# Simulated distribution of an invasive grass, Lehmann lovegrass, in the Chihuahuan Desert under future climate scenarios

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## Introduction

Lehmann lovegrass (*Eragrostis lehmanniana*), a perennial grass introduced to the Southwest US in the 1930s from South Africa, has had a limited distribution in the Chihuahuan Desert while it has dominated many grassland sites in the Sonoran Desert. Previous observational studies suggest, qualitatively, that climate (precipitation and temperature) determines spatial variation in the current distribution of the species in the two Southwest deserts.

We assumed that controls on seedling establishment represent the drivers on the distribution of this short-lived bunchgrass. Our goal was to quantify the climatic and edaphic controls on Lehmann lovegrass seedling establishment in order to predict where in the Chihuahuan Desert it may become invasive under alternative climate scenarios.

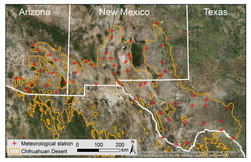
Specific objectives

1. We used site-based climate-soil data to simulate seedling establishment throughout the US portion of the Chihuahuan Desert under current climate.
2. We used site-based climate-soil data to simulate seedling establishment under alternative climate scenarios.
3. We developed regression equations with the best set of drivers to extrapolate the establishment prediction to the entire region under both current climate and alternative climate scenarios

## Methods

We used a daily time step, multi-layer model of soil water dynamics, SOILWAT, to simulate probability of seedling establishment for Lehmann lovegrass. For model validation, we compared simulated seedling establishment to field observations at two sites, Jornada Experimental Range, NM (Chihuahuan Desert), and Santa Rita Experimental Range, AZ (Sonoran Desert). The simulation results matched well to field data.

**Objective 1.** We simulated probability of seedling establishment in six standard soil types at 57 meteorological stations across the region, using daily precipitation and temperature data during 1981-2010 for current climate.




Six soil types
- Sand
- Loamy sand
- Sandy loam
- Loam
- Silt Loam
- Sandy clay loam

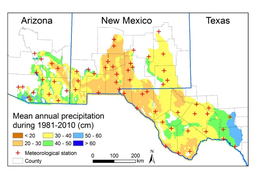
**Objective 2.** We simulated probability of seedling establishment at the same stations for three alternative climate scenarios, with temperature (T) increasing by 2.5 °C and varying precipitation (PPT) amounts (staying the same, decreasing by 10%, or increasing by 10%).

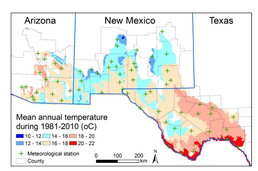
**Objective 3.** Using data from the same stations, we developed the best regression model to predict simulated probability of seedling establishment for each soil type and for current climate and alternative climate scenarios.

Candidate explanatory variables
- Mean monthly and annual precipitation (MAP)
- Mean monthly and annual maximum, mean, and minimum daily temperature (Tmax, Tmean, Tmin)

Multiple regression
- Stepwise selection in SAS
- Only those with significant correlation with the response variable were candidates for selection
- Highly correlated explanatory variables ($r > 0.7$) were excluded
- Significance level $p < 0.05$

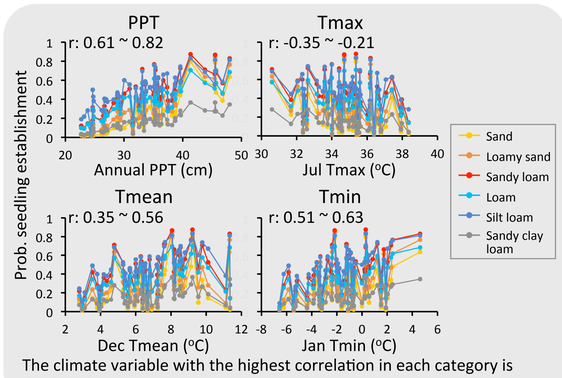
We then extrapolated probability of seedling establishment to the region using the best regression models and the PRISM (4 km$^2$) 30-year current data from 1981-2010. Alternative climate scenarios were adjusted based on the PRISM data.




## Results

**Objective 1.** Simulated probability of seedling establishment under current climate.



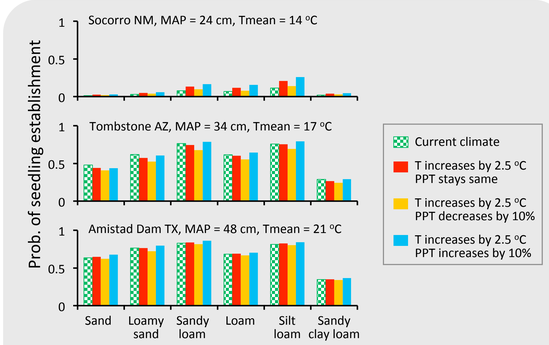

The climate variable with the highest correlation in each category is displayed.

Simulated probability of seedling establishment was:

POSITIVELY correlated with
- Mean annual and monthly PPT (except May and Jun)
- Mean Tmean and Tmin in winter months

NEGATIVELY correlated with
- Mean Tmax in summer months

**Objective 2.** Simulated probability of seedling establishment under alternative climate scenarios.




Simulation results from three representative stations along the current climate gradient in the region (MAP: 22 – 50 cm, Tmean: 13-22 °C).

Factors promoting simulated seedling establishment
- Soils with high capacity to hold plant available water (loamy sand, sandy loam, loam, silt loam)
- Increased precipitation
- Increased temperature at currently cold locations

Factors inhibiting simulated seedling establishment
- Soils with poor capacity to hold plant available water (sand, sandy clay loam)
- Decreased precipitation
- Increased temperature at currently hot locations

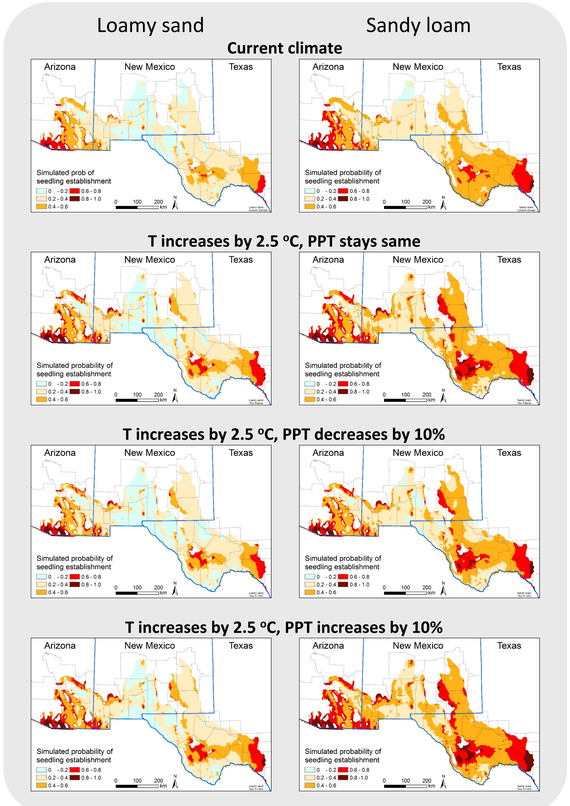
**Objective 3a.** The best regression models to predict seedling establishment under current climate and alternative climate scenarios.

Significant regression coefficients for loamy sand and sandy loam, the two most common soil types in the region that differ in plant available water. Note that compared to the regression models for current climate, temperature (2.5 °C hotter) was no longer a limiting factor under alternative climate scenarios.

| Soil | Y_int | MAP | PPT _Jul | PPT _Sep | Tmean _Dec | Tmin _Jan | $R^2$ |
|---|---|---|---|---|---|---|---|
| **Current climate** | | | | | | | |
| Loamy sand | -0.30 | 0.01 | 0.04 | | | 0.03 | 0.74 |
| Sandy loam | -0.40 | 0.01 | 0.03 | | 0.04 | | 0.65 |
| **T increases by 2.5 °C, PPT stays same** | | | | | | | |
| Loamy sand | -0.58 | 0.02 | 0.04 | | | | 0.89 |
| Sandy loam | -0.38 | 0.01 | 0.03 | 0.05 | | | 0.81 |
| **T increases by 2.5 °C, PPT decreases by 10%** | | | | | | | |
| Loamy sand | -0.58 | 0.02 | 0.05 | | | | 0.90 |
| Sandy loam | -0.44 | 0.02 | 0.04 | 0.06 | | | 0.84 |
| **T increases by 2.5 °C, PPT increases by 10%** | | | | | | | |
| Loamy sand | -0.57 | 0.02 | 0.04 | | | | 0.87 |
| Sandy loam | -0.32 | 0.01 | 0.03 | 0.04 | | | 0.78 |

N = 57, model $p < 0.0001$ for all cases.

**Objective 3b.** Simulated seedling establishment extrapolated to the region under current climate and alternative climate scenarios. Maps for loamy sand and sandy loam are shown as examples.




If future climate becomes hotter and drier
- In currently wet locations, Lehmann lovegrass distribution is predicted to expand, e. g., in southeast NM, and south central TX
- In currently dry locations, distribution is predicted to contract, e.g., at Big Bend National Park in south TX

If future climate becomes hotter and wetter
- Lehmann lovegrass distribution is predicted to expand everywhere in the region

## Conclusions

Our study shows that the future distribution of Lehmann lovegrass in the Chihuahuan Desert is expected to depend on the amount and direction of changes in annual precipitation and temperature. This uncertainty in the projected distribution adds one more challenge to land management of this invasive grass under climate change.