# Predicting *Triadica Sebifera* Occupied Probability by Climate Envelope Models in the Southeastern United States

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## Abstract

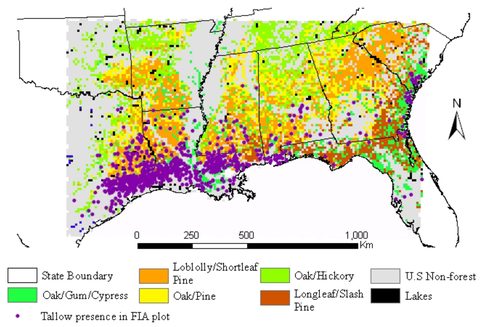
Chinese tallow (*Triadica sebifera*) as a nonnative species has dramatically spread its invasion area across southeastern United States since the 1990s. This study constructed and validated four climate envelope models in order to determine facilitated climatic factors on invasion status, predict its future occupied probability under the IPCC A1B scenario, and detect vulnerability of major forest type to tallow spread. Extreme temperature is critical factor, while water condition across the landscape (such as precipitation) also plays an important role in tallow occupation. This study applied four climatic envelope models to estimate tallow distribution. Maxent and Random Forest are slightly better than GLM and Bioclim. Under IPCC A1B scenario (2010-2070), the forest type of longleaf-slash pine achieves the highest invasion probabilities followed by oak-gum-cypress, while oak-hickory seems not to facilitate tallow invasion. Future study of tallow tree invasion ability can integrate climate envelope modeling with other analysis and simulation techniques to obtain a comprehensive knowledge of *T. sebifera* invasion mechanisms.

## Introduction

Chinese tallow (*T. sebifera*) was introduced into the United States in the late 1700s as an ornamental species (Bruce, 1993). It is reducing the richness of native plants and altering ecosystem productivity (McCormick, 2005). The population of Chinese tallow increased up to fivefold in Louisiana, east Texas and Mississippi since the early 1990s (Oswalt, 2010). In that species distribution and climate has a strong link (Woodward, 1987), this study is applying a climatic envelope modeling technique (Araújo, 2007) and trying to figure out (1) what are the significant climatic factors for *T. sebifera* presence among a set of climatic variables (general trends, extreme values, or variation), (2) how do the different bioclimatic modeling methods perform in simulating future distribution of *T. sebifera*? (3) what geographical range will *T. sebifera* invade in the future according to prescribed A1B scenario from IPCC? (4) which forest type will achieve the highest likelihood for *T. sebifera* invasion by the year of 2020, 2050, and 2070?

## Materials and Methods

### Study area



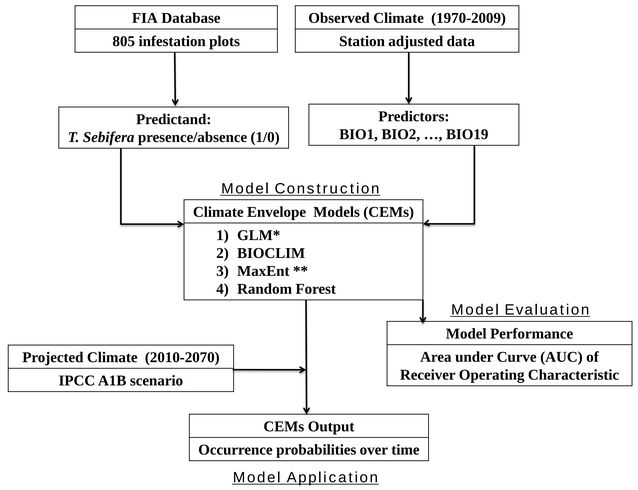

### Data source

Climate data (1970-2070): the monthly climate data provided by Western Kentucky University. The data are presented at 10km resolution.

- 1970-2009: station observed data
- 2010-2070: WRF model (IPCC A1B)

*T. sebifera* presence: 805 tallow infestation plots are obtained from FIA program (v5.1) phase 2 since the 1990s.

### Method flowchart




To implement model construction, evaluation, and application we are using *dismo* package within R software (Hijmans, 2012).

* GLM: generalized linear model; ** MaxEnt: Maximum Entropy

## Results

**Model construction:** 12 out of 19 climatic predictors are significant contributors in CEMs (Table 1).

**Model evaluation:** Swets (1988) recommends interpreting range values of AUC as: excellent AUC>0.90; good 0.80<AUC<0.90; fair 0.70<AUC<0.80; poor 0.60<AUC<0.70; fail 0.50<AUC<0.60. Figure 1 presents AUC scores of each model.

**Table1. Significant variables in CEMs by GLM (binomial: α ≤ 0.01)**

| ID | Description | Coefficient |
|---|---|---|
| BIO1 | Annual Mean Temperature | 0.118 |
| BIO2 | Mean Diurnal Range | 0.0208 |
| BIO3 | Isothermality (BIO2/BIO7) (*100) | -0.0048 |
| BIO4 | Temperature Seasonality | -0.0025 |
| BIO9 | Mean Temperature of Driest Quarter | -0.009 |
| BIO10 | Mean Temperature of Warmest Quarter | -0.0162 |
| BIO11 | Mean Temperature of Coldest Quarter | -0.1551 |
| BIO12 | Annual Precipitation | 0.0002 |
| BIO13 | Precipitation of Wettest Month | -0.0009 |
| BIO16 | Precipitation of Wettest Quarter | 0.0003 |
| BIO17 | Precipitation of Driest Quarter | 0.0017 |
| BIO18 | Precipitation of Warmest Quarter | -0.0004 |
| BIO19 | Precipitation of Coldest Quarter | -0.0008 |

**Model application:** Figure 2 is the predicted tallow occurrence probability of applying constructed CEMs and IPCC A1B scenario (2010-2070) by MaxEnt. Implementing Zonal Stats in ArcGIS, Figure 3 shows the invasion likelihood by forest types.

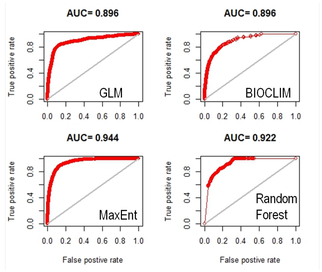



**Figure 1. AUC values from four CEMs**

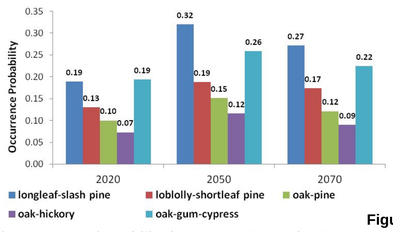



**Figure 3. Invasion ability by 2020, 2050, and 2070**

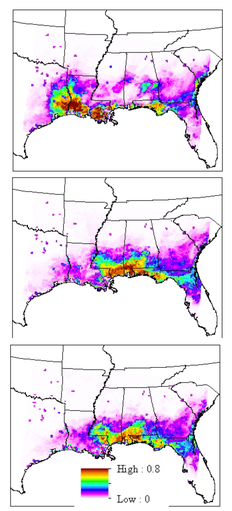



**Figure 2. Predicted invasion probability by MaxEnt approach**

## Conclusion and Discussion

Tallow tree (*T. sebifera*) occupations are highly correlated with the set of climatic variables which comprehensively represent general trends (mean), extreme values, and seasonal variation (seasonality). Based on AUC model evaluation criteria, four CEM approaches performed well in predicting tallow tree distribution. Thus, these models are spatially explicit and likely to predict future invasion probabilities. Lastly, longleaf-slash pine has the highest risk of invasion probabilities, while oak-hickory appears not to facilitate tallow invasion according to our models and climate scenario.

Despite the significant relationship revealed between *T. sebifera* distribution and climate variables, the climate-based models still have generic limitations that these models rarely considered. For instance biotic factors, such as competition, predation, parasitism, mutualism, and facilitation (Pearson and Dawson, 2003). Future study of tallow tree invasion ability, should integrate climate envelope modeling with other analysis and simulation techniques.

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