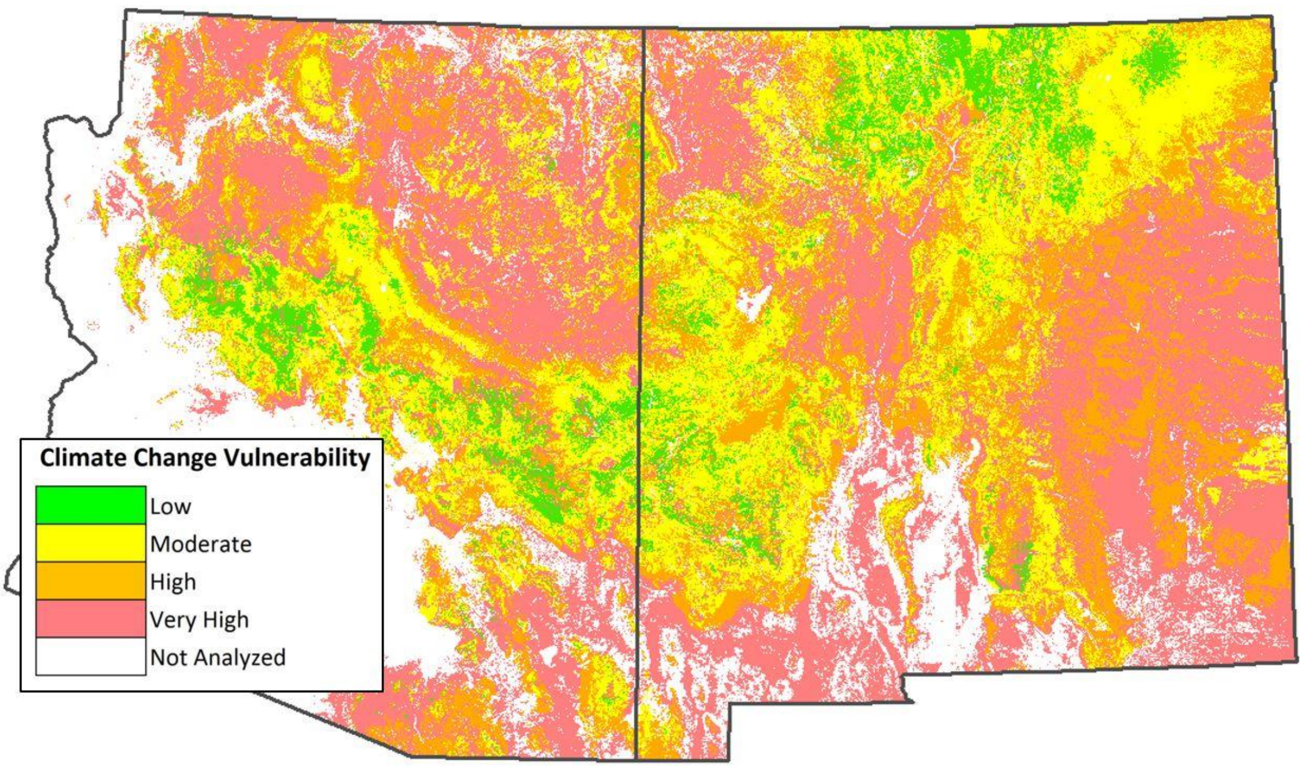
Climate Change Vulnerability Assessment

EXECUTIVE SUMMARY

USDA Forest Service – Southwestern Region – Rocky Mountain Research Station

Introduction and background: Land managers need to assess ongoing and potential effects of climate and drought and coordinate responses for the protection of communities from wildfire, ensuring water supplies, protecting biodiversity, conserving stored carbon, and other ecosystem services (Friggens et al. 2013). The Rocky Mountain Research Station (RMRS) of the US Forest Service, The Nature Conservancy (TNC), the Integrated Landscape Assessment Project (USDA Forest Service 2014), and others have developed assessments, tools, and methods for evaluating vulnerability for key ecological components. This climate change vulnerability assessment (CCVA) complements much of this work with an ecosystem-based vulnerability surface of sufficient spatial and thematic detail to support local analysis and decisions. The CCVA satisfies some requirements of the Forest Service Climate Change Scorecard. The CCVA is an all-lands vulnerability assessment for major upland ecosystems of AZ and NM (Triepke et al. 2019). Based on the anticipated effects of a changing climate to site potential, vulnerability was determined by the level of future climate departure from the climate envelope for given ecosystem types.



Analysis overview: The CCVA was an ecosystems approach to predicting vulnerability based on climate projections at the year 2090. Much of the underpinning knowledge and geography of vegetation-climate relationships stems from the Terrestrial Ecological Unit Inventory of the USFS Southwestern Region (USDA Forest Service 1986, Winthers et al. 2005). In order to adequately predict vulnerability, the landscape was stratified into recognizable ecosystem types, or Ecological Response Units (ERUs), that repeat across the landscape. Then, base level polygons (segments) were generated for the analysis area by RSAC, with each segment representing similar site potential at the scale of individual plant communities. Segments were attributed with biophysical, contemporary climate, and projected climate for multiple Global Climate Models (GCMs) and emissions scenarios. Climate envelopes were developed for each ERU based on pre-1990 climate data, according to the most discriminating climate variables. Finally, each segment was assigned a vulnerability score based on the projected departure in future climate from the characteristic climate envelope of each ERU. For a given reporting area (e.g., watershed, admin unit) vulnerability is summarized using graphics (see figure above) and tabular summaries (see example below). Finally, the vulnerability surface was tested against current patterns in ecological processes of fire severity, tree recruitment from lower life zones, and desert scrub encroachment into Semi-Desert Grassland; *in all cases there were significant relationships between these ongoing processes and vulnerability predictions*.

Climate models and downscaling: Downscaling outputs of GCMs is a widespread approach for providing climate projections at regional and subregional scales. Downscaled climate data for both pre-1990 and future projections were obtained from the RMRS Moscow Lab and included climate surfaces from multiple) GCMs and emission scenarios. Contemporary and future climate rendering were fitted to thin plate splines to create continuous high-resolution climate surfaces for AZ and NM. The reader is referred to Rehfeldt (2006) and Rehfeldt et al. (2012) for detailed discussion of spline models and applications. For this assessment, the overall vulnerability was scored using data derived from the CGCM3 GCM for the 2090 projection using the A1B emission scenario.

Vulnerability reporting: This assessment categorizes climate vulnerability based on individual plant communities and the projected difference between pre-1990 climate envelopes and projected climate conditions. Four categories of vulnerability are reported based on the level of envelope departure, with envelopes represented by the mean and two standard deviations (i.e., approx. 95% of the characteristic climate variability). Envelopes were developed independently for each discriminating variable, and combined according to their respective explanatory value.

Category	Note
Low Vulnerability:	These values are within 2 standard deviations of the envelope mean and are considered within their climate envelopes.
Moderate Vulnerability:	This represents values equivalent to all variables being 2<3 standard deviations from the envelope mean.
High Vulnerability:	This represents values equivalent to all variables being 3<4 standard deviations from the envelope mean.
Very High Vulnerability:	This represents values equivalent to all variables being >4 standard deviations from the envelope mean.

Uncertainty reporting: Future climate projections based on different GCMs provide somewhat different values, reflecting uncertainty with a given vulnerability prediction for some ERUs in some areas. To address this concern, the CCVA provides a measure of uncertainty, which represents the degree of disagreement between different GCMs, within a given emission scenario. Three GCMs were used to assess uncertainty (CGCM3, HADCM3, and GFDLCM21). Uncertainty is reported using a simple agreement process and categories. This process was run at the individual segment scale, and then aggregated up to watersheds as proportional values. The level of agreement is given by the following rule set:

- If all three GCMs produce the same vulnerability category then uncertainty is “Low”
- Otherwise if two of the GCMs produce the same vulnerability category, then uncertainty is “Moderate”
- When all three GCMs differ on vulnerability then uncertainty is “High”

Example tabular summary: CCVA results for the Apache-Sitgreaves NFs, showing the percentages of vulnerability and uncertainty categories.

Ecological Response Unit (hectares)	Vuln category	Vuln %	Uncertainty category Low	Moderate	High
All ERUs analyzed (826,814ha)	Low	17%	8%	9%	0%
	Moderate	46%	1%	31%	14%
	High	25%	8%	16%	0%
	Very high	12%	12%	0%	0%
	Uncertainty total		30%	56%	14%
Spruce-Fir Forest (SFF) (28,763ha)	Low	0%	0%	0%	0%
	Moderate	6%	0%	5%	1%
	High	24%	21%	3%	0%
	Very high	69%	69%	0%	0%
	Uncertainty total		90%	8%	1%
Mixed Conifer - Frequent Fire (MCD) (48,222ha)	Low	24%	19%	5%	0%
	Moderate	45%	6%	34%	6%
	High	21%	6%	15%	0%
	Very high	11%	11%	0%	0%
	Uncertainty total		41%	53%	6%
Mixed Conifer w/ Aspen (MCW) (63,311ha)	Low	4%	0%	4%	0%
	Moderate	78%	0%	34%	44%
	High	16%	3%	13%	0%
	Very high	2%	2%	0%	0%
	Uncertainty total		6%	50%	44%
Ponderosa Pine Forest (PPF) (278,304ha)	Low	6%	3%	3%	0%
	Moderate	42%	0%	33%	9%
	High	30%	17%	14%	0%
	Very high	22%	22%	0%	0%
	Uncertainty total		42%	49%	9%
Ponderosa Pine - Evergreen Oak (PPE) (21,943ha)	Low	48%	7%	40%	1%
	Moderate	45%	0%	19%	26%
	High	7%	0%	6%	0%
	Very high	0%	0%	0%	0%
	Uncertainty total		7%	66%	27%
PJ Woodland (PJO) (57,934ha)	Low	10%	9%	1%	0%
	Moderate	76%	1%	64%	11%
	High	14%	0%	14%	0%
	Very high	0%	0%	0%	0%
	Uncertainty total		11%	79%	11%
Madrean Pinyon-Oak Woodland (MPO) (138,548ha)	Low	21%	5%	17%	0%
	Moderate	54%	0%	27%	27%
	High	17%	2%	16%	0%
	Very high	7%	7%	0%	0%
	Uncertainty total		14%	59%	27%
Interior Chaparral (IC) (22,372ha)	Low	95%	29%	66%	0%
	Moderate	5%	0%	4%	1%
	High	0%	0%	0%	0%
	Very high	0%	0%	0%	0%
	Uncertainty total		29%	70%	1%
Montane / Subalpine Grassland (MSG) (29,242ha)	Low	73%	52%	21%	0%
	Moderate	23%	3%	17%	4%
	High	4%	0%	4%	0%
	Very high	0%	0%	0%	0%
	Uncertainty total		54%	42%	4%
Colo Plateau / Great Basin Grassland (CPGB) (94,397ha)	Low	20%	12%	8%	0%
	Moderate	26%	0%	24%	2%
	High	52%	10%	43%	0%
	Very high	2%	2%	0%	0%
	Uncertainty total		24%	74%	2%
Semi-Desert Grassland (SDG) (43,773ha)	Low	12%	5%	8%	0%
	Moderate	62%	1%	37%	23%
	High	21%	3%	17%	0%
	Very high	5%	4%	1%	0%
	Uncertainty total		14%	63%	23%
Minor and riparian ERUs (30,593ha)	n/a	n/a	n/a	n/a	n/a

Interpretation of Results: The CCVA infers vulnerability based on the projected climate departure from the historic climate envelope for a given ERU and location. In broad terms it may be helpful to think of future climate simply as a potential stressor of significant change (i.e., on structure, composition, function), with the vulnerability rating on par with risk or probability of stress, either low, moderate, high, or very high. In more specific terms, vulnerability can be considered the 'relative probability of type conversion'.

Vulnerability ratings are a consequence of at least three factors:

- Breadth of the envelope for a given ERU
- Current status of a given location relative to its ERU envelope
- Magnitude of projected change in climate at that location

The thematic resolution of most ERUs is similar, and the ERU framework was modified to ensure normal distributions for key climate variables. As a result, the breadth of the climate envelopes is fairly similar among ERUs. That said, all else equal an ERU with a relatively broad envelope is inherently less vulnerable, keeping in mind that climate departure also depends on the projected climate for a given location and on how a given plant community currently falls relative to its envelope. Also, though riparian ERUs were not specifically analyzed for CCVA, some inference of the vulnerability of these systems can be taken from the watershed-scale results in the final set of tables to follow.

The Region has used watershed-scale results to generate a vulnerability layer for 6^{th}-level watersheds of the Southwest, according to area-weighted vulnerability scores of all CCVA polygons within each watershed (see figure following page). Watershed vulnerability ratings are being considered with the Watershed Condition Framework.

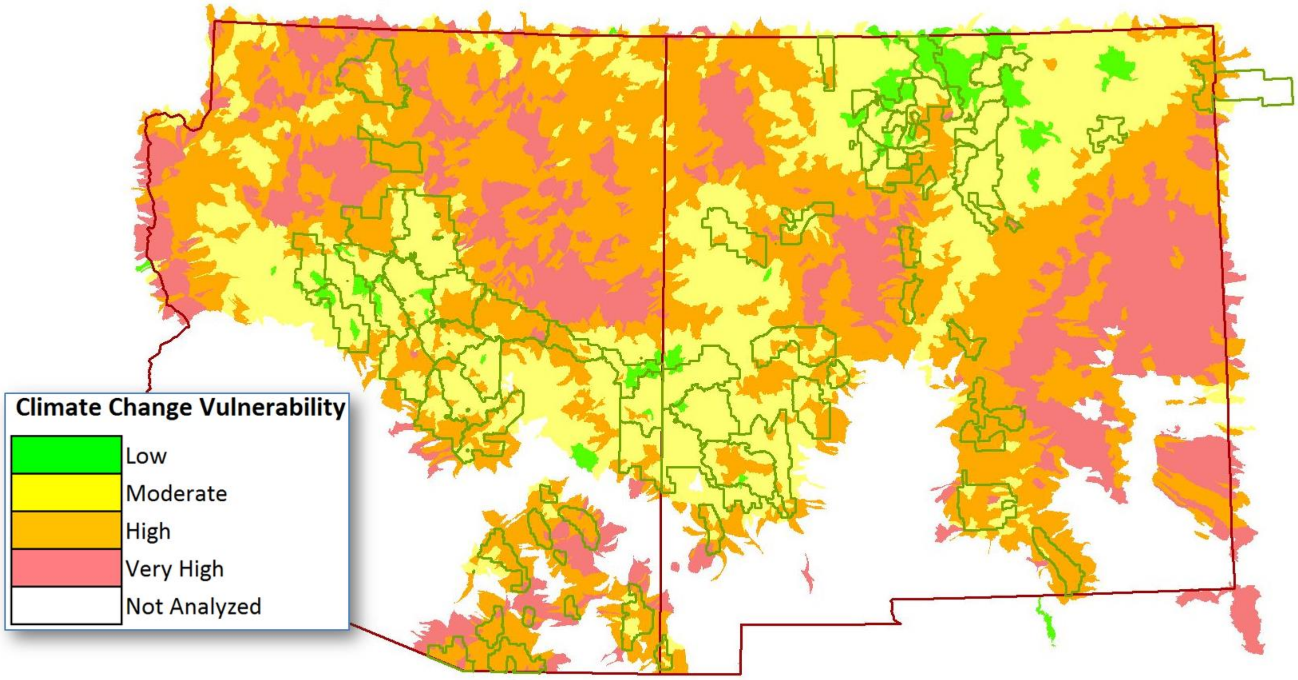
Note that the CCVA does not include the desert ERUs due to issues encountered in the initial interpretation of results:

- The desert units are represented by low sample numbers
- Non-normal distributions were evident for some climate variables
- The desert units are represented by samples only from the northern extents of the Chihuahuan and Sonoran provinces, suggesting that the resulting climate envelopes may be too conservative and that vulnerability may be artificially elevated.

For these reasons, results for desert units were excluded from the CCVA, affecting the four desert ERUs – MSDS, SDS, CDS, and CSDS. Each of these units is well-adapted to weather extremes and to variability across temporal scales.

Finally, the Region is now developing an adaptation strategy as an additional component in an overall climate adaptation framework to help identify management options for given circumstances of vulnerability, current condition, and local management objectives.

Climate change vulnerability ratings for 6th-level watersheds of the Southwest based on vulnerability predictions in all upland extents for each watershed (Triepke et al. 2019).



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