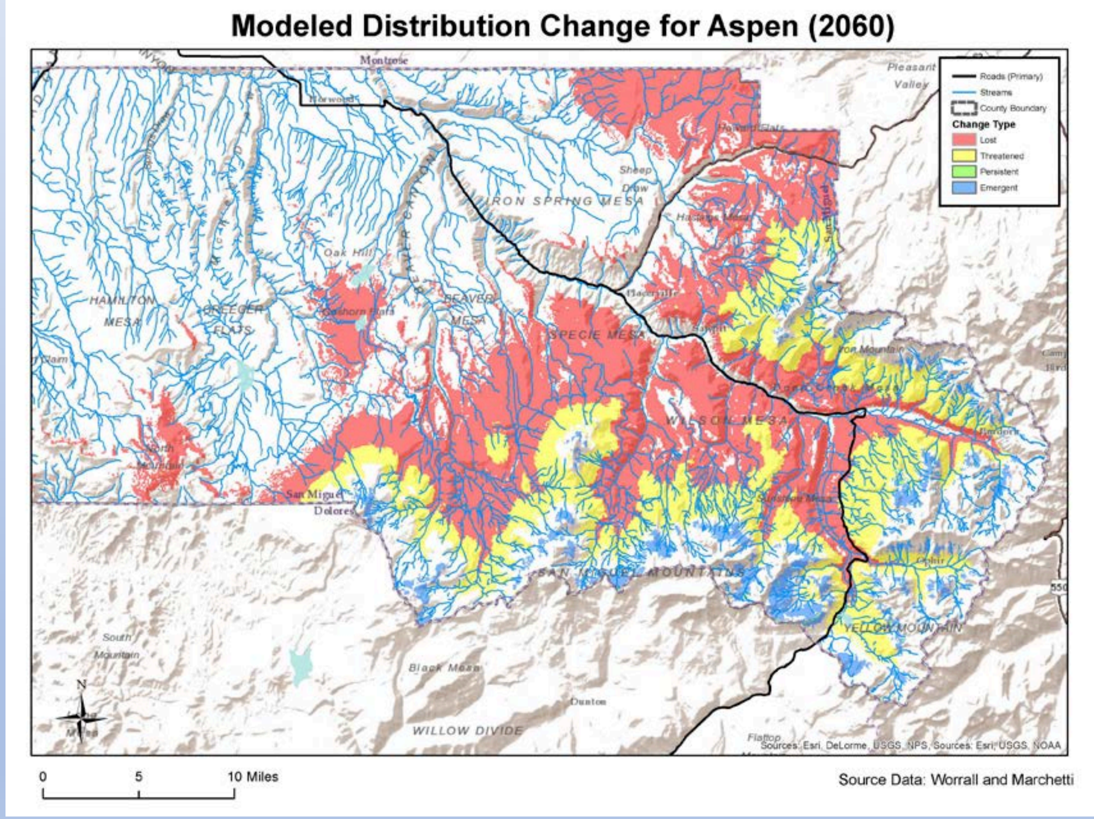


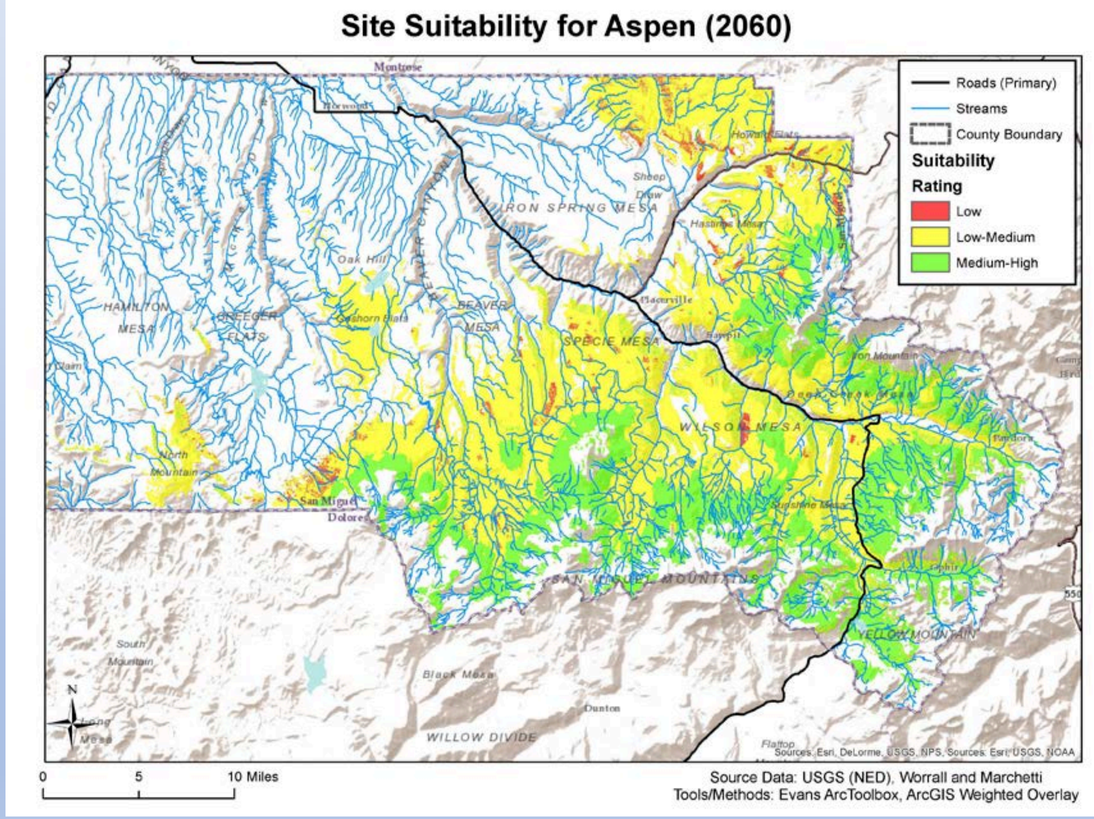
Weighted Overlay Suitability (Ponderosa Pine)





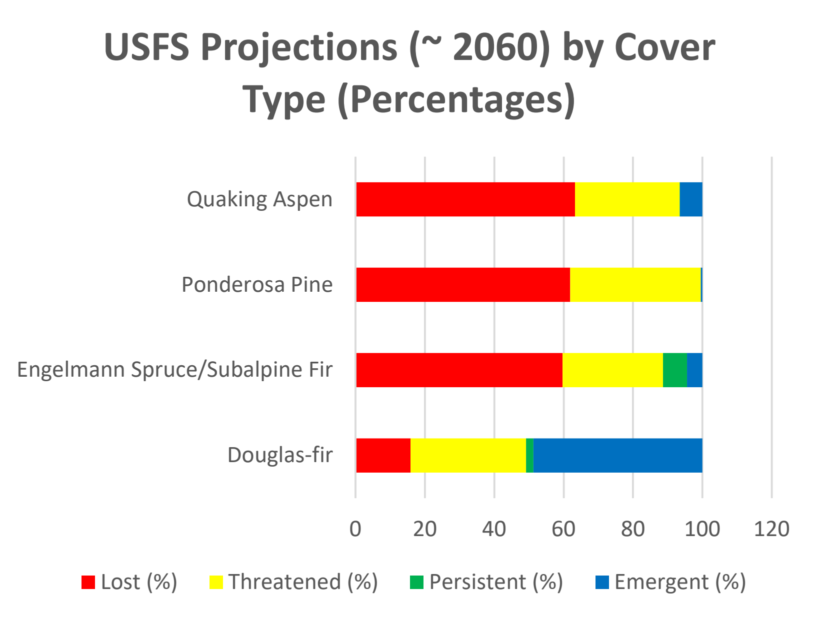
Weighted Overlay Suitability (Quaking Aspen)

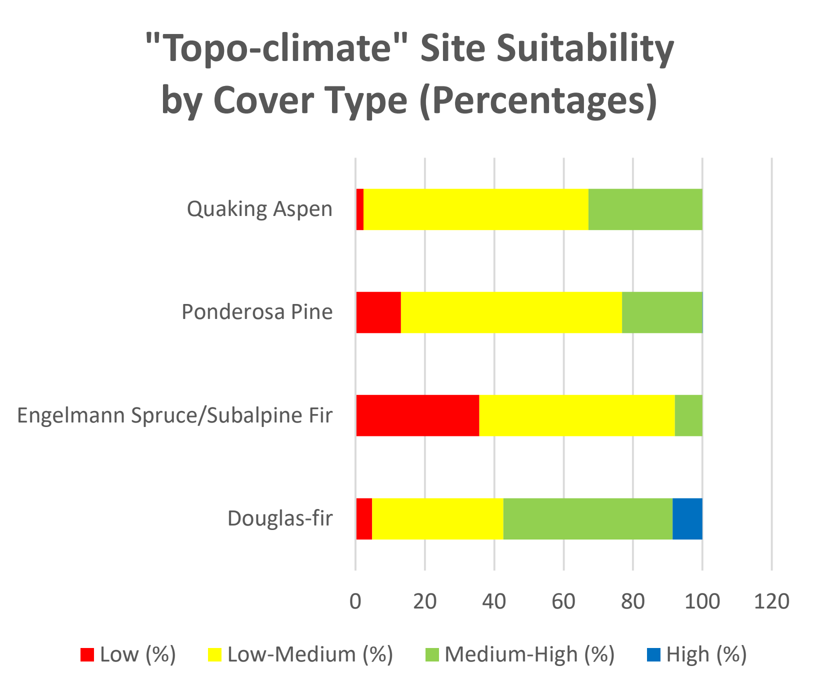




Preliminary Hypothesis

- Climate (heat stress and moisture availability variables) can be either accentuated or buffered by terrain, ergo…
- Future forest cover may be more patchily distributed than the Worrall/Marchetti projections would suggest, as seen by incorporating “topo-climate” variables (aspect and slope as expressed via “CTI+HLI” surface)





Recap of Key Points

- Climate change has been occurring and will continue to occur across the Rocky Mountain Region, with the following effects:
  - Expanding growing season (starts earlier, ends later)
  - Rising overnight low temperatures
  - Shift in precipitation patterns (distribution, e.g. snowpack / timing; e.g. increasing frequency of rain-on-snow events)*
- Climate trends will affect all forest cover types, particularly along their lower elevational boundaries
- *BUT* adverse effects of regional climate may be buffered in certain locations by “topo-climate” zones with relatively lower heat and higher wetness
- Perturbations matter and can have a large effect on the overall trajectory of change (e.g. “SAD” with extreme drought events such as 2002-2003)

* ref. Betancourt, Julio L., & McCabe, Gregory J. (2013). Regional patterns and proximal causes of the recent snowpack decline in the Rocky Mountains, US. *Geophysical Research Letters*., 40(9), 1811-1816. DOI: 10.1002/grl.50424

Potential Further Analysis

- Incorporate additional variables:
  - Remotely sensed indices (vegetation health, soil moisture, etc.)
  - Field observations (e.g. LogTag sensors to record temperature at 2-meters above ground level at 3-hour interval for approximately 3-year duration)
- Geoprocessing redux:
  - Obtain higher-resolution terrain model (DEM)
  - Re-generate geomorphometric surfaces using DEM
- Restructure / re-parameterize weighted overlay model, run again to regenerate suitability surfaces
- Consider implications of landscape modification/conversion (e.g. controlled burns, planting of trees, infrastructure expansion, etc.)

Acknowledgments

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Dr. Jason Sibold
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Comments, Questions, Suggestions

Feedback is appreciated, now or in the future:

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Thank you.