What can predictive modeling tell us about plant vulnerability to climate change in the Southwest?

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BACKGROUND

Predictive modeling can be used to map areas of suitable habitat for species under current conditions and under hypothetical future conditions. By establishing the relationship of known locations of the species with select environmental variables, the predictive map represents areas expected to be suitable to a species of interest.

In order to assess the vulnerability of dominant and indicator plants in the Southwest to climate change, we predicted the suitable habitat for those species in Southwest ecoregions using a climate envelope approach. This approach defines suitable habitat for the plant species by its relationship with average temperature and precipitation within the Southwest. While many other factors influence a plant's distribution at a landscape scale (for example soils, biological interactions, disturbance), the climate envelope approach approximates a plants distribution at a regional scale.

We developed maps of each species' current predicted habitat based on a climate envelope and their potential future distributions under three different climate change scenarios for two time periods (2050 and 2100, six scenarios total, only 2050 shown here). Potential vulnerability of an individual plant species is indicated where the plant's current habitat, defined by average temperate and precipitation, becomes less favorable in the future.

This approach to vulnerability assessment, while coarse, is one measure of the impact different scenarios of climate change may have upon each plant species. It gives an approximation of the plants' vulnerability due to exposure to regional climate change but does not take into account increased exposure caused by extreme weather events due to climate change (freezes or droughts), any buffering of that exposure by topography or microclimate, or any adaptive capability or resilience intrinsic to the species.

ANALYTIC METHODS

Predictive modeling algorithm

- **Maxent, a freely-available machine-learning method derived from statistical mechanics and based on maximum entropy, has been adapted for modeling species habitat where absence data are not available**

Input data

- **Occurrence locations for 166 species (only three species shown) collected in the field over the last 10 years: 128,619 total species/locations records**
- **Average annual and monthly temperature and precipitation: 26 variables (1971-2000, PRISM [http://www.prism.oregonstate.edu/], 800 m^2 cell resolution)**
- **Average annual and monthly temperature and precipitation: 26 variables for each of 6 future climate change scenarios (Climate Wizard [http://www.climatewizard.org/])**

Model output and processing

- **Continuous model output: output with 80% training data (20% occurrence data withheld) and with all training data (no occurrence data withheld); each 800 m^2 cell had a logistic prediction ranging from 0 to 1**
- **Predictive strength: Maxent produced an AUC (area under curve) metric for continuous model output with 80% training data and all training data**
- **Thresholding: Continuous model output was converted to binary predictive maps (present/absent) for each scenario by applying a threshold to the continuous map output; two different thresholds were applied: 1) logistic value of 50% or higher predicted presence and 2) logistic values of 10% or higher predicted presence (10% not shown)**
- **Overall accuracy: Occurrence locations for each species were overlain on the predictive map, overall accuracy was calculated as A = (# occurrences predicted/# all occurrences) *100**

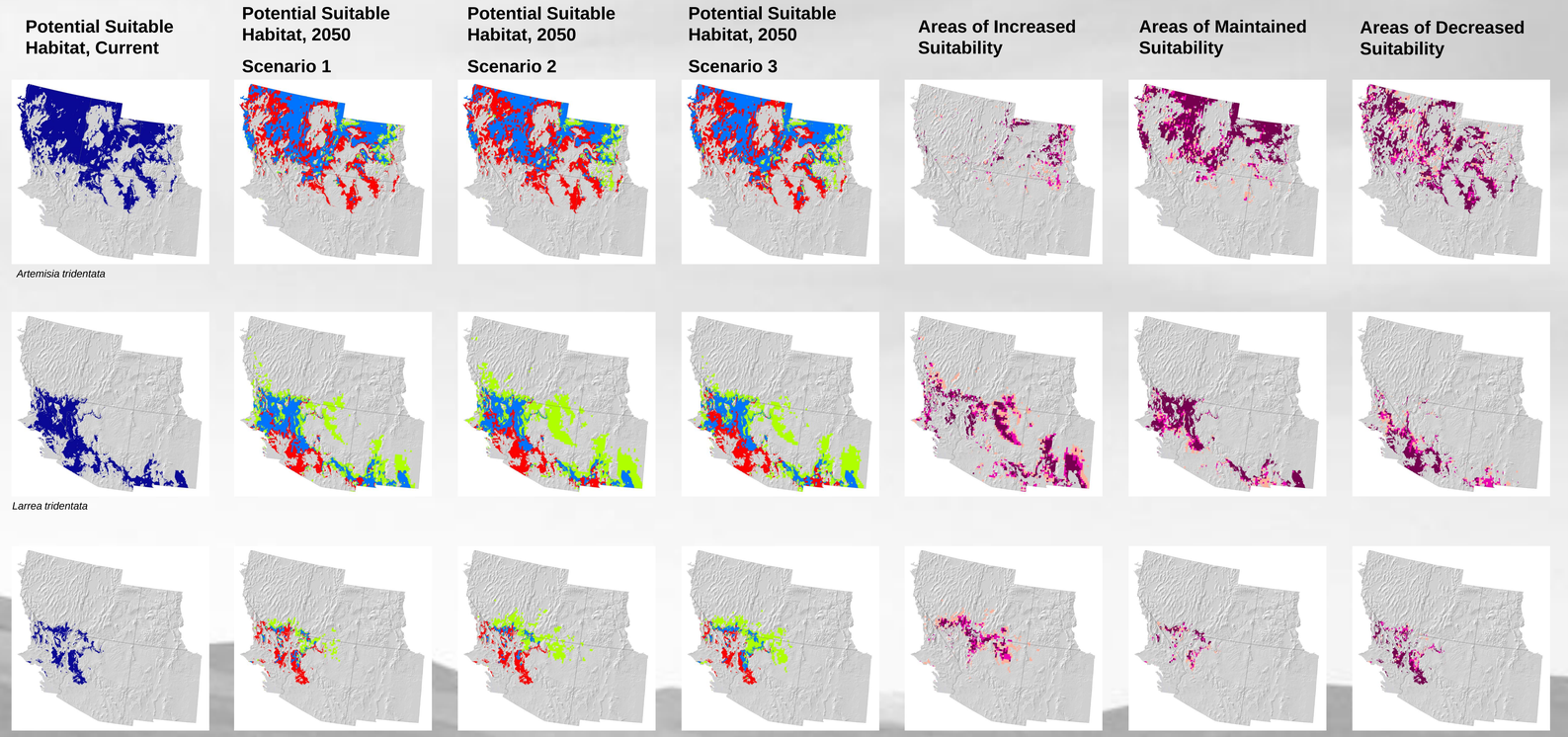
Potential Habitat Suitability Assessment

Future Scenarios

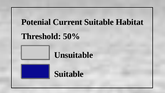
- **Future Potential Habitat Suitable & Current Potential Habitat Suitable = Maintained suitability**
- **Future Potential Habitat Suitable & Current Potential Habitat Unsuitable = Decreased suitability**
- **Future Potential Habitat Unsuitable & Current Potential Habitat Suitable = Increased suitability**
- **Future Potential Habitat Unsuitable & Current Potential Habitat Unsuitable = Unsuitable**

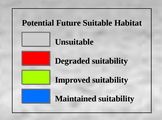
Model Agreement

- **Number of scenarios (3 total) that predict Maintained, Decreased or Increased suitability**



Potential habitat here is defined as the annual and monthly precipitation and temperature from 1971-2000 for a species. It is a broad view of the species actual distribution.





MODEL PERFORMANCE

Species	# training points	AUC (80%)	AUC (all)	Overall accuracy 50% threshold
Artemisia tridentata	10,139	.84 training, .83 test	.84	87%
Larrea tridentata	2,978	.95 training, .95 test	.95	88%
Yucca brevifolia	429	.99 training, .97 test	.99	91%

THE CLIMATE CHANGE SCENARIOS – The future climate change scenarios are based on three different emission scenarios that use an ensemble average of 16 general circulation models (GCMs) as developed by the ClimateWizard consortium (http://www.climatewizard.org/); the ensemble values are the middle values of all 16 GCMs and indicate precipitation or temperature change compared to a 1961-1990 baseline average. The scenarios are alternative futures of how society functions as an energy producer in the future. They are described in more detail in the Intergovernmental Panel on Climate Change 2007.

Scenario 1 (B1): Low population growth, service/information economy, clean and efficient technologies, global temperature change estimated to be 2.4 C (1.4 – 3.8 C range)

Scenario 2 (A1B): Low population growth, rapid economic growth, new and efficient technologies, global temperature change estimated to be 2.8 C (1.7 – 4.4 C range)

Scenario 3 (A2): High population growth, regional economic development, technologies changing slowly, global temperature change estimated to be 3.4 C (2 – 5.4 C range)

NEXT STEPS

- **Develop a qualitative metric of species vulnerability for each climate change scenario for 2050 and 2100 based on the species current extent and its predicted future extent of maintained and decreased suitable habitat**
- **Develop measures of uncertainty in the vulnerability assessment using information from model agreement and from habitat change assessment results for 50% and 10% threshold**
- **Evaluate species vulnerability by major ecoregions within the Southwest, in addition to the entire Southwest region**
- **Evaluate composite effects of species' vulnerability on vegetation communities and landscape areas in the Southwest**