

**From:** [Endries, Mark](#)  
**To:** [Reid, Rebekah N](#); [Marshall, Michael E](#)  
**Subject:** Updated Maxent Methodology  
**Date:** Thursday, April 12, 2018 10:53:43 AM  
**Attachments:** [HENA Maxent Model Methods NewUpdate.docx](#)  
**Importance:** High

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Hi Mike, Rebekah,

I've updated the Maxent methodology document. In short, not much has changed. Slight changes to area summaries and percentages but the results are essentially the same.

Please let me know if you have any questions.

I'll next work on the statistical test then work on the population summaries.

Thanks!

Mark

**Mark Endries**

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## *Study Extent, Coordinate System, and Cell Size*

Fifty three 10-digit hydrologic units (HUC) comprise the analysis extent (Figure 1). In North Carolina it includes all 10-digit HUC that fall within the boundaries of 8-digit HUC with known occurrence of *Hexastylis*. In South Carolina we also included all 10-digit HUC that fell within the boundaries of 8-digit HUC with known occurrence of *Hexastylis*, but excluded the southern portions of the HUC-8 areas due to the boundaries being exceedingly large and far away from any known occurrences.

Figure 1. Analysis extent. Red line indicates Maxent analysis extent, blue lines are 8-digit HUC boundaries, black lines are 10-digit HUC boundaries. The orange line in the inset map indicates where the analysis extent is situated in North and South Carolina



Coordinate System: USA Contiguous Albers Equal Area Conic USGS version

Cell Size: 30 x 30 meters derived from the USGS National GAP Landcover

### *Source Element Occurrence Data*

Hexastylis naniflora element occurrence data was obtained from the North and South Carolina Natural Heritage Programs. These data were in polygon format and digitized at scale that accurately identified the boundaries of the individual population areas. Current populations of Hexastylis naniflora were identified by reviewing the last observed data in the database and excluding all populations that have not been observed in the last 10 years (2007). To represent these current population areas in Maxent, a raster cell center was retained for every 30 x 30 meter pixel that was situated within the current element occurrence data polygons.

### *Source Datasets Used:*

**USGS National GAP Landcover** - The GAP National Terrestrial Ecosystems – Ver 3.0 is a 2011 update of the National Gap Analysis Program Land Cover Data – Version 2.2 for the conterminous U.S. The GAP National Terrestrial Ecosystems – Version 3.0 represents a highly thematically detailed land cover map of the U.S at a 30 x 30 meter pixel resolution. The map legend includes types described by NatureServe's Ecological Systems Classification (Comer et al. 2002) as well as land use classes described in the National Land Cover Dataset 2011 (Homer et al. 2015). These data cover the entire continental U.S. and are a continuous data layer. The land cover map identifies 49 different land cover types within the range of Hexastylis Naniflora.

**LandFire** - Landscape Fire and Resource Management Planning Tools, is a shared program between the wildland fire management programs of the U.S. Department of Agriculture Forest Service and U.S. Department of the Interior, providing landscape scale geo-spatial products to support cross-boundary planning, management, and operations.

**SSURGO Soils** - The SSURGO database contains information about soil as collected by the National Cooperative Soil Survey over the course of a century. The information was gathered by walking over the land and observing the soil. Many soil samples were analyzed in laboratories. The maps outline areas called map units. The map units describe soils and other components that have unique properties, interpretations, and productivity. The information was collected at scales ranging from 1:12,000 to 1:63,360.

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### *Model Variables Created:*

**Landcover** – Landcover represented by the default landcover classification (Table 1).

**Landcover Hexastylis Grouping** – Landcover represented by a grouping of landcover types. For the purposes of discussing Hexastylis naniflora habitat, many of the default landcover classifications are similar and could be grouped together. The definition of each landcover classification was reviewed and categorized using a much broader habitat definition (Table 1).

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| Default Landcover Classification                             | Hexastylis Grouping |
|--------------------------------------------------------------|---------------------|
| Southern Piedmont Glade and Barrens                          | Barren              |
| Southern Ridge and Valley / Cumberland Dry Calcareous Forest | Barren              |
| Undifferentiated Barren Land                                 | Barren              |
| Cultivated Cropland                                          | Disturbed           |
| Deciduous Plantations                                        | Disturbed           |
| Developed, High Intensity                                    | Disturbed           |
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| Disturbed/Successional - Grass/Forb Regeneration             | Disturbed           |
| Disturbed/Successional - Shrub Regeneration                  | Disturbed           |
| Evergreen Plantation or Managed Pine                         | Disturbed           |
| Harvested Forest - Grass/Forb Regeneration                   | Disturbed           |
| Harvested Forest-Shrub Regeneration                          | Disturbed           |
| Introduced Upland Vegetation - Annual Grassland              | Disturbed           |
| Introduced Upland Vegetation - Shrub                         | Disturbed           |
| Introduced Upland Vegetation - Treed                         | Disturbed           |
| Pasture/Hay                                                  | Disturbed           |
| Quarries, Mines, Gravel Pits and Oil Wells                   | Disturbed           |
| Ruderal forest                                               | Disturbed           |
| Southern Appalachian Low Mountain Pine Forest                | Evergreen           |
| Southern Appalachian Montane Pine Forest and Woodland        | Evergreen           |
| Southern and Central Appalachian Cove Forest                 | Hardwood            |
| Southern and Central Appalachian Oak Forest                  | Hardwood            |
| Southern and Central Appalachian Oak Forest - Xeric          | Hardwood            |
| Southern Piedmont Mesic Forest                               | Hardwood            |

|                                                                  |                    |
|------------------------------------------------------------------|--------------------|
| Central and Southern Appalachian Montane Oak Forest              | High Elevation     |
| Central and Southern Appalachian Northern Hardwood Forest        | High Elevation     |
| Central and Southern Appalachian Spruce-Fir Forest               | High Elevation     |
| Southern Appalachian Grass and Shrub Bald                        | High Elevation     |
| Southern Appalachian Grass and Shrub Bald - Shrub Modifier       | High Elevation     |
| Appalachian Hemlock-Hardwood Forest                              | Mixed              |
| Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier      | Mixed              |
| Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier | Mixed              |
| Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier         | Mixed              |
| Southern Ridge and Valley Dry Calcareous Forest                  | Mixed              |
| Southern Ridge and Valley Dry Calcareous Forest - Pine modifier  | Mixed              |
| Open Water (Fresh)                                               | Open Water/Wetland |
| Southern and Central Appalachian Bog and Fen                     | Open Water/Wetland |
| Southern Piedmont/Ridge and Valley Upland Depression Swamp       | Open Water/Wetland |
| Southern Appalachian Granitic Dome                               | Outcrop            |
| Southern Appalachian Montane Cliff                               | Outcrop            |
| Southern Appalachian Rocky Summit                                | Outcrop            |
| Southern Piedmont Cliff                                          | Outcrop            |
| Southern Piedmont Granite Flatrock                               | Outcrop            |
| South-Central Interior Large Floodplain - Forest Modifier        | Riparian           |
| South-Central Interior Small Stream and Riparian                 | Riparian           |
| Southern Piedmont Large Floodplain Forest - Forest Modifier      | Riparian           |
| Southern Piedmont Small Floodplain and Riparian Forest           | Riparian           |

**Landcover Diversity** – Identifies the number of landcover classes (default classification) within a 10-cell radius (300 meters) of an individual pixel.

**Landcover Majority** – Identifies the dominant landcover class (default classification) within a 10-cell radius (300 meters) of an individual pixel.

**Landfire Canopy Height** – Represents the vertically projected percent cover of the live vegetation canopy.

**Landfire Canopy Cover** – Represents the average height of the dominant vegetation across the landscape.

**SSURGO mukey** – SSURGO soils dataset represented by the Map Unit Key (mukey)

**SSURGO Drainage Class** – SSURGO soils dataset represented by wettest drainage class. Drainage class refers to the frequency and duration of wet periods in conditions similar to those under which the soil formed.

**SSURGO Hydrologic Group** – SSURGO soils dataset represented by hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

**Elevation** – National elevation dataset elevation values. This 10-meter dataset was reclassified to 30-meters.

**Aspect 9-class** – Using the national elevation dataset, the aspect was derived and categorized into the following classes: Flat, North, Northeast, East, Southeast, South, Southwest, West, and Northwest.

**Aspect 5-class** – Using the national elevation dataset, the aspect was derived and categorized into the following classes: Flat, North, East, South, and West.

**Slope** – The national elevation dataset represented by degree of slope.

**Geomorphons** – A pattern recognition analysis that converts a digital elevation dataset into 10 common landform elements: flat, peak, ridge, shoulder, spur, slope, pit, valley, footslope, and hollow. The national elevation dataset was used as the source elevation for the analysis.

**Solar Radiation** – An analysis of the amount of solar radiation (radiant energy) reaching the earth's surface using the national elevation dataset as the elevation model. The output solar model is reported in watt hours per square meter (WH/m<sup>2</sup>)

**Average Annual Precipitation** – Climate dataset of average annual precipitation according to a model using point precipitation and elevation data for the 30-year period of 1971-2000.

**Maximum Average Annual Temperature** – Climate dataset of average annual maximum temperature according to a model using point temperature data for the 30-year period of 1981-2010.

**Minimum Average Annual Temperature** – Climate dataset of average annual minimum temperature according to a model using point temperature data for the 30-year period of 1981-2010.

### *Maxent Model Development*

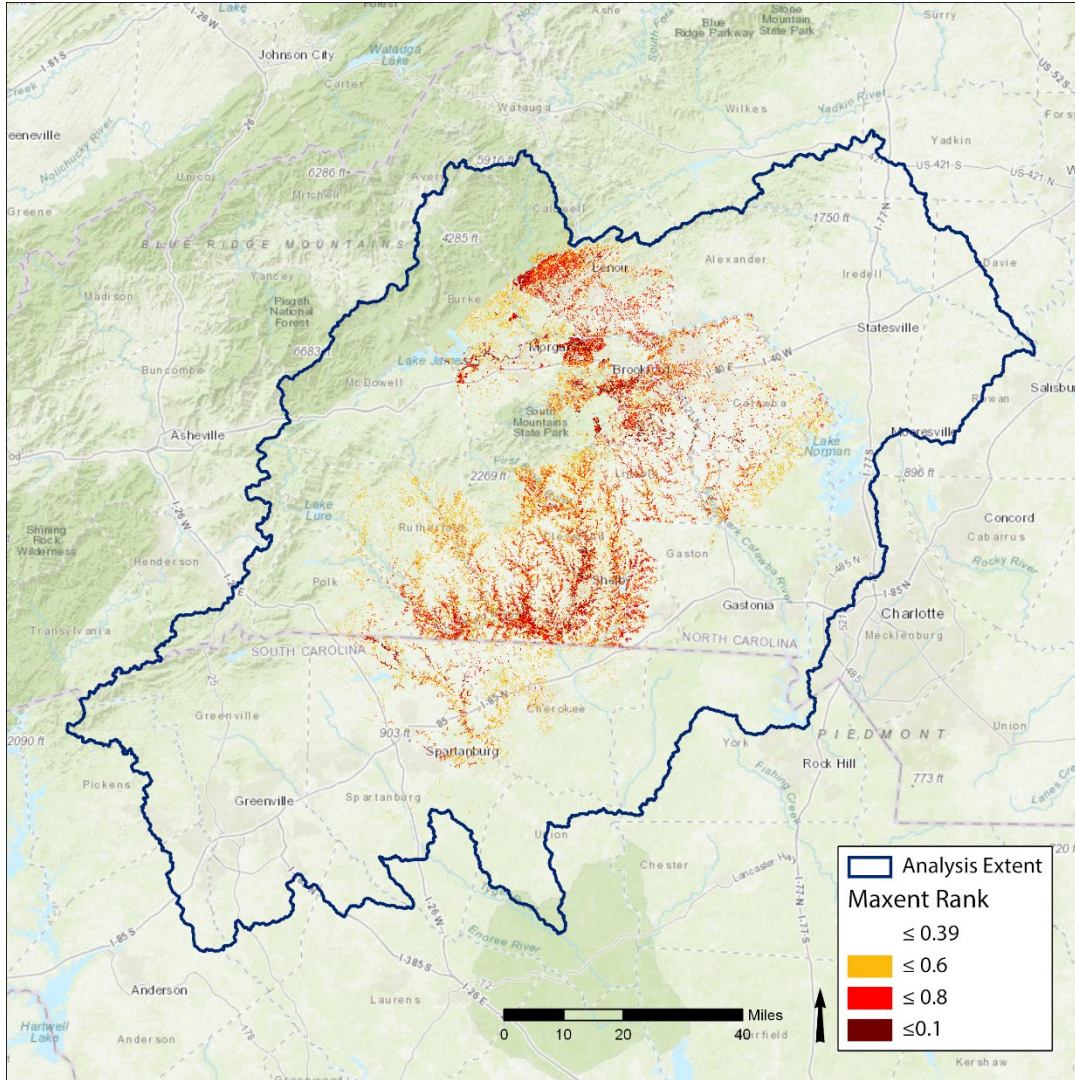
Maxent software for species habitat modeling (version 3.4.1) was used (Philips et al., 2018).

An initial single model Maxent run was done to determine which variables could be excluded due to limited percent contribution to the model. Any variable that contributed less than 1% to the single model run results was excluded in the final model. The following variables were excluded:

landcover diversity, canopy height, SSURGO drainage class, SSURGO hydrologic group, aspect 9-class, aspect 5-class, slope, solar radiation, and maximum annual temperature.

For the final model a 10-run replicate Maxent model was created using crossvalidation. For replicate models, the occurrence data is randomly split into a number of equal-sized groups called "folds", and separate models are created leaving out each fold in turn. The individual model runs are then averaged together to derive the final model. Cloglog output format was used. Cloglog output gives an estimate between 0 and 1 of probability of presence assuming an appropriate sampling design.

Figure 2. Maxent model output map.



## Results

Figure 2 shows the model output. The minimum cutoff value (to determine if an area is considered potential habitat for a species) of 0.39 was determined by using the average 10th percentile training presence. The 10th percentile training presence uses the suitability threshold associated with the presence record that occurs at the 10th percentile of presence records (Phillips 2018). This value excludes some of the outlier population areas in the Maxent predictions to focus on the typical habitat conditions for this species. The total area ranked greater than 0.39 in the Maxent model was just 6.0% of the total analysis area (Table 1).

Table 1. Area estimates of the Maxent model

| Maxent Score      | Acres      | Square Miles | Percent of Total |
|-------------------|------------|--------------|------------------|
| 0.406 and greater | 302,834.13 | 473.18       | 6.02%            |
| 0.6 and greater   | 128,273.52 | 200.43       | 2.55%            |
| 0.8 and greater   | 22,115.97  | 34.56        | 0.44%            |

The average area-under-curve (AUC) score for the replicate Maxent model is 0.86. The AUC is calculated from the receiver operating characteristic (ROC) plot. This value has a range of 0 – 1 and may be interpreted as a single test statistic that assesses model performance, indicating the ability of the model to correctly classify the occurrence data used. AUC values close to 0.50 indicate a model fit no better than random, values less than 0.5 indicate a model fit worse than random, a value of 1.0 indicate a perfect fit (Baldwin 2009). A value of 0.86 is a good fitting model.

The Maxent output supplies estimates of the relative contributions of the environmental variables to the Maxent model (Table 2.)

Table 2. Percent contribution of the environmental variables

| Environmental Variable        | Percent Contribution |
|-------------------------------|----------------------|
| SSURGO mukey                  | 23.5%                |
| Minimum Annual Temperature    | 17.8%                |
| Average Annual Precipitation  | 15.7%                |
| Landcover                     | 12.9%                |
| Landcover Majority            | 12.0%                |
| Landcover Hexastylis Grouping | 5.4%                 |
| Geomorphons                   | 4.9%                 |
| Elevation                     | 4.6%                 |
| Canopy Cover                  | 3.2%                 |

SSURGO mukey is the top contributing variable. 135 different individual soil types are present within the polygon boundaries of the Hexastylis element occurrences. Many of these individual soil types are part of soil complexes and are separated by things such as percent slope, erosion, how stony/rocky, and amount of clay. The most common individual soil type was Meadowfield-Rhodhiss complex, 25 to 60 percent slopes, very stony (14.1% of total). However, collectively the Meadowfield soils only comprised 14.3% of all soils). The individual Pacolet soil types were very common and collectively comprise 32.2% of all soil types present. Woolwine, Rion, and Fairview

soils were also collectively common, comprising 10.4%, 9.7%, and 8.8% of all soils present respectively.

The minimum annual average temperature range in the analysis extent is 39 – 51 degrees Fahrenheit. The majority of the *Hexastylis* element occurrences (89%) are found at the 47 and 48 degrees. The Average annual precipitation range in the analysis extent is 42 – 81 inches per year. The majority of the *Hexastylis* element occurrences (82%) are found in the 47 – 49 inches per year range.

Piedmont forested landcover habitats dominate the land area of the element occurrences. Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier (53%), Southern Piedmont Mesic Forest (9%), Southern Piedmont Dry Oak-Pine Forest (5.2%), Southern Piedmont Small Floodplain and Riparian Forest (4.4%), and collectively comprise 71% of the element occurrences area. Unfortunately, non-native habitats are also present. Evergreen Plantation or Managed Pine (9%), Harvested Forest (7.2%), Developed, Open Space (5%), Pasture/Hay (2.1%) collectively comprise 22% of the total element occurrence area. The Remaining 6 percent of element occurrence area is comprised of a mix of 14 other natural and disturbed landcover classes, but each at small percentages.

The landcover majority classification scheme reduces the total number of landcover classes present in the analysis extent from 23 to 11. Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier is still the dominant landcover class (58%). However disturbed categories are increased in area (sum total of 35%). Evergreen plantation or managed pine (12%) and Pasture/Hay (12%) are the only other categories that have at least 10% or greater area. The increase in disturbed landcover area representation in the landcover majority layer suggests that many *Hexastylis* population areas are situated in areas impacted by disturbed landcover. This is likely due to urban encroachment and increasing fragmentation of habitats.

The landcover *Hexastylis* grouping reveals the amount of disturbance present in *Hexastylis* population areas. Landcover classes grouped as disturbed comprises 27% of the total area. Mixed forest (deciduous and evergreen) comprises 58%, pasture/hay 12%, and hardwood forest 2%,

Geomorphons revealed that the majority of *Hexastylis* element occurrence areas are situated in concave landforms. Geomorphon categories hollow (13%), valley (46%), and depression (10%) collectively comprise 69% of all *Hexastylis* population areas. Flat landforms comprise 15.5% of the area and convex landforms the remaining 15.5%.

Within the analysis extent, the range of elevation present is 335 – 5,265 feet. For *Hexastylis*, the prime elevation range is from 666 – 908 feet (53% of total element occurrence area). A lesser elevation range is present from 935 – 1,184 (37% of total element occurrence area).

Canopy cover for the *Hexastylis* populations are dominated by Tree Cover 70-80% (20.2%) and Tree Cover 80-90% (63.9%). The rest of the canopy cover categories are 2% or less.

## *Citations*

Baldwin, R.A. 2009. Use of maximum entropy modeling in wildlife research. *Entropy*. 11:854-866.

Phillips, S. J. 2018. A Brief Tutorial on Maxent. Available from url:

[http://biodiversityinformatics.amnh.org/open\\_source/maxent/](http://biodiversityinformatics.amnh.org/open_source/maxent/). Accessed on 2018-02/21.

Steven J. Phillips, Miroslav Dudík, Robert E. Schapire. [Internet] Maxent software for modeling species niches and distributions (Version 3.4.1). Available from url:

[http://biodiversityinformatics.amnh.org/open\\_source/maxent/](http://biodiversityinformatics.amnh.org/open_source/maxent/). Accessed on 2018-2-20.

**From:** [Marshall, Michael E](#)  
**To:** [Endries, Mark](#)  
**Cc:** [Reid, Rebekah N](#)  
**Subject:** Re: Updated Maxent Methodology  
**Date:** Thursday, April 12, 2018 11:07:35 AM  
**Importance:** High

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Thanks Mark...off the cuff, I see on page 2, you mention using EO back to 2007....is this correct, or did you include EOs back to 2005?

Thanks,

Mike

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**Subject:** Re: Updated Maxent Methodology  
**Date:** Thursday, April 12, 2018 11:39:15 AM  
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**Subject:** Re: Updated Maxent Methodology  
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**Importance:** High

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I also forgot to mention that in the Maxent write-up you'll notice a couple of added variables from the original Maxent model. I added **Solar Radiation**, **Canopy Cover**, and **Canopy Height** to the mix. Solar Radiation measures how much sun reaches each pixel over the year. Canopy Cover is the density of green vegetation, and Canopy Height is the height of the vegetation. Only Canopy Cover made it into the final model and was the least contributing variable present. So the further exploration of additional variables resulted in a minor change to the conclusions.

Thanks!

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| Pasture/Hay                                                  | Disturbed           |
| Quarries, Mines, Gravel Pits and Oil Wells                   | Disturbed           |
| Ruderal forest                                               | Disturbed           |
| Southern Appalachian Low Mountain Pine Forest                | Evergreen           |
| Southern Appalachian Montane Pine Forest and Woodland        | Evergreen           |
| Southern and Central Appalachian Cove Forest                 | Hardwood            |
| Southern and Central Appalachian Oak Forest                  | Hardwood            |
| Southern and Central Appalachian Oak Forest - Xeric          | Hardwood            |
| Southern Piedmont Mesic Forest                               | Hardwood            |

|                                                                  |                    |
|------------------------------------------------------------------|--------------------|
| Central and Southern Appalachian Montane Oak Forest              | High Elevation     |
| Central and Southern Appalachian Northern Hardwood Forest        | High Elevation     |
| Central and Southern Appalachian Spruce-Fir Forest               | High Elevation     |
| Southern Appalachian Grass and Shrub Bald                        | High Elevation     |
| Southern Appalachian Grass and Shrub Bald - Shrub Modifier       | High Elevation     |
| Appalachian Hemlock-Hardwood Forest                              | Mixed              |
| Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier      | Mixed              |
| Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier | Mixed              |
| Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier         | Mixed              |
| Southern Ridge and Valley Dry Calcareous Forest                  | Mixed              |
| Southern Ridge and Valley Dry Calcareous Forest - Pine modifier  | Mixed              |
| Open Water (Fresh)                                               | Open Water/Wetland |
| Southern and Central Appalachian Bog and Fen                     | Open Water/Wetland |
| Southern Piedmont/Ridge and Valley Upland Depression Swamp       | Open Water/Wetland |
| Southern Appalachian Granitic Dome                               | Outcrop            |
| Southern Appalachian Montane Cliff                               | Outcrop            |
| Southern Appalachian Rocky Summit                                | Outcrop            |
| Southern Piedmont Cliff                                          | Outcrop            |
| Southern Piedmont Granite Flatrock                               | Outcrop            |
| South-Central Interior Large Floodplain - Forest Modifier        | Riparian           |
| South-Central Interior Small Stream and Riparian                 | Riparian           |
| Southern Piedmont Large Floodplain Forest - Forest Modifier      | Riparian           |
| Southern Piedmont Small Floodplain and Riparian Forest           | Riparian           |

**Landcover Diversity** – Identifies the number of landcover classes (default classification) within a 10-cell radius (300 meters) of an individual pixel.

**Landcover Majority** – Identifies the dominant landcover class (default classification) within a 10-cell radius (300 meters) of an individual pixel.

**Landfire Canopy Height** – Represents the vertically projected percent cover of the live vegetation canopy.

**Landfire Canopy Cover** – Represents the average height of the dominant vegetation across the landscape.

**SSURGO mukey** – SSURGO soils dataset represented by the Map Unit Key (mukey)

**SSURGO Drainage Class** – SSURGO soils dataset represented by wettest drainage class. Drainage class refers to the frequency and duration of wet periods in conditions similar to those under which the soil formed.

**SSURGO Hydrologic Group** – SSURGO soils dataset represented by hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

**Elevation** – National elevation dataset elevation values. This 10-meter dataset was reclassified to 30-meters.

**Aspect 9-class** – Using the national elevation dataset, the aspect was derived and categorized into the following classes: Flat, North, Northeast, East, Southeast, South, Southwest, West, and Northwest.

**Aspect 5-class** – Using the national elevation dataset, the aspect was derived and categorized into the following classes: Flat, North, East, South, and West.

**Slope** – The national elevation dataset represented by degree of slope.

**Geomorphons** – A pattern recognition analysis that converts a digital elevation dataset into 10 common landform elements: flat, peak, ridge, shoulder, spur, slope, pit, valley, footslope, and hollow. The national elevation dataset was used as the source elevation for the analysis.

**Solar Radiation** – An analysis of the amount of solar radiation (radiant energy) reaching the earth's surface using the national elevation dataset as the elevation model. The output solar model is reported in watt hours per square meter (WH/m<sup>2</sup>)

**Average Annual Precipitation** – Climate dataset of average annual precipitation according to a model using point precipitation and elevation data for the 30-year period of 1971-2000.

**Maximum Average Annual Temperature** – Climate dataset of average annual maximum temperature according to a model using point temperature data for the 30-year period of 1981-2010.

**Minimum Average Annual Temperature** – Climate dataset of average annual minimum temperature according to a model using point temperature data for the 30-year period of 1981-2010.

### *Maxent Model Development*

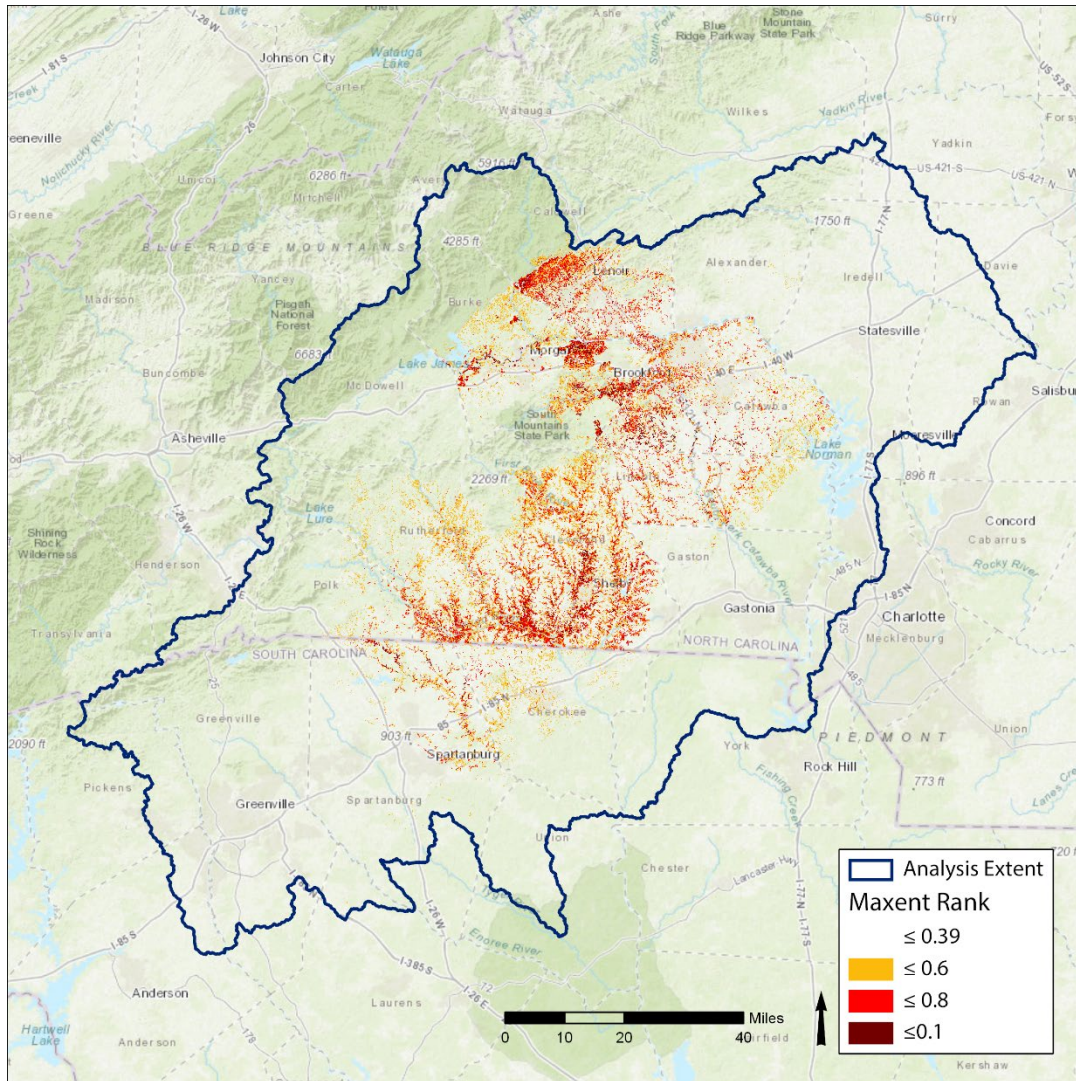
Maxent software for species habitat modeling (version 3.4.1) was used (Philips et al., 2018).

An initial single model Maxent run was done to determine which variables could be excluded due to limited percent contribution to the model. Any variable that contributed less than 1% to the single model run results was excluded in the final model. The following variables were excluded:

landcover diversity, canopy height, SSURGO drainage class, SSURGO hydrologic group, aspect 9-class, aspect 5-class, slope, solar radiation, and maximum annual temperature.

For the final model a 10-run replicate Maxent model was created using crossvalidation. For replicate models, the occurrence data is randomly split into a number of equal-sized groups called "folds", and separate models are created leaving out each fold in turn. The individual model runs are then averaged together to derive the final model. Cloglog output format was used. Cloglog output gives an estimate between 0 and 1 of probability of presence assuming an appropriate sampling design.

Figure 2. Maxent model output map.



## Results

Figure 2 shows the model output. The minimum cutoff value (to determine if an area is considered potential habitat for a species) of 0.39 was determined by using the average 10th percentile training presence. The 10th percentile training presence uses the suitability threshold associated with the presence record that occurs at the 10th percentile of presence records (Phillips 2018). This value excludes some of the outlier population areas in the Maxent predictions to focus on the typical habitat conditions for this species. The total area ranked greater than 0.39 in the Maxent model was just 6.0% of the total analysis area (Table 1).

Table 1. Area estimates of the Maxent model

| Maxent Score      | Acres      | Square Miles | Percent of Total |
|-------------------|------------|--------------|------------------|
| 0.406 and greater | 302,834.13 | 473.18       | 6.02%            |
| 0.6 and greater   | 128,273.52 | 200.43       | 2.55%            |
| 0.8 and greater   | 22,115.97  | 34.56        | 0.44%            |

The average area-under-curve (AUC) score for the replicate Maxent model is 0.86. The AUC is calculated from the receiver operating characteristic (ROC) plot. This value has a range of 0 – 1 and may be interpreted as a single test statistic that assesses model performance, indicating the ability of the model to correctly classify the occurrence data used. AUC values close to 0.50 indicate a model fit no better than random, values less than 0.5 indicate a model fit worse than random, a value of 1.0 indicate a perfect fit (Baldwin 2009). A value of 0.86 is a good fitting model.

The Maxent output supplies estimates of the relative contributions of the environmental variables to the Maxent model (Table 2.)

Table 2. Percent contribution of the environmental variables

| Environmental Variable        | Percent Contribution |
|-------------------------------|----------------------|
| SSURGO mukey                  | 23.5%                |
| Minimum Annual Temperature    | 17.8%                |
| Average Annual Precipitation  | 15.7%                |
| Landcover                     | 12.9%                |
| Landcover Majority            | 12.0%                |
| Landcover Hexastylis Grouping | 5.4%                 |
| Geomorphons                   | 4.9%                 |
| Elevation                     | 4.6%                 |
| Canopy Cover                  | 3.2%                 |

SSURGO mukey is the top contributing variable. 135 different individual soil types are present within the polygon boundaries of the Hexastylis element occurrences. Many of these individual soil types are part of soil complexes and are separated by things such as percent slope, erosion, how stony/rocky, and amount of clay. The most common individual soil type was Meadowfield-Rhodhiss complex, 25 to 60 percent slopes, very stony (14.1% of total). However, collectively the Meadowfield soils only comprised 14.3% of all soils). The individual Pacolet soil types were very common and collectively comprise 32.2% of all soil types present. Woolwine, Rion, and Fairview

soils were also collectively common, comprising 10.4%, 9.7%, and 8.8% of all soils present respectively.

The minimum annual average temperature range in the analysis extent is 39 – 51 degrees Fahrenheit. The majority of the *Hexastylis* element occurrences (89%) are found at the 47 and 48 degrees. The Average annual precipitation range in the analysis extent is 42 – 81 inches per year. The majority of the *Hexastylis* element occurrences (82%) are found in the 47 – 49 inches per year range.

Piedmont forested landcover habitats dominate the land area of the element occurrences. Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier (53%), Southern Piedmont Mesic Forest (9%), Southern Piedmont Dry Oak-Pine Forest (5.2%), Southern Piedmont Small Floodplain and Riparian Forest (4.4%), and collectively comprise 71% of the element occurrences area. Unfortunately, non-native habitats are also present. Evergreen Plantation or Managed Pine (9%), Harvested Forest (7.2%), Developed, Open Space (5%), Pasture/Hay (2.1%) collectively comprise 22% of the total element occurrence area. The Remaining 6 percent of element occurrence area is comprised of a mix of 14 other natural and disturbed landcover classes, but each at small percentages.

The landcover majority classification scheme reduces the total number of landcover classes present in the analysis extent from 23 to 11. Southern Piedmont Dry Oak-Pine Forest – Hardwood Modifier is still the dominant landcover class (58%). However disturbed categories are increased in area (sum total of 35%). Evergreen plantation or managed pine (12%) and Pasture/Hay (12%) are the only other categories that have at least 10% or greater area. The increase in disturbed landcover area representation in the landcover majority layer suggests that many *Hexastylis* population areas are situated in areas impacted by disturbed landcover. This is likely due to urban encroachment and increasing fragmentation of habitats.

The landcover *Hexastylis* grouping reveals the amount of disturbance present in *Hexastylis* population areas. Landcover classes grouped as disturbed comprises 27% of the total area. Mixed forest (deciduous and evergreen) comprises 58%, pasture/hay 12%, and hardwood forest 2%,

Geomorphons revealed that the majority of *Hexastylis* element occurrence areas are situated in concave landforms. Geomorphon categories hollow (13%), valley (46%), and depression (10%) collectively comprise 69% of all *Hexastylis* population areas. Flat landforms comprise 15.5% of the area and convex landforms the remaining 15.5%.

Within the analysis extent, the range of elevation present is 335 – 5,265 feet. For *Hexastylis*, the prime elevation range is from 666 – 908 feet (53% of total element occurrence area). A lesser elevation range is present from 935 – 1,184 (37% of total element occurrence area).

Canopy cover for the *Hexastylis* populations are dominated by Tree Cover 70-80% (20.2%) and Tree Cover 80-90% (63.9%). The rest of the canopy cover categories are 2% or less.

## *Citations*

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