



USING GIS TO DETERMINE WHERE TO INVEST IN WHITE OAK GROWTH

Summary of Analysis Methodology

Abstract

Timmons Group partnered with American Forest Foundation (AFF) to help them determine where to invest their resources to restore and promote sustainable White Oak growth across the Eastern United States.



TIMMONS GROUP
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May 6, 2021

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Summary and Key Findings

The goal of the WOI Spatial Assessment Secondary Analysis is to aid AFF and WOI partners in assessing where restoration of upland and white oak forests should be prioritized to ensure a sustainable future for white oak.

The Primary Analysis was conducted by Lance A. Vickers, PhD and Benjamin O. Knapp, PhD of the University of Missouri, School of Natural Resources. Their findings are detailed in the White Oak Regeneration Spatial Analysis Final Report. In general, the Primary Analysis focuses on ecological conditions and white and upland oak range and prevalence using USDA Forest Service Forest Inventory (FIA) data.

The Secondary Analysis, henceforth referred to simply as “this analysis,” uses data generated by the Primary Analysis and overlays it with many other data layers representing social, economic, and industrial factors as well as additional biological factors that have been identified.

The driving question behind this analysis is “Where should we work to restore and promote sustainable and free to grow white oak across the 20 identified states?” Timmons Group worked closely with AFF to identify appropriate data layers to use and a strategy for overlaying and analyzing the two sets of data. Furthermore, we were tasked with analyzing the following sub-components of the driving question:

- Probability of regeneration success
- Landowner efficacy
- Barriers to success
- Forest product demand
- Enabling conditions management
- Conservation impact

“Where should we work to restore and promote sustainable and free to grow white oak across the 20 identified states?”

Overview of key terms used in this report

- EcoState: this is the intersection of state boundaries with ecosections and is the primary unit of analysis.
- A “score” is a relative ranking of all EcoStates based on, typically, one attribute. There are some cases where multiple attributes are processed (added, multiplied, divided, etc.), and the derived value is used to score. In some cases the scores are generated at the state level instead of the EcoState level. These nuances are detailed in the Methodology section.
- Scores are typically a value from 1 to 5, where each rank (1, 2, 3, 4, and 5) has an equal number of EcoStates within it (or an equal number of states within it when states are scored). This is an equal quintile method. There are some exceptions where scores are not a 1 to 5 value, as noted in the methodology section.
- Weights allow scores to be adjusted. Scores are multiplied by the weights.
- The “Overall Score” is a final score created by summing up all scores for the EcoState.
- The final analysis layer is the output data layer that contains the Overall Score, all individual scores, weights, adjusted scores, and raw attributes from which the scores were calculated. It also contains additional attributes that were not used in score generation, but that could be useful for exploring the data layer.

The image below shows an ecosection (223E) on the left, in blue. This ecosection spans across Kentucky, Tennessee, and Alabama. The right shows the same ecosection cut along state lines, showing the resulting EcoState units (KY223E - green, TN223E - blue, and AL223E - purple).

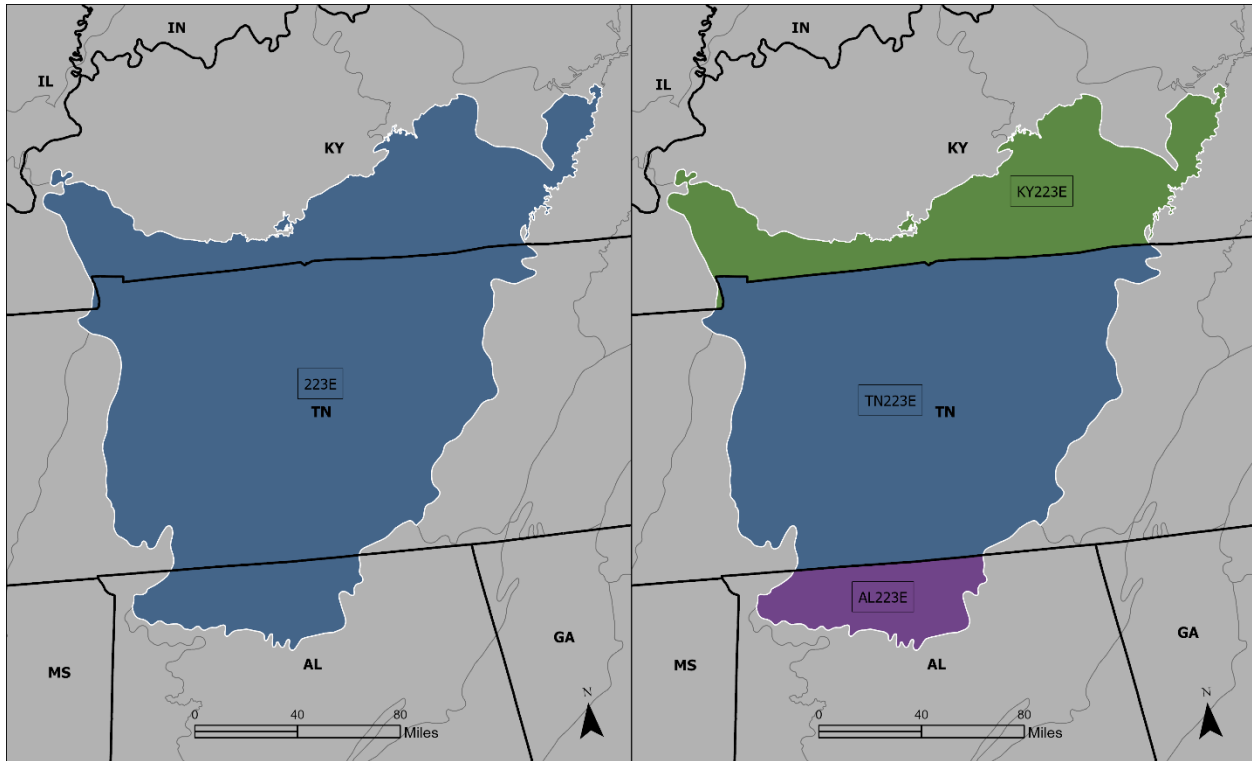


Figure 1 - Illustration of EcoState analysis units

Overview of Analysis Approach

The core challenge of this analysis is to bring together and overlay many disparate data sources and use the result to prioritize where to work to promote sustainable white oak forestland. Timmons Group and AFF devised a methodology for scoring these different data layers and weighting those scores based on feedback from the White Oak Initiative Steering Committee. We have decided to use a 1 to 5 score for each data layer (with rare exceptions), where 1 represents less suitable areas to work and 5 represents more suitable and more highly prioritized areas to work. These scores were adjusted by weights determined through outreach to stakeholders and expert forestry and silvicultural experts. Each of the data layers used in this analysis contributes to an analysis sub-component:

- Probability of regeneration success
- Landowner efficacy
- Barriers to success
- Forest product demand
- Enabling conditions management
- Conservation impact

Weights exist at three levels. At the first level, some data layer scores are derived from multiple attributes within the data layer; in this case, we've consulted with AFF and Paul DeLong to apply weights to generate the data layer score. A second level of weighting happens within the analysis sub-component level (often referred to as the data theme level). A final weighting occurs across the data theme level, adjusting how much each data theme contributes to the overall final score. These last two

levels of weighting – within the data theme level, and across the data themes – can be adjusted based on further outreach and as a result of further study.

To summarize, weighting has occurred at three levels in this analysis:

1. **Within a data layer**, to generate the data layer's score. This does not apply to all data layers; it applies to some data layers that have multiple attributes that contributed toward the data layer's overall score. Examples include the WOI Landowner Survey score and the BLS NAICS job code score. These weights are not adjustable.
2. **Within a data theme**, to derive the overall analysis sub-component score. Some data themes only contain one data layer; in this case, that layer's score contributes 100% towards the overall data theme score. Other data themes have multiple data layers that contribute to the data theme score. For these, weights have been applied to adjust how much each data layer contributes to the data theme score. These weights can be adjusted, allowing the final score to be recalculated.
3. **Across data themes**, to derive the final overall score. These weights adjust how much each data theme contributes to the final overall score. For example, the Probability of Regeneration Success theme consists of 60% of the final overall score. These weights can also be adjusted, allowing the final score to be recalculated.

The weights used at the second and third tier can be adjusted, allowing the final overall score to be recalculated. We reached out to stakeholders to provide feedback on the relative importance of each data layer. In response to that feedback, we demoted one of the data layers to an “additional information” role rather than an analysis role involved in scoring (this applies to the PAD-US protected areas data). This feedback also played a role in determining how to weight the BLS NAICS jobs data to determine the overall BLS NAICS jobs data score (weights at the 1st tier for the BLS NAICS jobs data). However, we did not ask stakeholders to judge the importance of each analysis sub-component. The weights at the 2nd and 3rd tiers were ultimately assigned by Dr. Jeffrey Stringer and Paul DeLong, silvicultural and forestry experts.

Scores are assigned by sorting the data on the applicable attribute, then breaking up the data into equal groups.¹ If there are 100 features, for example, then the first 20 with the lowest values in that attribute are given a score of 1. The next 20 get scored as 2. The last group of features with the highest values are scored as 5. Note that not all scores are generated by sorting the attribute in ascending order; some scores are generated by sorting the attribute in descending order. For descending scores, the features with the highest attribute values will have the lowest score. This general rule for score generation has a few exceptions. For site productivity data, values on the high end and low end are scored lower than values in the middle range. This is discussed in greater detail in the Scoring Methods section.

Some scores are generated at the ecosection level, some are generated at the state level, and some are generated at the EcoState level. This is based on what level the data is applicable to. For example, the WOI Landowner Survey data applies to the state level. In that case, the raw Landowner Survey data on the state polygons is used to score. Later the state-based scores for Landowner Survey data are joined to the EcoStates. In the end, all scores are put onto the EcoState features. The final data layer will be

¹ Note: there are some notable exceptions. Site productivity is not scored this way; neither is Critical Habitat for T&E species. These methods are discussed in greater detail in the Scoring Methods section.

the EcoState features with all scores. And why is this the case? Why wouldn't we apply all the raw data to the EcoState and then generate all the scores there? That's because the scoring method is relative, using equal groups of features to assign scores. We have many more EcoStates than we have states (there are 20 states total, and 146 EcoStates). It makes sense for all EcoStates within a state to have the same score as the overall state. Therefore, the score is derived at the state level and then joined to the EcoStates.

These relative ranking scores are designed to show us where conditions are most favorable for white oak regeneration success, relative to other areas, based on attribute values. This allows us to sum up multiple scores across very different data, essentially answering the question: "where are conditions most favorable for promoting forestry management and regenerating white oak forest, based on ecological, social, conservation, and other factors combined?"

Why focus on the EcoState as the primary analysis unit?

This analysis brings together disparate data layers across a large range: 20 eastern US states. The data sources supplied data at different levels:

- Summarized to the state level (for example, BLS NAICS jobs data; WOI Landowner Survey data)
- Summarized to the ecosection level (Primary Data)
- Summarized to the county level (for example, Timber Product Output data)
- Points showing exact location (site productivity of certain white oak FIA plots)
- Polygons showing location (Critical Habitat T&E species)

This analysis necessarily had to make a compromise: how can such wildly different data sources be organized and analyzed to give a coherent result across this wide range? We settled on EcoState, the intersection between ecosections and state boundaries. This breaks the ecosections into smaller pieces, but these pieces are still larger than counties. Each EcoState inherits the same attribute values as all other pieces of the same ecosection for data layers that are summarized to the ecosection level. Each EcoState inherits the attributes of the state that it falls within for state-level data. County level data is processed and summarized to the EcoState based on majority overlap of the county (county data values are not reapportioned to different EcoStates, they're assigned to one EcoState). Other spatial data such as points and polygons are summarized to the EcoState as well, either based on attributes or on spatial relationship (polygons are typically split at EcoState lines and a percent area overlap is calculated as the attribute value there; different processing methodologies are used for different data layers as detailed in the separate data processing document).

Area calculations

The source datasets varied widely in spatial reference. Much of the analysis relies on calculating the percent area coverage between data layers. In order to calculate these values accurately, the data were reprojected to USA Contiguous Albers Equal Area Conic before making area calculations.

Limitations

At the outset of this analysis, we intended to include data that speak to climatic conditions. This information would have been supplied by the TNC Resilient and Connected Landscapes dataset. However, due to time limitations we did not feel we could allocate adequate time toward learning to use the complex data and toolset available to get the most out of this dataset and use it appropriately.

We feel we would need to devote considerable effort to understanding how the resilience scores are derived before we could use them in an analysis such as this one. Therefore, Timmons Group and AFF jointly decided to strike this dataset from this current analysis project. This could be an area for further study.

At the time this analysis was performed, the Timber Product Outputs (TPO) data for the northern region of the study area had some major issues. Our contact for this data, Ron Piva, encountered technical difficulties with extracting and converting the most recent data for the northern region. Therefore, we used a mix of some older datasets for that region. Furthermore, we had originally intended to use the TPO mill data rather than the BLS mill data because the TPO mills have coordinate information. We created a process to determine the number of mills per EcoState for the southern region. However, the northern region did not support this use of the data; ME, NH, NY, OH, and PA do not report mill locations, or only report summaries. Therefore, we reverted to using the less specific BLS mills data at the state level. A further refinement to this analysis can be done if more recent TPO data is received for the northern region.

This analysis methodology has been performed to purposefully simplify many disparate datasets across a very large range. The purposeful simplification here is meant to make it easier to judge the relative conditions and differences between EcoStates. The main methodology here results in scores for each data layer, on a scale of 1 through 5, where each score category has the same number of features (an equal quintile method). Part of the analysis relies on dictating that one end of an attribute's value spectrum is the "good end" and the other is the "bad end."² Typically, less = bad and more = good (some attributes are reversed, where more = bad, as discussed in the methodology section). This is probably appropriate for simple things such as the number of foresters per state. But for other data layers, this may be too simplistic. In the scope of this project, we've done our best due diligence to consult with experts as much as possible to help define which end of a particular data value spectrum is the "good end."

Ultimately, one data layer in particular broke the mold of the typical methodology. Site Productivity is complex and nuanced; high site productivity is not ideal for our objectives with white oak (they're ecologically competitive, and would be very expensive), and low site productivity may be so good for white oak that working there is not as high priority because the white oak could thrive there naturally without additional intervention. This means the one size-fits-all method of identifying a good end and a bad end of the spectrum doesn't work for site productivity for white oak.³ We've altered the methodology for this data layer in particular to account for that. High productivity sites are still marked very low, and low productivity sites are likewise marked low. The EcoStates with an average Classification closest to FIA Class 5 become the more highly ranked sites, scoring lower the further they get from there in either direction. A suggested refinement for this analysis would involve fine-tuning the scores for each of the data layers. A different methodology might involve more closely deciding which source data values correspond to which scores and moving away from using the equal quintile methodology for comparing relative conditions.

² Paul DeLong, "One issue I am flagging is that we overtly decide how to define an attribute (which is the "good end" and which is the "bad end")," Basecamp discussion, Analysis Plan Draft.

https://basecamp.com/2654389/projects/17609937/messages/93751254#comment_787436446

³ Discussions with Jeffrey Stringer, 12/1/2020.

Another limitation is our assumption that good condition + good condition = better place to work.⁴ By necessity, this analysis has created a simplified model using scores and composite scores. The resulting final analysis layer is then sorted on the composite score, and we are effectively assuming better individual data layer scores + better individual data layer scores = better place to do engagement and forest management work. The reality is not as simple, and there is much to explore in the data and final analysis layer that is not directly explored and reported on in this document. For example, this report generally focuses on highlighting EcoStates with the highest final scores. However, it could be incredibly useful to dive deeper into the data and focus on specific individual data layer scores (or smaller combinations of these) to find specific scenarios, or even combinations where some layers scored high and others scored low. One might be interested in finding suitable ecological scores with low social scores, for example. Those EcoStates could be key for longer term outreach to secure a future for white oak, as the community and social relationships to do that work may not currently exist. This type of scenario-defining and -analyzing was outside the scope of this current project, but it is incredibly vital to WOI's and AFF's aims. The final output data layer created by this effort will allow WOI, AFF, and partners to continue to explore the data and interrogate those more narrowly focused scenarios.

This analysis is purposefully focused at the regional scale, with the primary analysis unit at the EcoState level. The final analysis layer is meant to work at this scale and cannot guide decisions at a site or stand specific level. For guiding site and stand level decisions, it is recommended to refer back to source data at a more granular scale. Further study at the state level and deeper is recommended for identifying specific stand-level sites to work in.

This analysis leverages data developed in the Primary Analysis by the University of Missouri.⁵ Specifically, we've used Primary Analysis data that has been filtered to regeneration eligible white oak and upland oak lands. This applies to the site productivity data as well. The mean site productivity value generated for each EcoState in this analysis is not the overall site productivity value for that EcoState – it is specifically the mean site productivity value for plots on regeneration eligible upland oak forestland. Additionally, this data is then summarized to the EcoState for this analysis. Other data sources are likewise summarized to the EcoState or assigned to the EcoState based on which ecosection or state the area is within. The final analysis layer does not represent specific sites on the ground within an EcoState that meet specific conditions. In order to find appropriate sites within an EcoState, more granular data sources must be consulted.

⁴ Paul DeLong, "One issue I am flagging is that we overtly decide how ... different attributes stack (i.e., how does one factor influence another; I am not sure in all cases it's a simple good+good=better)," Basecamp discussion, Analysis Plan Draft. <https://basecamp.com/2654389/projects/17609937/messages/93751254>

⁵ Vickers, Lance A., PhD; Knapp, Benjamin O., PhD; University of Missouri, School of Natural Resources. White Oak Regeneration Spatial Analysis – Final Report.

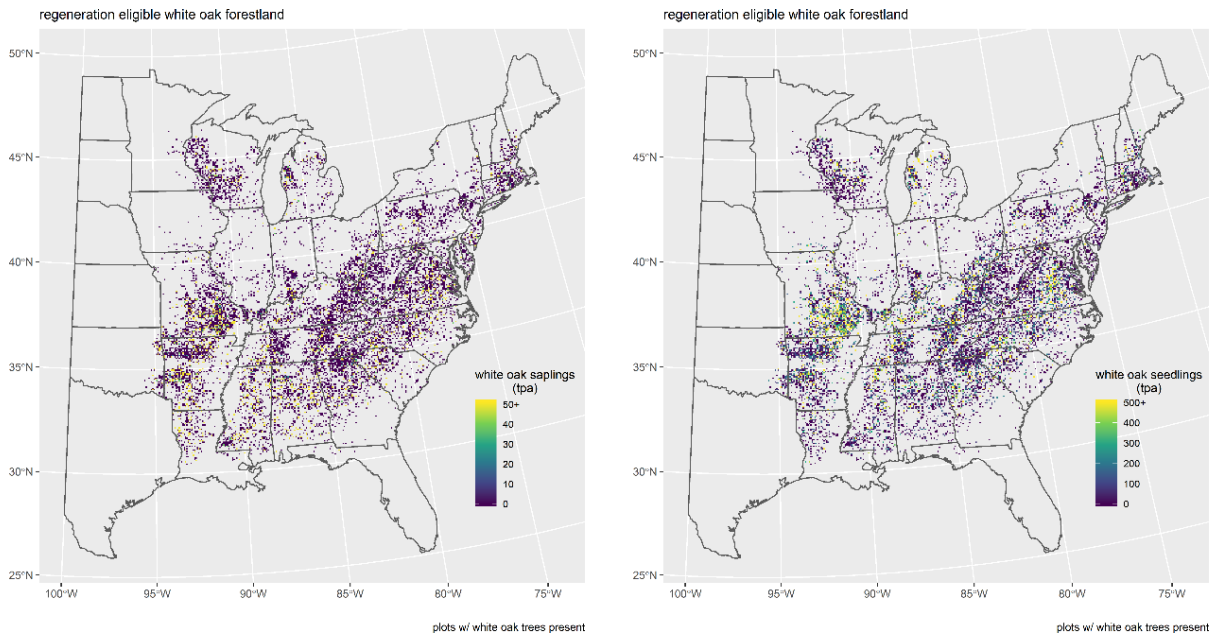


Figure 22. White oak sapling and seedling abundance, local scale, trees per acre, saplings (dbh 1-3 in.) [L], seedlings (dbh < 1 in; height ≥ 12 in.) [R], eastern US regeneration eligible white oak forestland, 2017. Each cell represents ≈ 12,000 acres.⁶

There is a lot of room for additional exploration of the data to occur. This analysis focused on one conception of “probability of regeneration success.” This analysis assumes that regeneration eligible white and upland oak forestland with greater numbers of seedlings and saplings are higher priority because that indicates a greater probability of regeneration success. However, it could very likely be the case that WOI and AFF will want to parse the data further and use different criteria to select EcoStates meeting different conditions so different treatment and engagement activities can be prescribed. We have been very deliberate in our analysis approach, documentation, and data deliverables to ensure WOI and AFF have the ability to understand the data and easily perform further analysis, queries, and final score recalculation. The final analysis layer contains all raw data, unweighted individual data layer scores, and additional data for context.

Additional information included

In addition to the attributes used for deriving the final overall score, several more attributes are included in the final analysis layer that provide information without contributing to the final score. This section details those attributes. Furthermore, the final data deliverables of this project include some data layers beyond the final analysis layer that can be added to the same map for additional context.

We’ve included these additional pieces of information because we intend for the final analysis layer to be explored further and used as a valuable tool to enhance future planning and engagement discussions.

⁶ Vickers, Lance A., PhD; Knapp, Benjamin O., PhD; University of Missouri, School of Natural Resources. White Oak Regeneration Spatial Analysis – Final Report. 37p, Figure 22.

BLS NAICS Codes

Included Avg Employees and Establishments for NAICS Codes 321920 (Barrel, Pallet, Packaging Manufacturing) and 321999 (Misc Wood Products Manufacturing).

Limiting Factors: Percent PAD-US Protected Area

For this analysis, Timmons Group consulted with Paul DeLong to review the USGS Protected Areas Database of the United States (PAD-US 2.0) data and determine which classes of data represent areas where intensive forestry management are not allowed. The resulting data layer was analyzed and added as an attribute to the final analysis layer, however this attribute does not contribute to the final overall score. We have provided the filtered PAD-US data layer to be used in maps and visualizations of the final results. This data layer will be useful when looking at a site-specific scale, rather than at the regional scale that is the focus of this analysis and report.

Protected Areas were found using the USGS Protected Areas Database of the United States (PAD-US 2.0). Specifically, the GAP Status field (See Below) was used to filter out areas where more intensive forestry management is allowed (GAP Statuses 2, 3, and 4). The resulting layer (representing only GAP Status 1) was intersected with the EcoState layer and calculated as a percent area of each EcoState polygon.

Attribute_Label: GAP_Sts

Attribute_Definition:

The 'GAP Status Code' is a measure of management intent to conserve biodiversity defined as:

'GAP Status Code 1': An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events (of natural type, frequency, intensity, and legacy) are permitted to proceed without interference or are mimicked through management.

'GAP Status Code 2': An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive uses or management practices that degrade the quality of existing natural communities, including suppression of natural disturbance.

'GAP Status Code 3': An area having permanent protection from conversion of natural land cover for most of the area, but subject to extractive uses of either a broad, low-intensity type (e.g., logging, Off Highway Vehicle recreation) or localized intense type (e.g., mining). It also confers protection to Federally listed endangered and threatened species throughout the area.

'GAP Status Code 4': There are no known public or private institutional mandates or legally recognized easements or deed restrictions held by the managing entity to prevent conversion of natural habitat types to anthropogenic habitat types. The area generally allows conversion to unnatural land cover throughout or management intent is unknown. See the PAD-US Standards Manual for a summary of methods or the geodatabase look up table for short descriptions.⁷

Range of Threatened & Endangered Species

This data from the U.S. Fish and Wildlife Service represents the countrywide range for threatened and endangered species. We did not use this data for scoring, but we did include an attribute on the final analysis layer that lists all Threatened & Endangered species that have any amount of range within each

⁷ U.S. Geological Survey (USGS) Gap Analysis Project (GAP), 2018, Protected Areas Database of the United States (PAD-US): U.S. Geological Survey data release, <https://doi.org/10.5066/P955KPLE>.

EcoState. This information can be queried to find particular species of interest. We filtered the source data to include only those records that were marked as Threatened or Endangered, and excluded all other records.

National Wild Turkey Federation (NWTF) Constituent data

Maria Swindells reached out to NWTF and procured a table noting the number of NWTF constituents per state in the WOI analysis range. This data has been provided as an attribute on the final analysis layer. Please note that each EcoState that intersects any given state will have the total number of constituents in that state; the number of constituents have not been reapportioned out across the EcoStates that fall within a given state.

Forest ownership in the conterminous United States circa 2017

The Forest ownership dataset from the USDA Forest Service depicts patterns of forest land ownership across the lower 48 states. This data contains eight ownership classes: federal, state, local, family, corporate, Timber Investment Management Organization (TIMO), and Real Estate Investment Trust (REIT), other private (including conservation organizations and unincorporated associations), and Native American tribal land. This data is modeled from Forest Inventory and Analysis (FIA) points and publicly available boundaries. While this data is not used to generate scores, it can be useful to see a breakdown of the ownership classes by EcoState. Including this data in maps can also give a general sense of forest ownership across the region. However, the metadata notes it should not be used at a local scale.⁸

We have added attributes to the final analysis layer that represent the total forestland per EcoState based on the source data, as well as the percent of forestland owned by each of the eight ownership classes per EcoState.

Scoring Methods

This section organizes the data layers by theme (analysis sub-component) and discusses the attributes from each data layer and how scores are derived.

Data Theme: Probability of Regeneration Success

Ecological conditions related to upland oaks and white oak on regeneration eligible lands

This data is scored at the ecosection level, then applied to EcoStates.

The first component of the Probability of Success analysis relates to ecological conditions within an ecological section. This information is derived from the Primary Analysis. These data apply to the entire ecological section and have not been redistributed or divided out to apply to the EcoState polygons; each EcoState polygon will have the same attribute values as all other EcoState polygons within an ecological section.

Create ranks (1, 2, 3, 4, 5), with 5 indicating a higher probability of success, and 1 indicating lower probability of success and lower amount of regeneration eligible lands, based on the following attributes:

⁸ Sass, Emma M.; Butler, Brett J.; Markowski-Lindsay, Marla A. 2020. Forest ownership in the conterminous United States circa 2017: distribution of eight ownership types - geospatial dataset. Fort Collins, CO: Forest Service Research Data Archive. <https://doi.org/10.2737/RDS-2020-0044>

Upland Oak:

1. Upland oak: % of total UOK lands that is regeneration eligible. UOK_PERC_reAC attribute, created with the calculation: $UOK_reAC_TOTAL/UOK_AC_TOTAL$
 - a. 1 = lowest percent (less regen-eligible lands)
 - b. 5 = highest percent (core area to protect)
2. Amount of Upland Oak regeneration eligible lands. UOK_reAC_TOTAL
 - a. 1 = lowest acreage (less regen-eligible lands)
 - b. 5 = highest acreage (core area to protect)
3. Upland oak: % of regeneration eligible area that does not have seedlings. UOK_reAC_PERC_noseed
 - a. 1 = highest percent (these are less successful / need more management)
 - b. 5 = lowest percent (these are going to be more successful)
4. Percentage of total regeneration eligible upland oak forestland acres with upland oak trees present but upland oak saplings absent for an ecological section. UOK_reAC_PERC_nosaps
 - a. 1 = highest percent (these are less successful / need more management)
 - b. 5 = lowest percent (these are going to be more successful)
5. Trees per acre (diameter ≥ 1 inch) of upland oak species (white, black, northern red, southern red, scarlet, chestnut, chinkapin, post) by ecological section on regeneration eligible upland oak forestland. TPA_UOK
 - a. 1 = lower density of trees
 - b. 5 = higher density of trees

White Oak:

6. White oak: % of total WOK lands that is regeneration eligible. WOK_PERC_reAC attribute, created with the calculation: $WOK_reAC_TOTAL/WOK_AC_TOTAL$
 - a. 1 = lowest percent (less regen-eligible lands)
 - b. 5 = highest percent (core area to protect)
7. Amount of White Oak regeneration eligible lands. (could be weighted lower than %) WOK_reAC_TOTAL
 - a. 1 = lowest acreage (less regen-eligible lands)
 - b. 5 = highest acreage (core area to protect)
8. White oak: % of regeneration eligible area that does not have seedlings. WOK_reAC_PERC_noseed
 - a. 1 = highest percent (these are less successful / need more management)
 - b. 5 = lowest percent (these are going to be more successful)
9. White oak: % of regeneration eligible area that does not have saplings. WOK_reAC_PERC_nosaps
 - a. 1 = highest percent (these are less successful / need more management)
 - b. 5 = lowest percent (these are going to be more successful)
10. Trees per acre (diameter ≥ 1 inch) of white oak alone by ecological section on regeneration eligible upland oak forestland. TPA_WOK
 - a. 1 = lower density of trees
 - b. 5 = higher density of trees

We chose these attributes from the Primary Analysis data because we believe they best represent and tell the story of ecological conditions important to the success and future of white and upland oaks. Timmons Group and AFF met with Lance A. Vickers, PhD to discuss the outcomes of the Primary Analysis and to determine which factors were most important for inclusion in the Secondary Analysis. We have included attributes related to upland oaks in addition to those specifically about white oak because the Primary Analysis assumes that upland oak forestland is generally suited for white oaks.

All attributes we've used from the Primary Analysis relate to 'regeneration eligible' areas. From the Primary Analysis final report:

We defined 'regeneration eligible' areas, i.e., stands that are or will soon be mature enough for a forester to begin contemplating regeneration, as plots in the 'mature' and 'late' stages. Age estimates for regeneration eligible areas vary but are generally ≥ 65 years.⁹

This analysis assumes that ecosections with a higher percent of regeneration eligible upland oak acreage are more desirable to work in.

In this analysis, ecosections with more regeneration eligible areas lacking seedlings are ranked lower. Areas with the lowest percent of areas lacking seedlings (that is, with the most seedlings on the ground in regeneration eligible areas) are probably going to be more successful, with less cost and less management.

Ecological conditions: Site Productivity of regeneration eligible upland oak forestland
This data is scored at the EcoState level.

Site productivity represents the inherent capacity to grow crops of industrial wood. Lower numbers in the SITECLCD field correspond to greater site productivity. The Primary Analysis provided a filtered set of plot points: plots on regeneration eligible upland oak forestland. For the Secondary Analysis, these filtered plot points were then summarized to the EcoState polygons using the plot point attributes (not a spatial join). Site productivity scores represent the average SITECLCD value within the EcoState, not the average value within the entire ecological section. This differs from all other Primary Analysis attributes used in the Secondary Analysis, which are largely unaltered and apply to the entire ecosection.

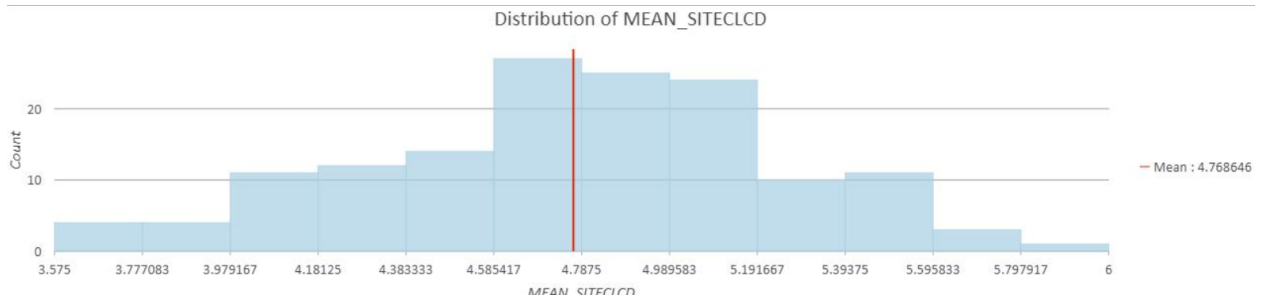
For this analysis, we consulted a panel of oak silviculturists for their expert opinions about which FIA classes are the best to work in for cultivating white oak. Dr. Jeffrey Stringer coordinated this call for subject matter expertise, and reported feedback indicating that FIA classes 4, 5 and 6 encompass the site index range indicated by all experts as best for white oak cultivation. Classes 1 and 2 are extreme and probably impossible to functionally cultivate white oak.

FIA Class	Ranking	Weighting
7	4	30%
6	2	65%
5	1	70%
4	3	65%
3	5	20%
2	6	5%
1	7	5%

⁹ Vickers, Lance A., PhD; Knapp, Benjamin O., PhD; University of Missouri, School of Natural Resources. White Oak Regeneration Spatial Analysis – Final Report. 12p.

Based on the feedback from Dr. Jeffrey Stringer and the silviculture experts, the productivity data cannot be scored on a simple sliding scale where one end of the spectrum is ranked lower, and the other end of the spectrum is ranked higher. Partly that's because the very high productivity sites are too competitive and would cost much more to manage on, and at the other end of the spectrum on very low productivity sites it is not as important to intervene and actively manage because oak will generally fare well there. Instead, the middle of the range of productivity values should be ranked highest for our purposes of prioritizing where to work. For this analysis, we therefore broke up the range of mean SITECLCD values into separate ranks based on their value, rather than on a relative equal quintile method as is done for nearly all other data layers.

The average productivity values across all EcoStates ranged from 3.575 to 6. The overall mean across all EcoStates is approximately 4.76.



Test Condition	Attribute Value
If @Value(MEAN_SITECLCD) RANGE (4.75,5.25]	5
Else If @Value(MEAN_SITECLCD) RANGE (4.5,4.75]	4
Else If @Value(MEAN_SITECLCD) RANGE (5.25,5.5]	4
Else If @Value(MEAN_SITECLCD) RANGE (4.25,4.5]	3
Else If @Value(MEAN_SITECLCD) RANGE (5.5,5.75]	3
Else If @Value(MEAN_SITECLCD) RANGE (5.75,6]	2
Else If @Value(MEAN_SITECLCD) RANGE (4,4.25]	2
Else If @Value(MEAN_SITECLCD) RANGE (3.5,4]	1
Else If	
Else <All Other Conditions>	<No Action>

1. Site Productivity: MEAN_SITECLCD per EcoState.
 - a. 1 = Sites with average class values more than 1 point away from FIA class 5. (3.5-4)
 - b. 5 = Sites with averages within 0.5 of FIA Class 5 (4.75-5.25)

2.4.22 SITECLCD

Site productivity class code. A classification of forest land in terms of inherent capacity to grow crops of industrial wood. Identifies the potential growth in cubic feet/acre/year and is based on the culmination of mean annual increment of fully stocked natural stands. This attribute may be assigned based on the site trees available for the plot, or, if no valid site trees are available, this attribute is set equal to SITECLCDEST, a default value that is either an estimated or predicted site productivity class. If SITECLCDEST is used to populate SITECLCD, the attribute SITECL_METHOD is set to 6.

Codes: SITECLCD

Code	Description
1	225+ cubic feet/acre/year.
2	165-224 cubic feet/acre/year.
3	120-164 cubic feet/acre/year.
4	85-119 cubic feet/acre/year.
5	50-84 cubic feet/acre/year.
6	20-49 cubic feet/acre/year.
7	0-19 cubic feet/acre/year.

Figure 2 - FIA Database SITECLCD description¹⁰

Data Theme: Landowner Efficacy

Social Conditions: WOI Landowner Survey (LOS)

This data is scored at the state level, then applied to EcoStates.

This survey conducted by WOI gauges landowner sentiment and experience regarding their land management history, methods, and plans. Below is a list of the 12 questions identified by AFF as key to understanding the social climate of each state as it pertains to white oak restoration. There are more than 12 items listed below because many of the questions allowed for multiple choices to be selected (the questions themselves had multiple choices, and users could have selected more than one answer for a single question). Each of the responses below were tallied by state and divided by the total number of responses for that state to derive the percentage of respondents for each who selected the specified answer. These responses were then joined to the states polygons, and were scored using the same equal quintile scoring method to give them a 1-5 score based on numerical order of percentage of respondents (either ascending or descending, depending on the question).

Because the scores were calculated based on each response, adjustments were made to ensure that questions with multiple responses were not given out-size representation in the final overall Landowner Survey Score. This involved creating an aggregate for all similar-direction (Ascending or Descending) responses for multi-response questions. Some of these aggregate question and response combinations also feature internal weighting – created in concert with Dr. Paul DeLong – and denoted below as (*#.##) indicating the multiplier applied to that response score. All weights were applied after initial response % scoring, and were combined to create an aggregate score, which was then scored again, resulting in a single 1-5 score for that question’s response cluster.

Finally, all response cluster scores are summed into an overall combined value, with a weight applied to the single most important question (“would you like more oak on your land?”). This combined value is then assigned an equal quintile 1-5 score. This is the final WOI Landowner Survey score that can be weighted against all other data layer scores.

¹⁰ FIA Database Description and User Guide for Phase 2 (version: 8.0). https://www.fia.fs.fed.us/library/database-documentation/current/ver80/FIADB%20User%20Guide%20P2_8-0.pdf

Only these two attributes (Future actions: None 15_8, Acceptable Cut Intensity: No cutting 19_1) were ranked descending, and are denoted in **RED**. These responses indicate less favorable attitudes toward active forest management and tree removal.

1. Advice: Have Received in past 5 yrs. (8_1 Range: 32%-85%)
 - a. 1 = Low advice Percentage
 - b. 5 = High advice percentage
2. Advice: Want to receive in next 5 yrs. (9_1 Range: 54%-83%)
 - a. 1 = Low advice Percentage
 - b. 5 = High advice percentage
3. Have a written management plan? (11_1 Range: 27%-87%)
 - a. 1 = Low Percentage
 - b. 5 = High Percentage
4. "Future Actions" Cluster
 - a. Cut trees for sale (15_1 Range: 27%-70%) (*Weight = 1.50*)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage
 - b. Cut trees not for sale (15_2 Range: 17%-63%) (*Weight = 1.50*)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage
 - c. Cut Brush (15_3 Range: 52%-81%)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage
 - d. Remove Invasives (15_4 Range: 42%-85%)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage
 - e. Plant Trees (15_5 Range: 37%-73%) (*Weight = 1.50*)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage
 - f. Use Herbicides (15_6 Range: 25%-67%)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage
 - g. Use Prescribed Fire (15_7 Range: 2%-72%) (*Weight = 1.50*)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage
5. **Future actions: None (15_8 Range: 1%-17%)**
 - a. **1 = High Percentage**
 - b. **5 = Low Percentage**
6. Planning to cut for sale (16_1 Range: 31%-87%)
 - a. 1 = Low Percentage
 - b. 5 = High Percentage
7. **Acceptable Cut Intensity: No cutting (19_1 Range: 27%-70%)**
 - a. **1 = High Percentage**
 - b. **5 = Low Percentage**
8. "Acceptable Cut Intensity" Cluster

- a. Few trees per acre (19_2 Range: 38%-82%)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage
- b. Many trees per acre (19_3 Range: 15%-41%) (*Weight = 1.25*)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage
- c. Many trees per acre, clustered (19_4 Range: 1%-23%) (*Weight = 1.50*)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage
- d. Most trees per acre (19_5 Range: 1%-100%) (*Weight = 1.75*)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage
- e. All trees per acre (19_6 Range: 1%-49%) (*Weight = 2.00*)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage
- 9. Planning to Plant in the future (20_1 Range: 24%-85%)
 - a. 1 = Low Percentage
 - b. 5 = High Percentage
- 10. Planning to use Herbicide in the future (23_1 Range: 21%-70%)
 - a. 1 = Low Percentage
 - b. 5 = High Percentage
- 11. Planning to use burns in the future (26_1 Range: 1%-74%)
 - a. 1 = Low Percentage
 - b. 5 = High Percentage
- 12. Like more oak on your land? (30_1 Range: 32%-65%) (*Weight = 2.00*)
 - a. 1 = Low Percentage
 - b. 5 = High Percentage
- 13. "Think upland oaks are at risk of decline" Cluster
 - a. Agree (30_10_4 Range: 13%-32%)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage
 - b. Strongly Agree (30_10_5 Range: 3%-33%)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage
- 14. "Orgs you would be interested in cooperating with" Cluster
 - a. Federal (164_1 Range: 30%-56%)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage
 - b. State (164_2 Range: 48%-87%)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage
 - c. Non-gov (164_4 Range: 17%-35%)
 - i. 1 = Low Percentage
 - ii. 5 = High Percentage

WOI Landowner Survey summary of internal weighting methods

This section presents much of the same information that is presented in the previous section, but with a focus on the internal weighting methods. The primary purpose of the list in the previous section was to describe each of the attributes and what a low (1) vs. high (5) score means for that attribute.

Highlighted information in this table shows the odd cases – the two data layers that are scored in a descending direction, and the single most important question that receives a weight at this level.

#	Survey Question - Each has a 1 - 5 Score	Ascending or Descending	Question Weight
1	Advice: Have Received in past 5 yrs.	Ascending	1
2	Advice: Want to receive in next 5 yrs.	Ascending	1
3	Have a written management plan?	Ascending	1
4	Future Actions Cluster	Ascending	1
5	Future Actions: None	Descending	1
6	Planning to cut for sale	Ascending	1
7	Acceptable Cut Intensity: No Cutting	Descending	1
8	Acceptable Cut Intensity Cluster	Ascending	1
9	Planning to Plant in the future	Ascending	1
10	Planning to use Herbicide in the future	Ascending	1
11	Planning to use burns in the future	Ascending	1
12	Like more oak on your land?	Ascending	2
13	Think upland oaks are at risk of decline Cluster	Ascending	1
14	Orgs you would be interested in cooperating with Cluster	Ascending	1

Overall, there are 14 questions that receive a 1-5 score. These 14 1-5 scores are summed, with item 12 (like more oak on your land?) weighted by multiplying it by 2, then the 1-5 equal quintile method is applied, producing a final 1-5 score for the WOI Landowner Survey data layer. Item 12, the question “would you like more oak on your land?” is the most important question, and therefore is the only question that is weighted at this level; it is given twice the impact of every other data layer. All other questions have an equal weight and contribute equally to the final overall score.

There are 4 questions that have subcomponents; these questions are called “clusters.” Item 4 in the table above is a cluster. This means that there were attributes within this cluster that each receive a 1-5 score, then are weighted, summed, and the entire thing is given a 1-5 score. This, again, is done to ensure that specific multi-choice questions are not given outsized weight in the final WOI Landowner Survey data layer score. The tables below summarize the attributes and weights within each cluster.

	4- Future Actions Cluster. Each answer below has a 1-5 score, multiplied by the weight, then all added up & finally scored 1-5. This overall combined score is the "cluster" score.	Ascending or Descending	Answer Weight
a	Cut trees for sale	Ascending	1.5
b	Cut trees not for sale	Ascending	1.5
c	Cut Brush	Ascending	1

d	Remove Invasives	Ascending	1
e	Plant Trees	Ascending	1.5
f	Use Herbicides	Ascending	1
g	Use Prescribed Fire	Ascending	1.5

	8 - Acceptable Cut Intensity Cluster. Each answer below has a 1-5 score, multiplied by the weight, then all added up & finally scored 1-5. This overall combined score is the "cluster" score.	Ascending or Descending	Answer Weight
a	Few trees per acre	Ascending	1
b	Many trees per acre	Ascending	1.25
c	Many trees per acre, clustered	Ascending	1.5
d	Most trees per acre	Ascending	1.75
e	All trees per acre	Ascending	2

	13 - Think upland oaks are at risk of decline Cluster. Each answer below has a 1-5 score, multiplied by the weight, then all added up & finally scored 1-5. This overall combined score is the "cluster" score.	Ascending or Descending	Answer Weight
a	Agree	Ascending	1
b	Strongly Agree	Ascending	1

	14 - Orgs you would be interested in cooperating with Cluster. Each answer below has a 1-5 score, multiplied by the weight, then all added up & finally scored 1-5. This overall combined score is the "cluster" score.	Ascending or Descending	Answer Weight
a	Federal	Ascending	1
b	State	Ascending	1
c	Non-gov	Ascending	1

Data Theme: Barriers to Success

National Insect & Disease Risk and Hazard Mapping

This data is scored at the EcoState level.

The source data is in raster format, with each pixel corresponding to an estimated Basal Area loss percentage for that area of forest. We summarized this data to the EcoState level, using Zonal Statistics as Table, calculating the mean value for all pixels within each ecostate. We then scored the ecostates in descending order based on the mean percent area loss from this layer.

1. Estimated percent white oak Basal Area loss due to all causes per EcoState.
 - NIDRM_WO_Risk_Score (Range 0-38%)
 - a. 1 = Highest percent

- b. 5 = Lowest percent

Deer Density

This data is scored at the EcoState level.

The Primary Analysis by the University of Missouri discusses deer density estimate data. For this analysis, we've used the deer density data to derive the average deer density per EcoState. This data is used as a proxy for deer browse, a significant pressure on vegetation growth and a barrier to success. The source data is in GIS boundary format, with a wide range of polygon shapes. Some states report by county, some by larger regional areas. Each area polygon has a deer density number value. We calculated an average per EcoState by finding the total area overlap per polygon per state, and deriving a weighted value per EcoState. For example, if 75% of the EcoState is covered with a polygon with a value of 2, and 25% of the EcoState is covered with a polygon with a value of 3, the EcoState's average value would be close to 2, but above 2. The number values correspond to the following densities: (1) rare, absent, or urban area with unknown population, (2) less than 15 deer per square mile, (3) 15 to 30 deer per square mile, (4) 30 to 40 deer per square mile, or (5) greater than 45 deer per square mile. We calculated an average per EcoState by finding the total area overlap per polygon per state, and deriving a weighted value per EcoState.

1. Average Deer Density per EcoState. Weighted_Deer_Dnsty_sum_Score (Range 1.99-5)
 - a. 1 = Highest percent
 - b. 5 = Lowest percent

Data Theme: Forest Product Demand

Timber Product Output (TPO) – white oak percentage of total green tons removed

This data is scored at the EcoState level.

Timber Product Output data is used to quantify recent extraction/demand for white oak in the 20 study states. The source data is recorded at the state and county level and is further categorized according to these 5 variables: Owner, Species Group, Removal Class, Source, and Product. Additionally, the amounts of timber from each class are recorded in both class-specific units of measure, as well as a universal unit – Green Tons.

For our analysis, we have chosen to sum green tons for white oak roundwood products at the county level. These values were then intersected with the EcoStates based on majority overlap, so that each county's value was attributed to only one EcoState. The data was summed to the EcoState, creating attributes that represent the white oak roundwood product green tons removals per EcoState.

1. White oak roundwood products green ton removal per EcoState. WO_RP_GreenTons_sum_Score (Range 1-5)
 - a. 1 = lowest percent (the white oak roundwood removals represent a lower percentage of the total overall green tons removal within the EcoState)
 - b. 5 = highest percent (the white oak roundwood removals represent a lower percentage of the total overall green tons removal within the EcoState)

Information about the TPO data for the Southern Region:

- States: AL, AR, GA, KY, MS, NC, SC, TN, VA
- Year: 2019

Information about the TPO data for the Northern Region:

- States (Year): IL (2010), IN (2013), IA (2009), MD (2008), MI (2014), MN (2010), OH (2009), PA (2012), WV (2007), WI (2013)

Data Theme: Enabling Conditions Management

The enabling conditions component of the analysis refers to capacity to manage forests and process timber as represented by the number of state foresters and jobs across various relevant industries and the presence of timber mills. It does not include infrastructure like roads; while this factor plays into analyses in the western US, the eastern US has high road-density as is. Furthermore, the individual, raw attributes for number of jobs per NAICS code are also included in the data alongside the grouped and summed numbers and scores described in this section.

Protected areas, where active management of forests is not allowed, should be excluded from consideration as sites to work with. See the “Additional information included” section for more information about this layer. Ultimately, we chose not to create scores based on the PAD-US data because it applies more at a site-specific scale.

BLS – number of jobs by industry NAICS

This data is scored at the state level.

The NAICS codes shown in the table below were selected as relevant to this analysis. The BLS data contains the number of jobs per industry NAICS code per state. For this analysis, similar NAICS codes are grouped together and the associated jobs numbers values are summed per group. NAICS codes are grouped by type, allowing each group to be weighted separately. We weighted the 4 groups below based on feedback from members of the WOI steering committee. Weights are noted in each group description.

To calculate the overall BLS Jobs layer score, we did the following:

- Sum the NAICS jobs numbers per group, for each of the 4 groups
- Apply a 1-5 equal quintile score to each of the 4 NAICS code groups. Lower number of jobs = 1, higher number of jobs = 5.
- Multiply each group score by the group weight to get the adjusted scores
- Summed up all groups’ adjusted scores to get an overall combined score
- Apply a 1-5 equal quintile score based on the overall combined score attribute. This is the final BLS Jobs layer score. It can be weighted in relation to scores for other data layers.

Table 1 - Full list of NAICS codes used in the Secondary Analysis, with notes about group number and weight

NAICS	NAICS Description	Group #	Weight
1153(1)	Support activities for agriculture and forestry	1	2.12
1131	Forestry, forest products, and timber tract production		
1133	Commercial logging		

321	Wood Products Manufacturing (Includes 32192(0): Wood container and pallet manufacturing; 321113: sawmills; 321999: all other misc wood product manufacturing)	2	2.25
322	Paper Manufacturing	3	1
33711	Wood kitchen cabinet and countertop manufacturing	4	1.75
337122	Nonupholstered wood household furniture manufacturing		
337211	Wood office furniture manufacturing		
337212	Custom architectural woodwork and millwork		

1. Number of jobs per NAICS related to forestry, forest products, and commercial logging. (FOR_LOG_SUP_EMPL Range: 64-5326)
 - a. 1 = lower number of jobs in this category
 - b. 5 = higher number of jobs in this category
 - c. Weight = 2.12

NAICS	NAICS Description
1153(1)	Support activities for agriculture and forestry
1131	Forestry, forest products, and timber tract production
1133	Commercial logging

2. Number of jobs per NAICS related to specific wood products manufacturing. (Range: 2476-22386)
 - a. 1 = lower number of jobs in this category
 - b. 5 = higher number of jobs in this category
 - c. Weight = 2.25

NAICS	NAICS Description
321	Wood Products Manufacturing (Includes 32192(0): Wood container and pallet manufacturing; 321113: sawmills; 321999: all other misc wood product manufacturing)

3. Number of jobs per NAICS related to paper manufacturing. (Range: 455-29258)
 - a. 1 = lower number of jobs in this category
 - b. 5 = higher number of jobs in this category
 - c. Weight = 1 (unweighted)

NAICS	NAICS Description
322	Paper Manufacturing

4. Number of jobs per NAICS related to furniture, architectural woodwork, cabinetry and countertop manufacturing. (OTHER_WOOD_PROD Range: 782-16020)
 - a. 1 = lower number of jobs in this category
 - b. 5 = higher number of jobs in this category

c. Weight = 1.75

NAICS	NAICS Description
33711	Wood kitchen cabinet and countertop manufacturing
337122	Nonupholstered wood household furniture manufacturing
337211	Wood office furniture manufacturing
337212	Custom architectural woodwork and millwork

Origin of the weight values for the BLS data

We asked the committee for feedback using a survey. This survey asked respondents how important the four different NAICS code groups are, from 1-10. We generated a mean (average) value based on these responses. From that, we calculated the weights by identifying the group with the lowest rank and treating that as unweighted; we divided all other average ranks by that lowest rank value. For example, the lowest mean rank value from the survey was 3.63 for group 3. For group 3, $3.63/3.63 = 1$. For group 2, $8.15/3.63 = 2.25$. Group 2 was considered the most important group, and in this scheme, it's ranked just over twice as important as group 3.

BLS NAICS	Description	MEAN survey value	Weight
Group 1	Forestry, Forest Products, Commercial Logging	7.69	2.12
Group 2	Specific Wood Products Manufacturing	8.15	2.25
Group 3	Paper Manufacturing	3.63	1.00
Group 4	Furniture, Cabinetry, etc.	6.35	1.75

BLS – number of mills per State BLS NAICS Code 321113 - Mills

This data is scored at the state level.

BLS data contains the number of establishments per industry NAICS code per state. One of the NAICS codes corresponds to mills. This represents the number of mills in each state.

Number of mills per State: annual_avg_estabs_count_321113Mills_Score (Range: 16-255)

- a. 1 = Low Count
- b. 5 = High Count

Foresters per state

This data is scored at the state level.

Foresters per state was obtained via NASF data per state. We joined and scored the total permanent Foresters, as well as the overall total foresters (Including temporary forestry workers). The score for the inclusive total was included in the Enabling Conditions score.

1. Foresters per state: Attribute Name (Total_PermSeas_Forestry_EMP_Rank Range: 35-1093)
 - a. 1 = Low Count
 - b. 5 = High Count

Data Theme: Conservation Impact

Critical Habitat T&E Species

The Critical Habitat T&E Species data is handled uniquely within the analysis. We have treated this data as a binary: either it receives a score of 5 because there is Critical Habitat present, or it receives a 0 because there is no Critical Habitat present. There simply is too large a number of EcoStates without any Critical Habitat present; only 40% of EcoStates have any critical habitat present. This presents a problem for the typical scoring method which breaks the EcoStates into equal quintiles (at least two of the quintiles would have no critical habitat). We decided not to apply the equal quintile method to features that do have values (excluding the ones that have Null values) because the critical habitat areas themselves are also very odd: some are very large polygon areas, and some are exceedingly small polygon areas (especially around streams). This too would be problematic for the typical equal quintile method; the large polygons representing bat habitats would have a much larger impact compared to stream based critical habitat. We've resolved this issue by treating it as a binary.

1. Presence of Critical Habitat: Attribute Name (Attribute_Name Range: 0-0)
 - a. 0 = No critical habitat within the EcoState
 - b. 5 = Any critical habitat within the EcoState

National Wild Turkey Federation (NWTF) Focal Landscapes

1. Overlap per EcoState: Attribute Name (Attribute_Name Range: 0-0)
 - a. 1 = Low percent
 - b. 5 = High percent

American Forest (AF) Priority Landscapes

1. Overlap per EcoState: Attribute Name (Attribute_Name Range: 0-0)
 - a. 1 = Low percent
 - b. 5 = High percent

The Nature Conservancy (TNC) Lands

1. Overlap per EcoState: Attribute Name (Attribute_Name Range: 0-0)
 - a. 1 = Low percent
 - b. 5 = High percent

Weighting Methods

This section discusses weighting the scores from all data layers and combining the outcome into a final overall score. Weights are applied at three levels in the entire analysis; the first level of weighting occurs within a data layer if there are multiple attributes used to derive a data layer's score. For example, the BLS NAICS jobs data layer has NAICS jobs numbers summed into 4 groups, scored 1-5, and then weights are applied to the 4 groups before creating the final BLS NAICS jobs data layer score. This section does not detail that first level of weighting; for those "internal" data layer score weights, consult the Scoring Methods section. Instead, this section details the weighting that happens at two other levels:

1. Weighting within a Data Theme Score
2. Weighting across all Data Themes, to create the final overall score

Calculating a Data Theme Score

There are 6 data themes in this analysis:

1. Probability of regeneration success
2. Landowner efficacy
3. Barriers to success
4. Forest product demand
5. Enabling conditions management
6. Conservation impact

Each data theme is calculated as such:

- Each data layer that contributes to a theme has a 1-5 score. Those scores are multiplied by the weight (a percent) and summed to give an overall score of no greater than 5.

Some data themes have only one constituent data layer. These layers will comprise 100% of their data theme's score, and there's essentially no weighting to apply there within the data theme. For data themes with more than one layer, we apply weights to those layers to derive an overall data theme score. For example, Enabling Conditions Management has 3 data layers, and weights are applied such that one layer contributes less to the overall Enabling Conditions Management score than the other two layers. For example, layer one contributes 35%, layer two contributes 35%, and layer three contributes 30%. In this case, we'd multiply score 1 by .35, multiply score 2 by .35, and multiply score 3 by .3. Then add those up, arriving at an Enabling Conditions Management data theme score.

Calculating the Overall Final Score

Additionally, each data theme has a weight. The Data Theme Weights allow the amount each theme contributes to the final overall score to be adjusted. The Probability of Success accounts for 60% of the overall final score.

Additionally, each data theme has a weight. The Probability of Success accounts for 60% of the overall final score.

The maximum final score will be 50.

Probability of Success has a maximum value of 5. The value will be multiplied by 6, for a maximum possible score of 30.

All the other data theme scores are a maximum unweighted value of 5. The maximum value of Landowner Efficacy + Barriers to Success + Forest Product Demand + Enabling Conditions Management + Conservation Impact = 20. The Data Theme Weights allow the amount that any data theme contributes to that total 20 points to be adjusted.

Weights across Data Themes

Across all data themes, the sum of the weights equals 100.

Data Theme	Data Theme Weight
Probability of Regeneration Success	60
Landowner Efficacy	6
Barriers to Success	6
Forest Product Demand	8
Enabling Conditions of Management	12
Conservation Impact	8

Weights within Data Themes

Within each data theme, the sum of the weights equals 100.

Probability of Regeneration Success

Layer Name	Weight
Site Productivity: MEAN_SITECLCD	40
<i>Upland Oak (5 attributes)</i>	
Upland oak: % of total UOK lands that is regeneration eligible.	4
Amount of Upland Oak regeneration eligible lands	4
Upland oak: % of regeneration eligible area that does not have seedlings.	6
Percentage of total regeneration eligible upland oak forestland acres with upland oak trees present but upland oak saplings absent for an ecological section.	10
Trees per acre (diameter >=1 inch) of upland oak species (white, black, northern red, southern red, scarlet, chestnut, chinkapin, post) by ecological section on regeneration eligible upland oak forestland.	6
<i>White Oak (5 attributes)</i>	

Layer Name	Weight
White oak: % of total WOK lands that is regeneration eligible.	3
Amount of White Oak regeneration eligible lands.	3
White oak: % of regeneration eligible area that does not have seedlings.	8
White oak: % of regeneration eligible area that does not have saplings.	11
Trees per acre (diameter ≥ 1 inch) of white oak alone by ecological section on regeneration eligible upland oak forestland.	5

Landowner Efficacy

Layer Name	Weight
White Oak Initiative Landowner Survey	100

Barriers to Success

Layer Name	Weight
National Insect & Disease Risk and Hazard Mapping	60
Deer Browse	40

Forest Product Demand

Layer Name	Weight
Timber Products Output	100

Enabling Conditions Management

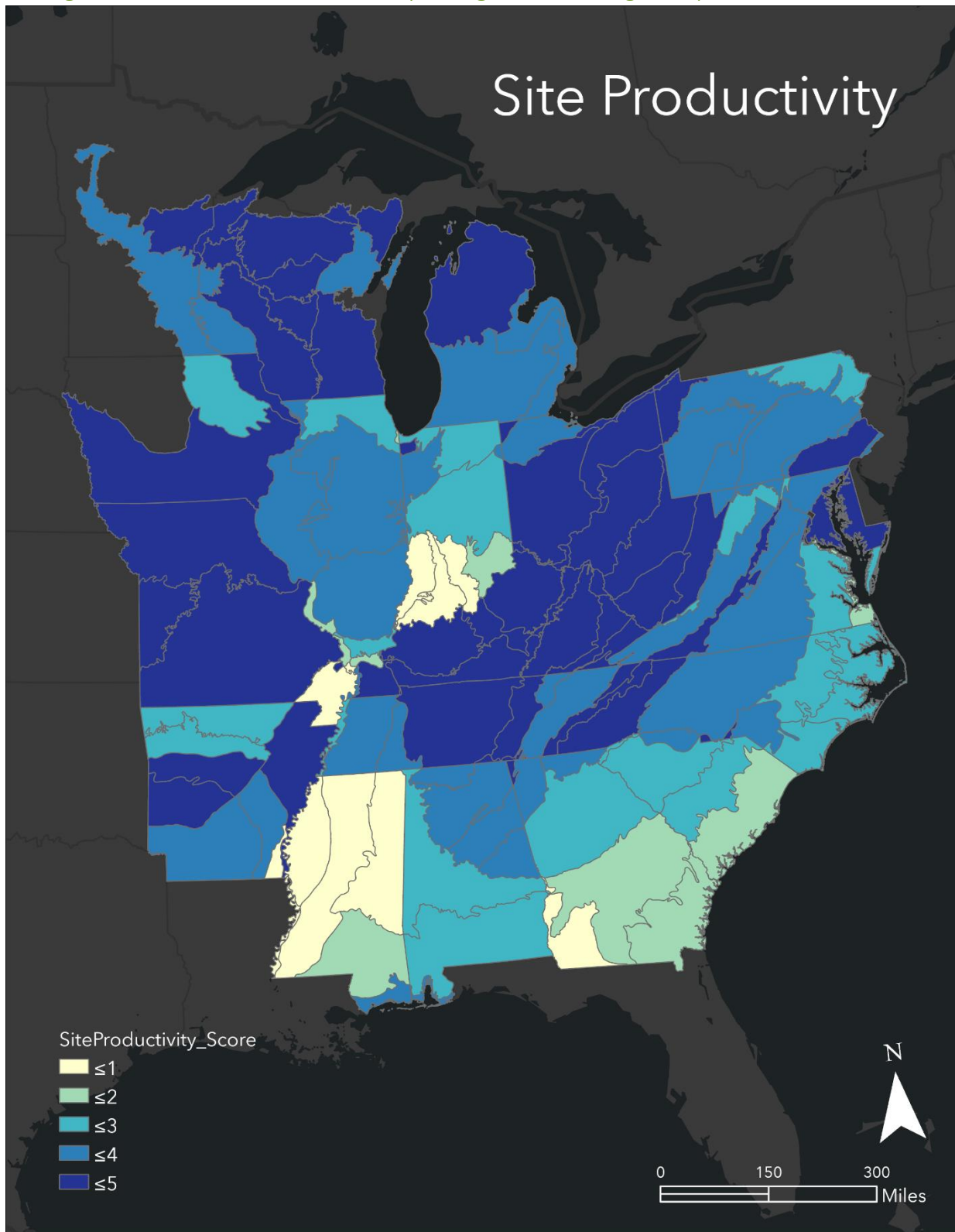
Layer Name	Weight
Timber Products Output (Mills)	35
Quarterly Census of Employment and Wages - NAICS (BLS)	35
Number of Foresters per State (Forest and Manager Capacity)	30

Conservation Impact

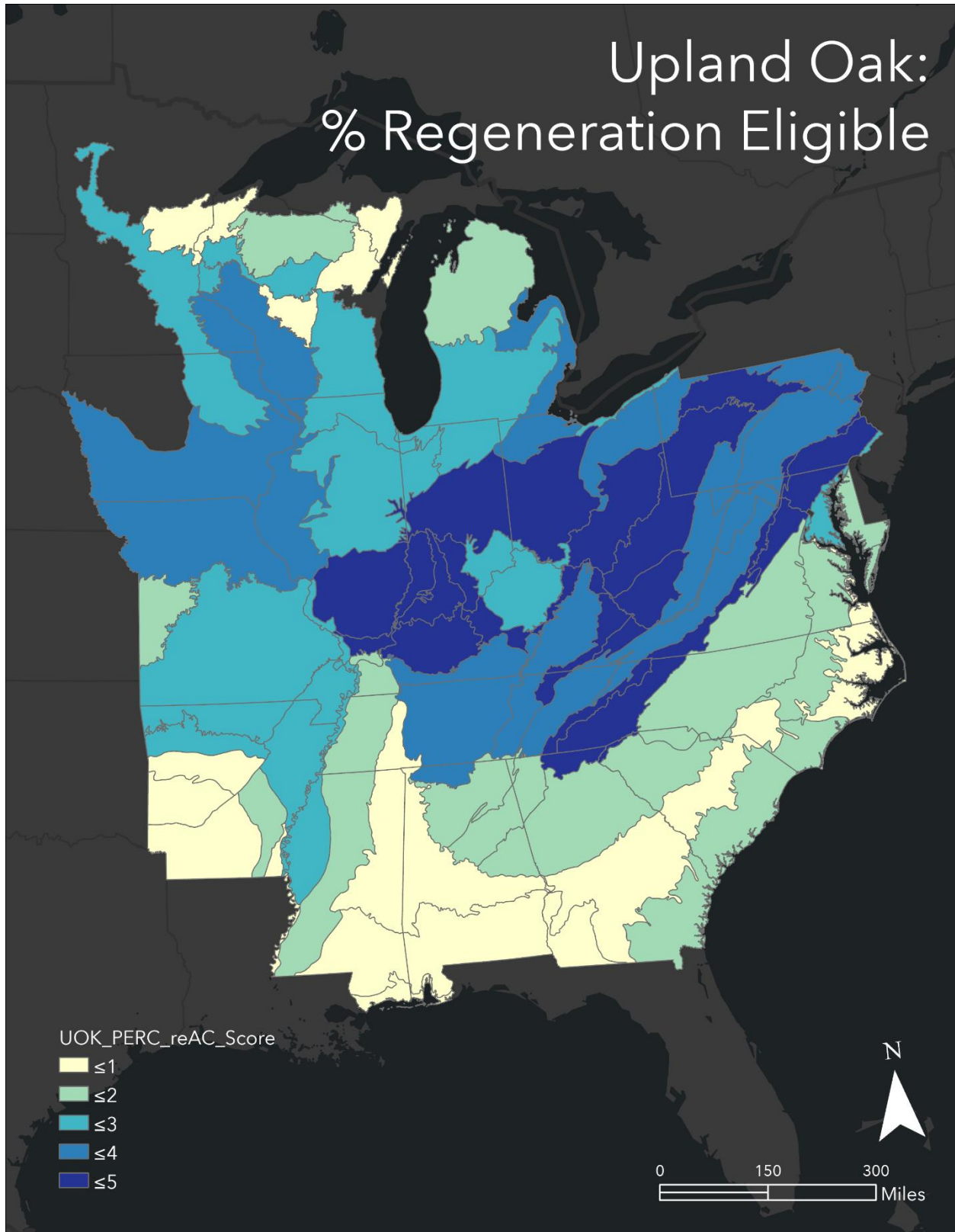
Layer Name	Weight
<i>(This is a binary score of either 0 or 5 denoting absence or presence of any crit hab area within an EcoState)</i> Critical Habitat T&E Species	50
<i>(This is a single 1-5 combined score)</i> NWTF_Focal_Landscapes AFPriorityLandscapes TNC_Lands	50

Results

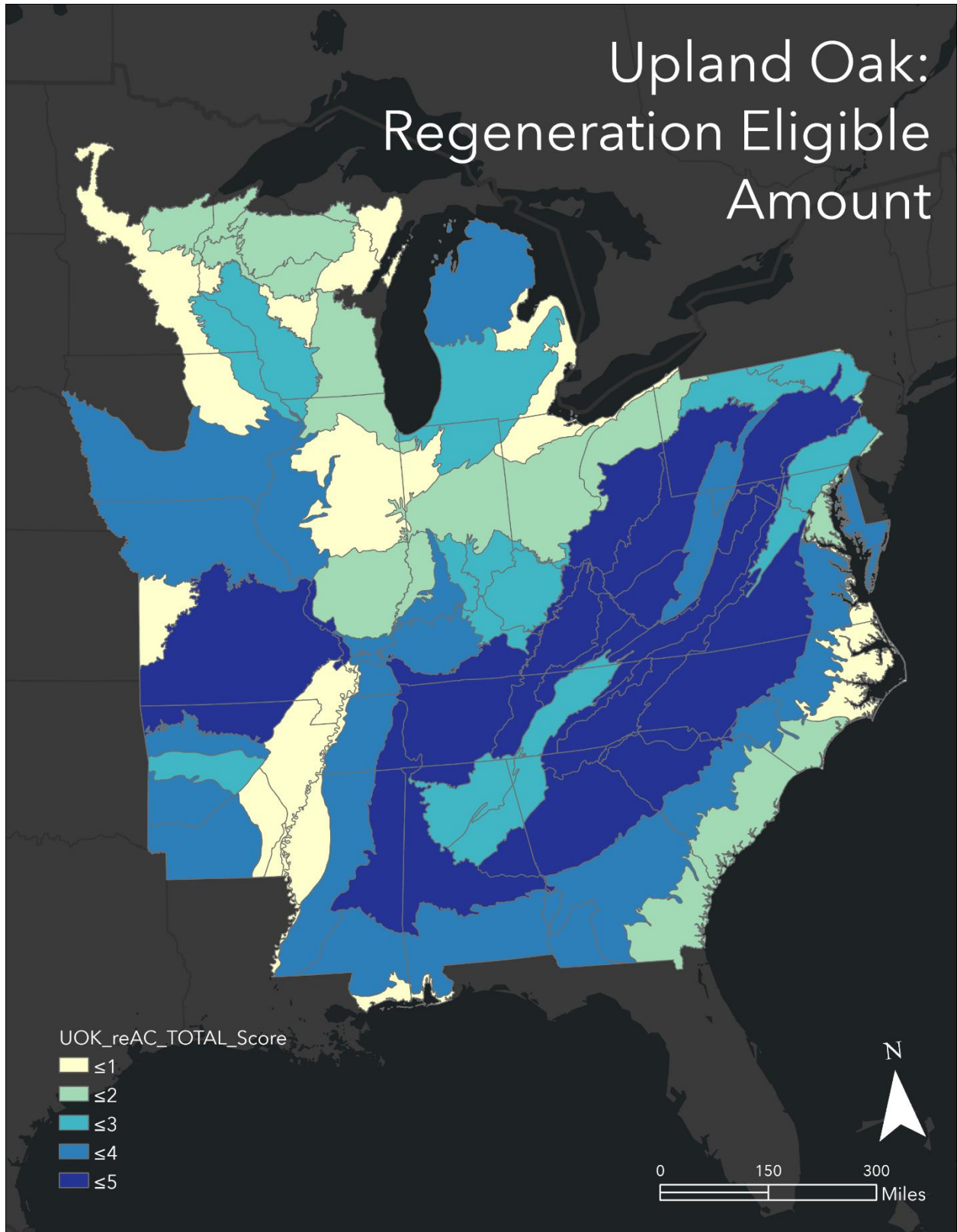
Ecological conditions: Site Productivity of regeneration eligible upland oak forestland



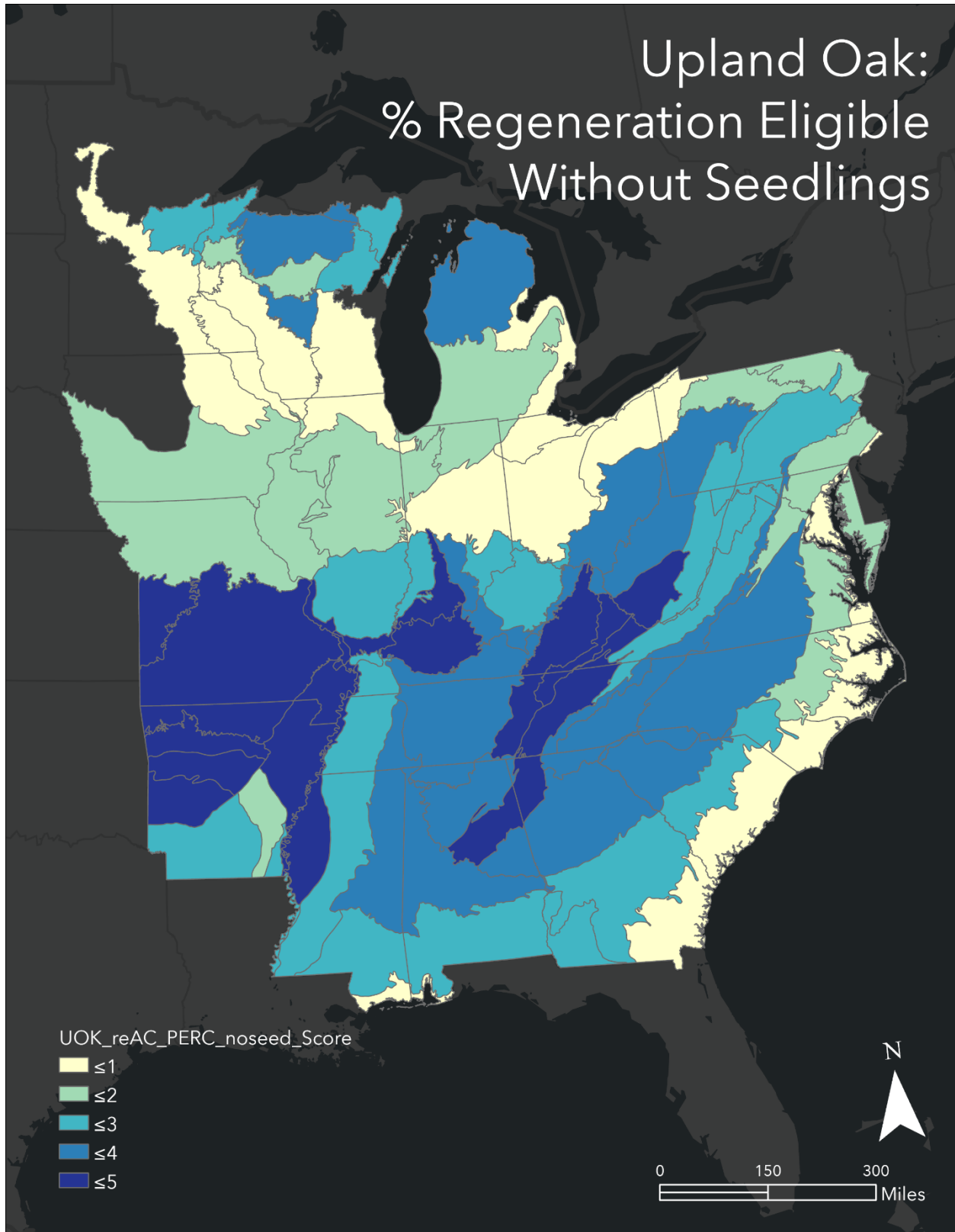
Upland oak: % of total UOK lands that is regeneration eligible



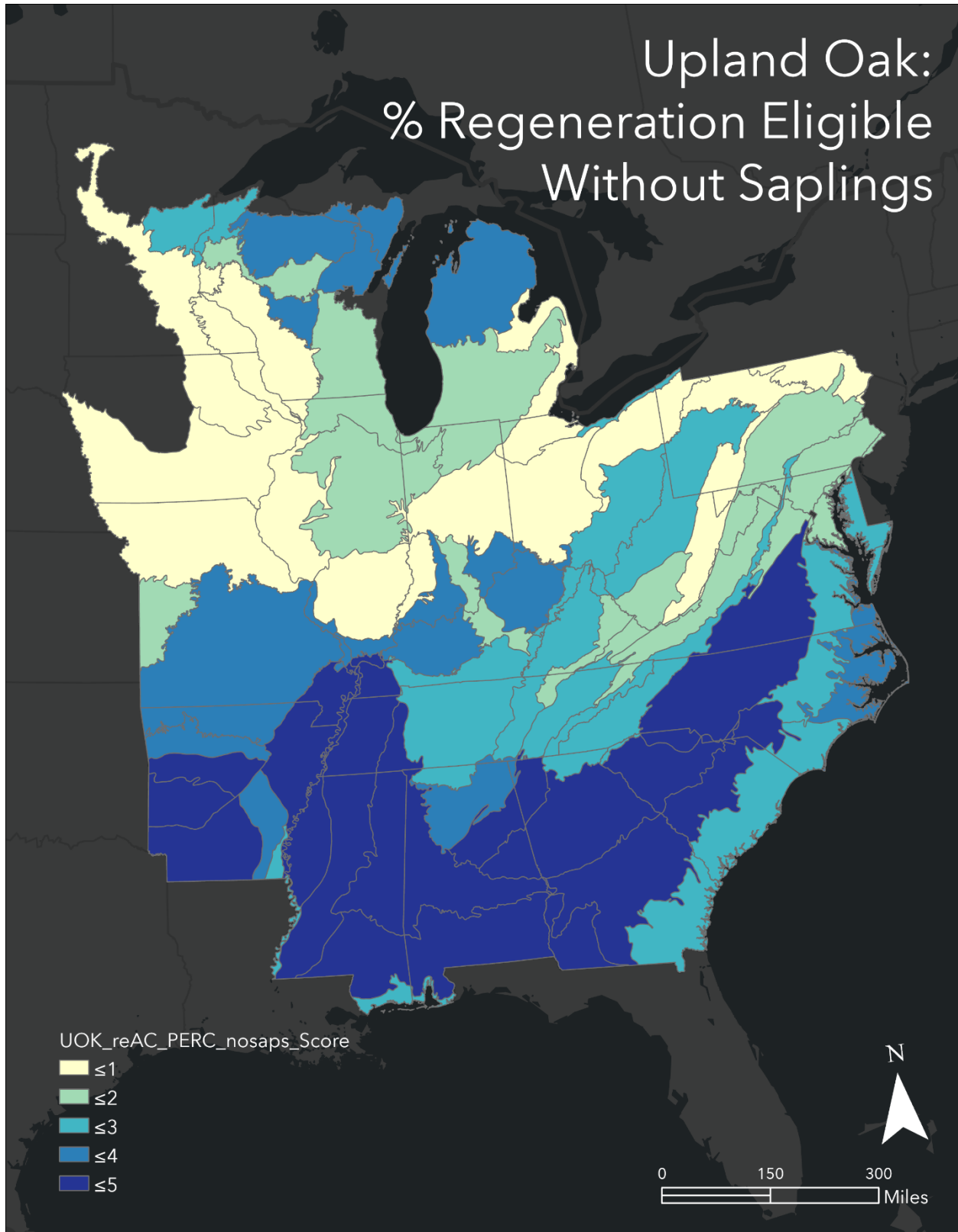
Amount of Upland Oak regeneration eligible lands



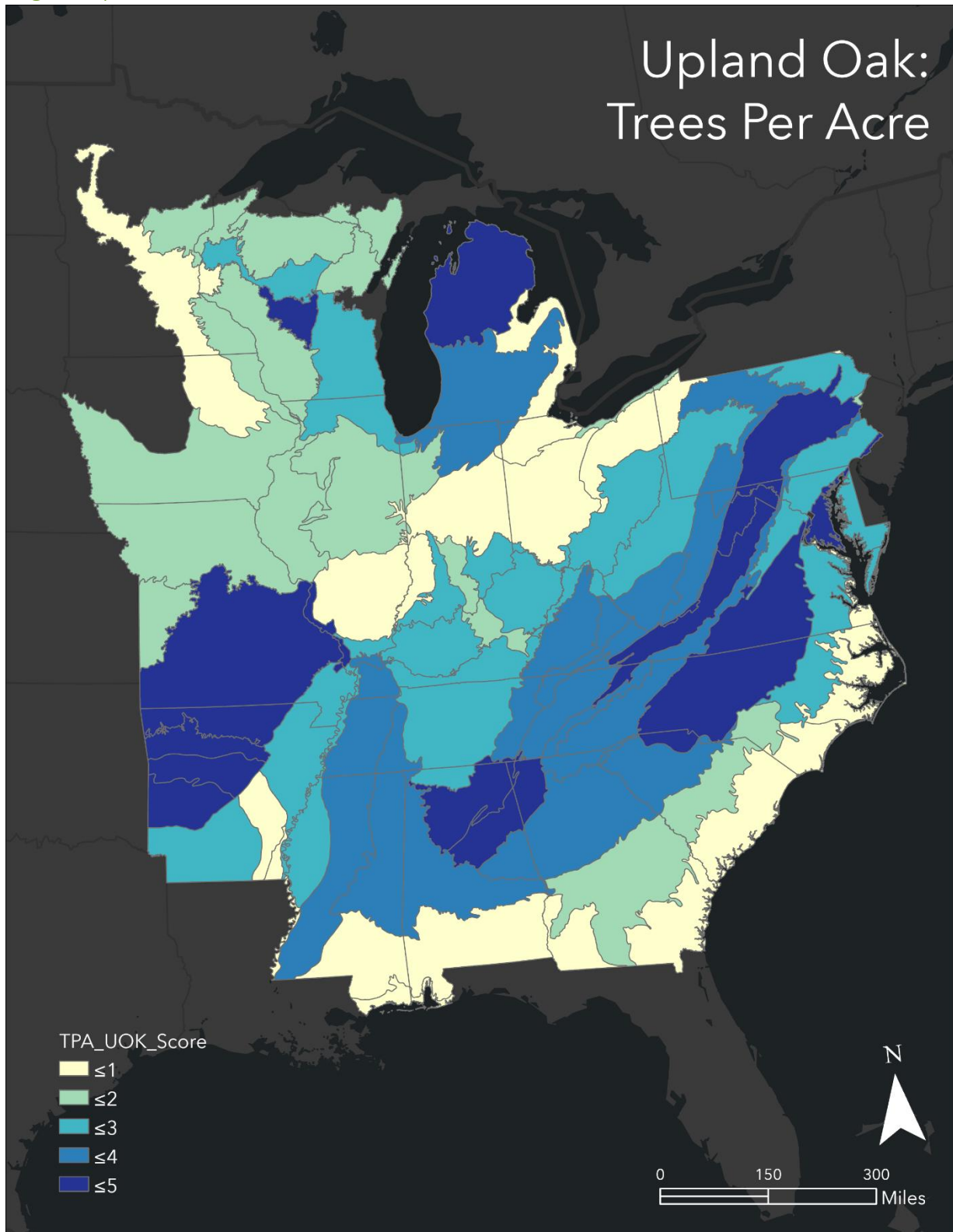
Upland oak: % of regeneration eligible area that does not have seedlings



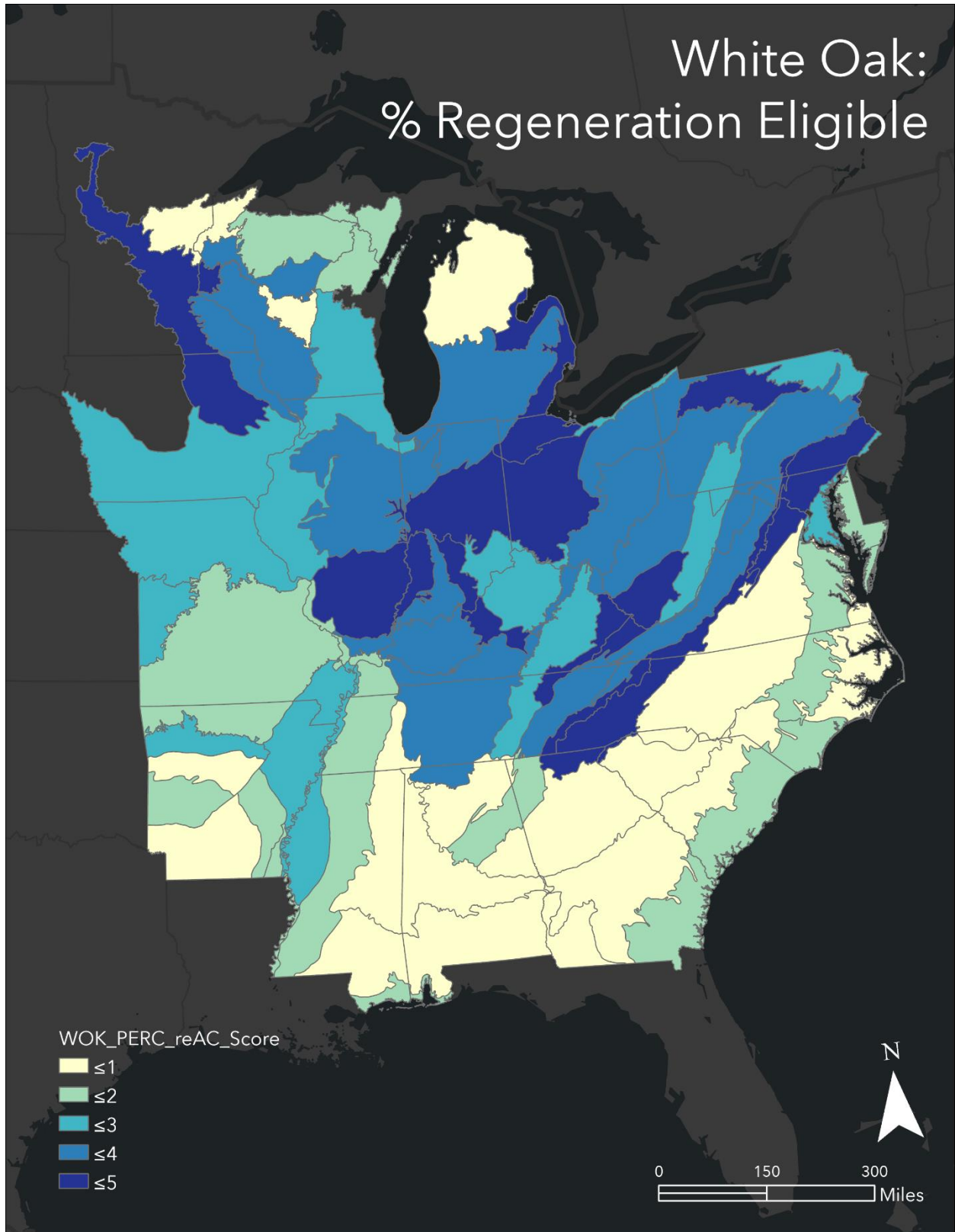
Percentage of total regeneration eligible upland oak forestland acres with upland oak trees present but upland oak saplings absent for an ecological section



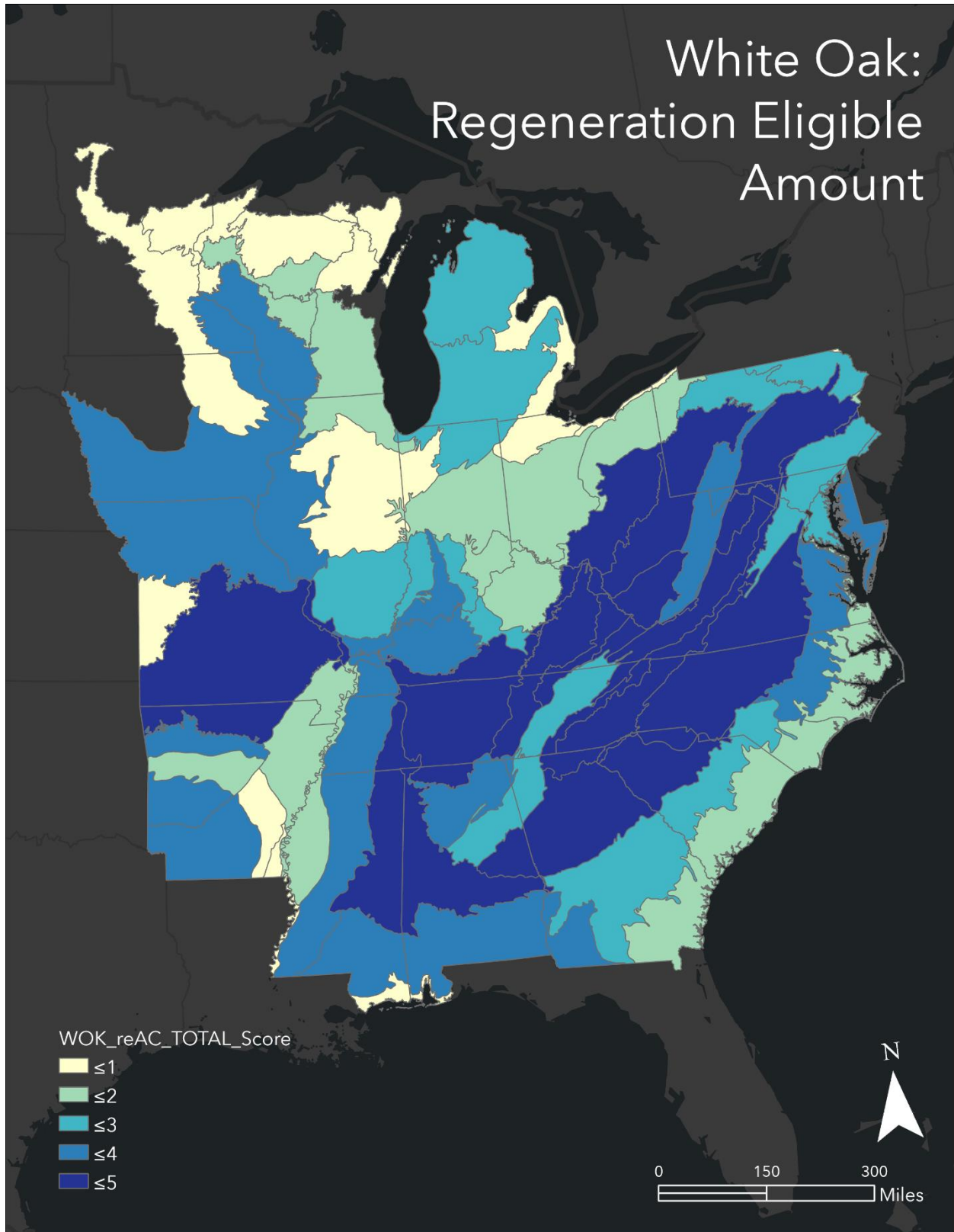
Trees per acre (diameter ≥ 1 inch) of upland oak species (white, black, northern red, southern red, scarlet, chestnut, chinkapin, post) by ecological section on regeneration eligible upland oak forestland



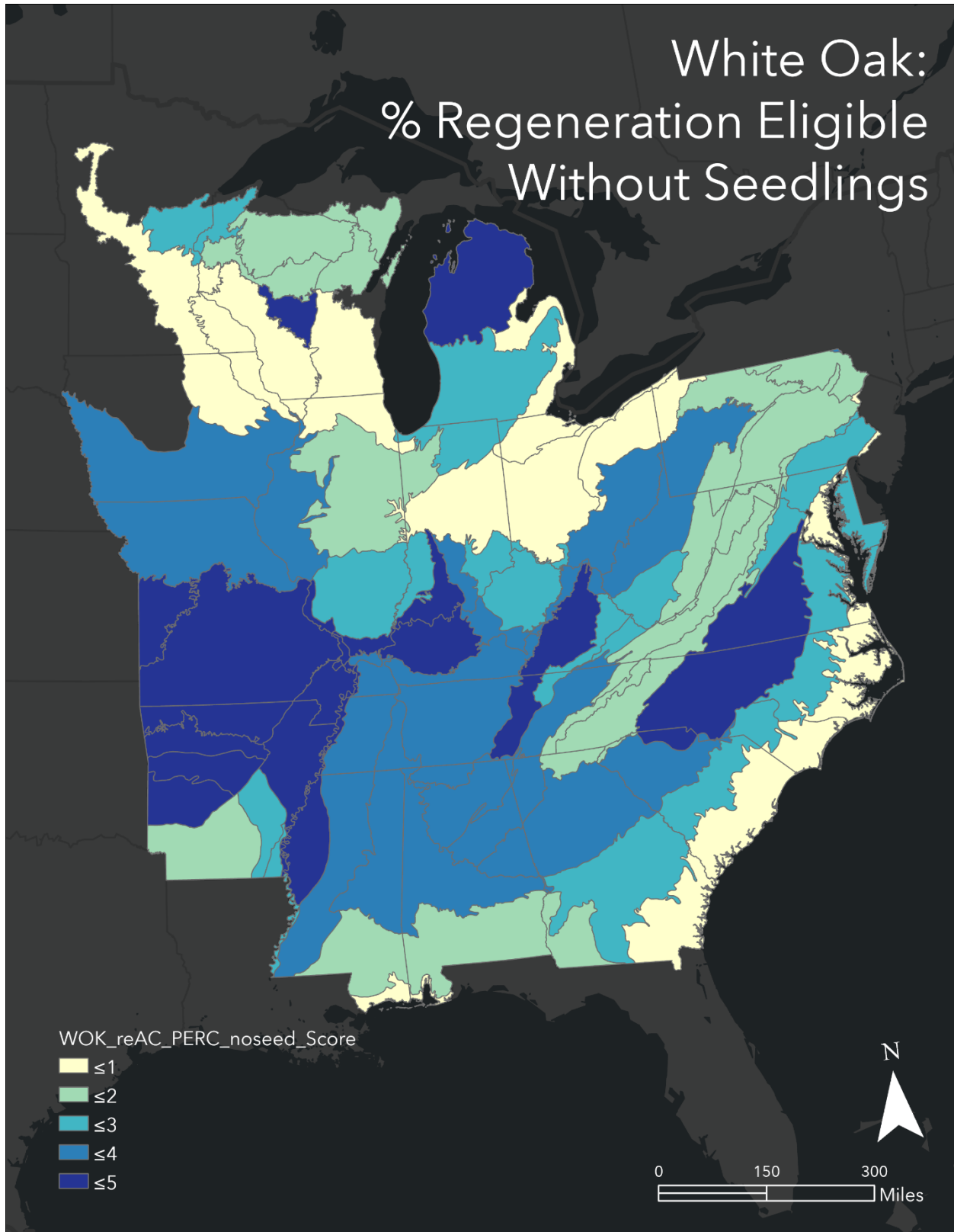
White oak: % of total WOK lands that is regeneration eligible



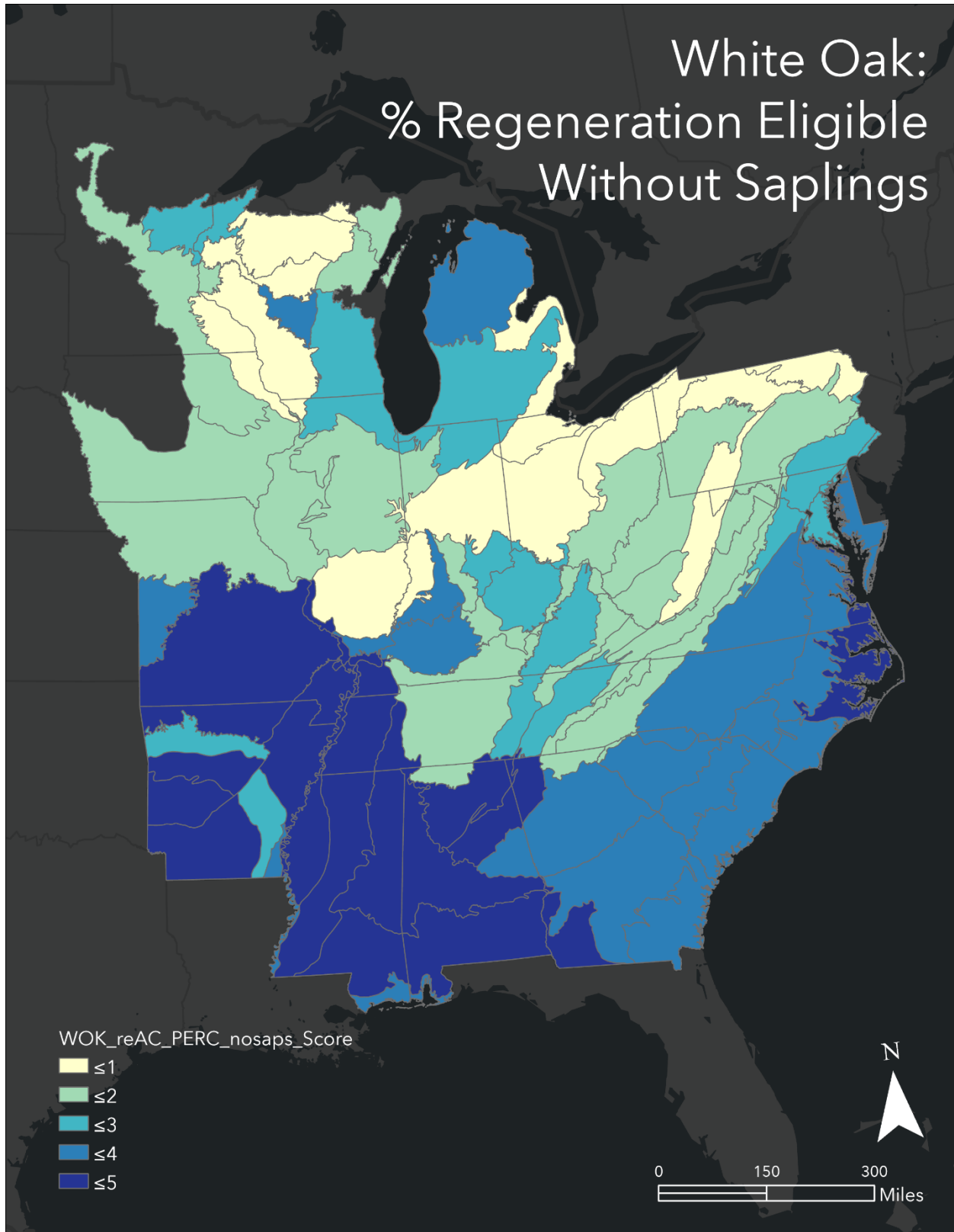
Amount of White Oak regeneration eligible lands



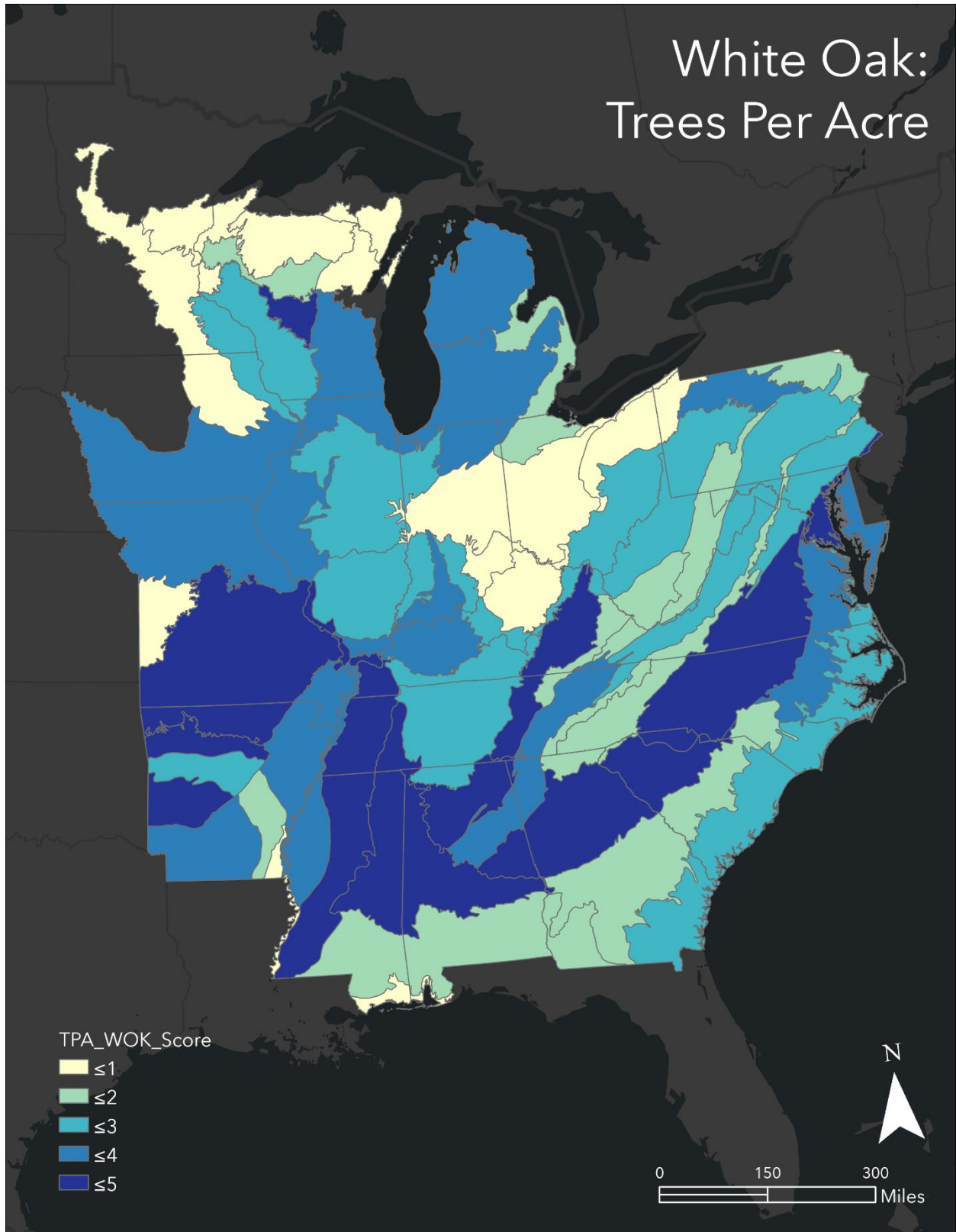
White oak: % of regeneration eligible area that does not have seedlings



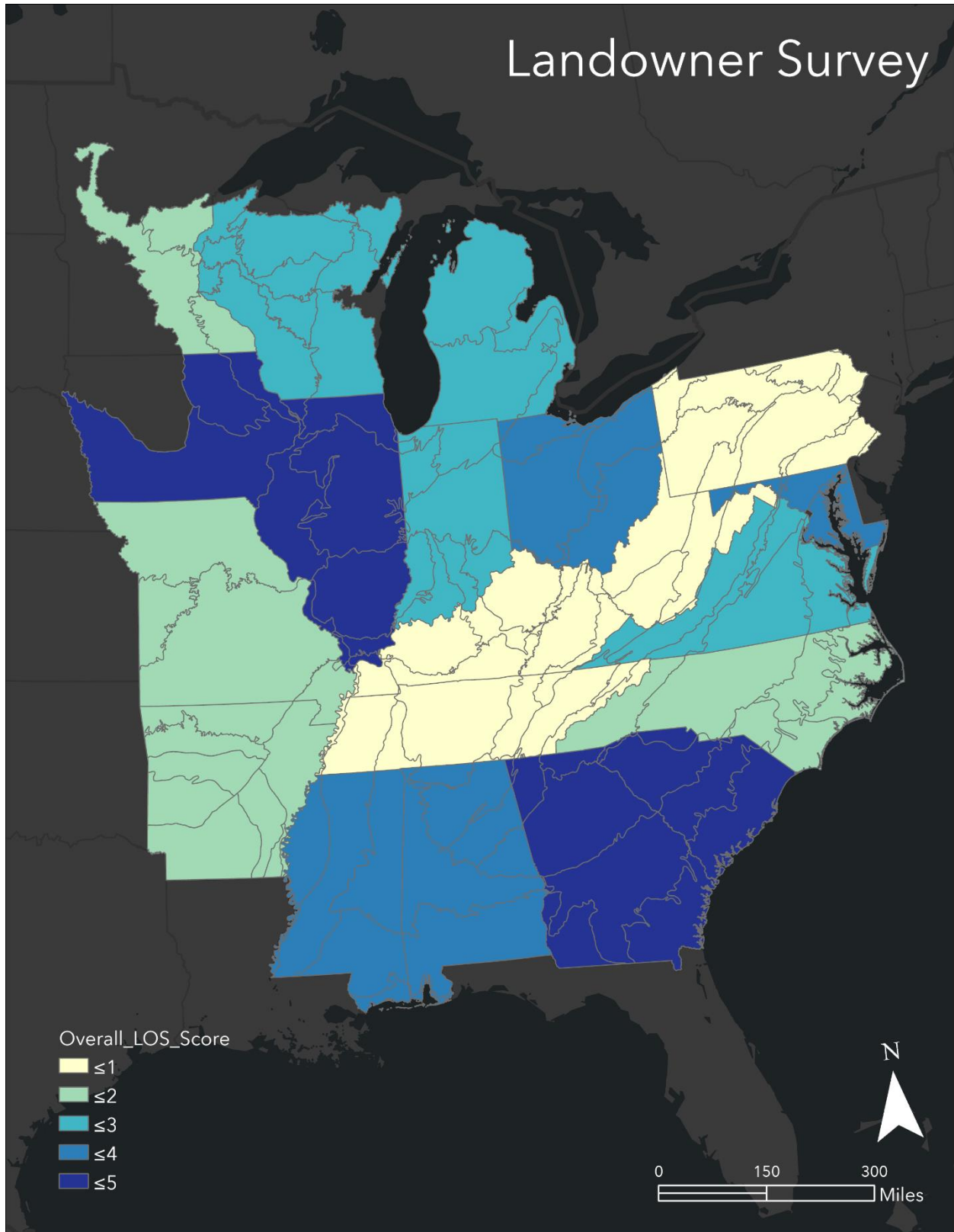
White oak: % of regeneration eligible area that does not have saplings



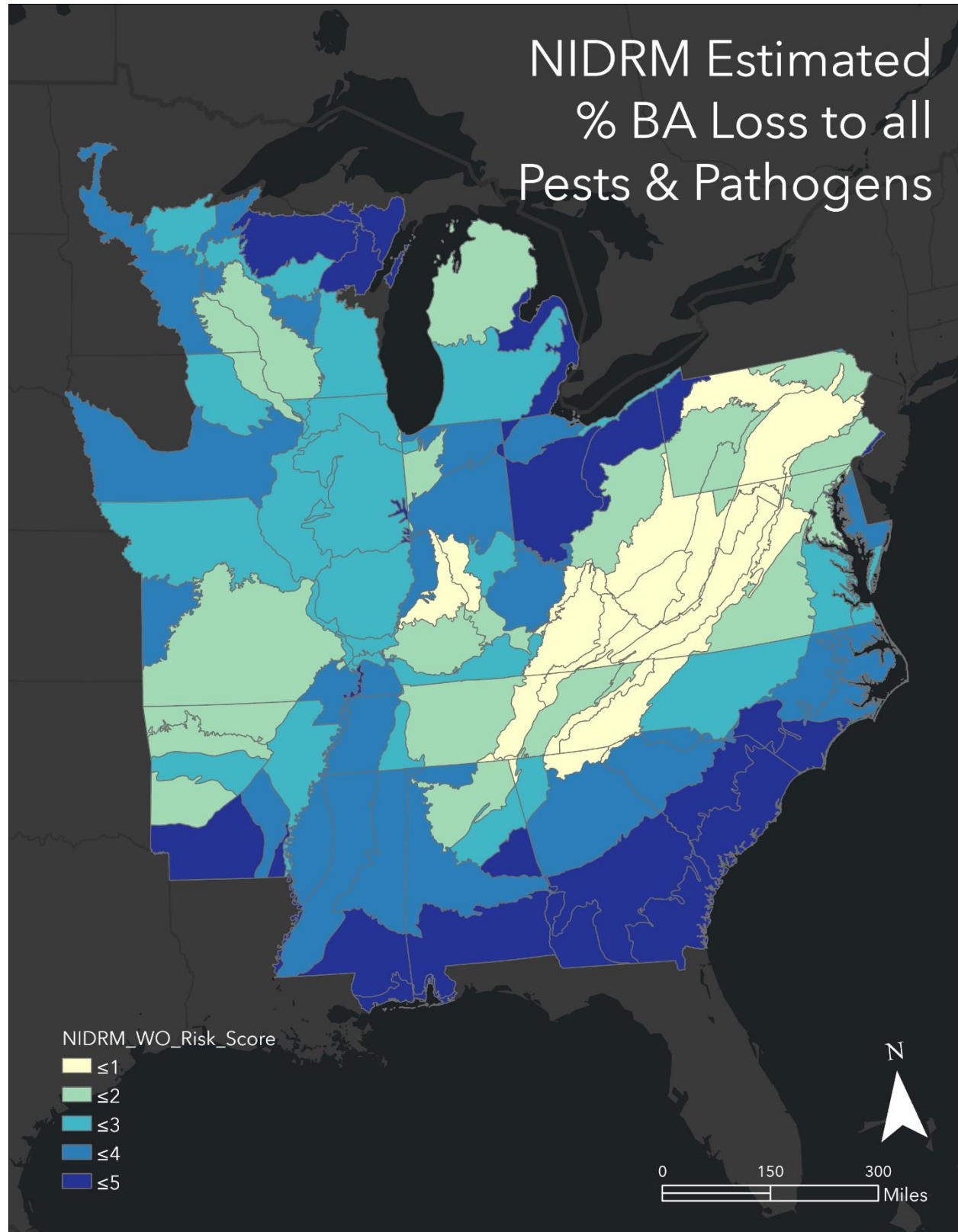
Trees per acre (diameter ≥ 1 inch) of white oak alone by ecological section on regeneration eligible upland oak forestland



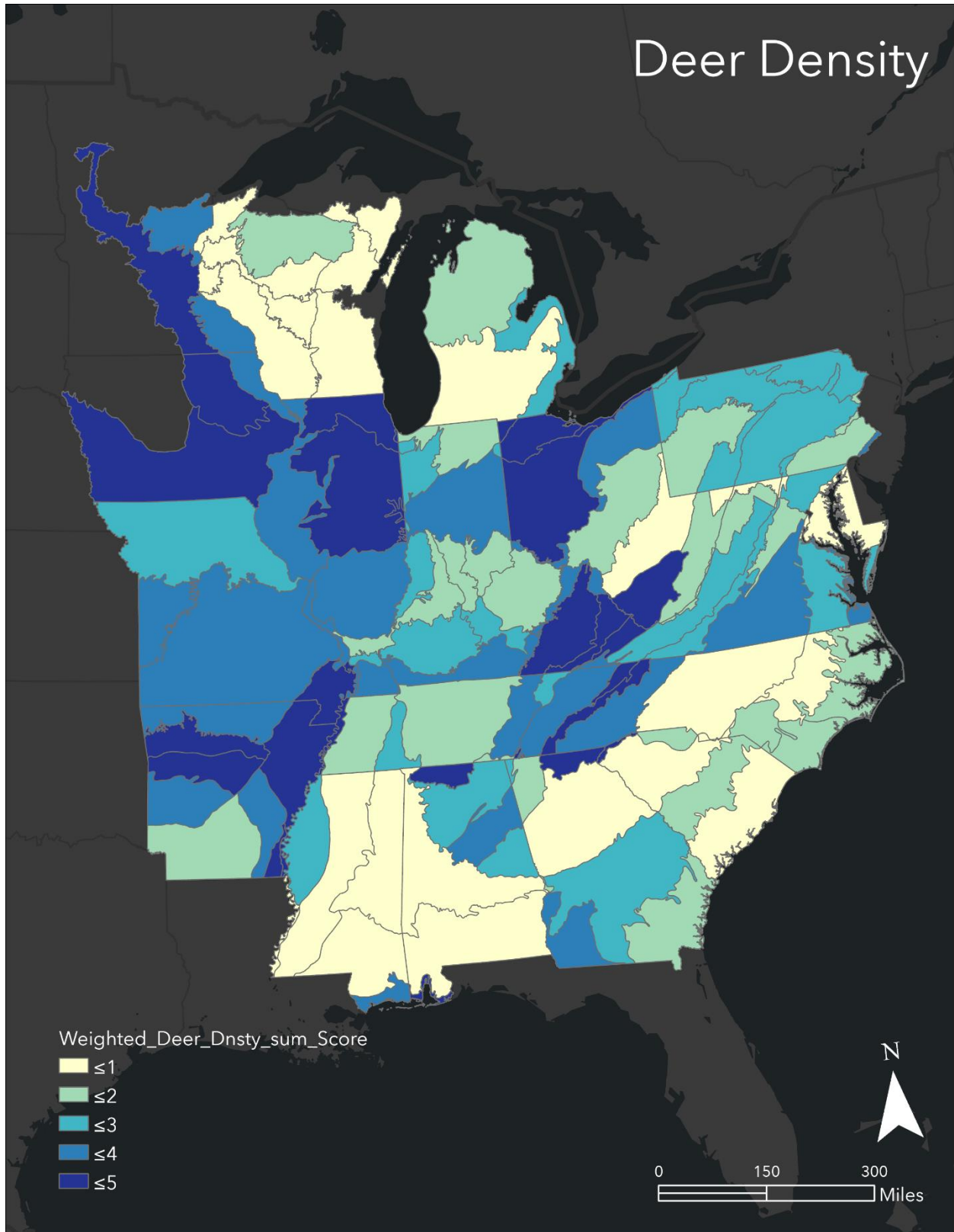
Landowner Survey



NIDRM Estimated % BA Loss to all Pests & Pathogens

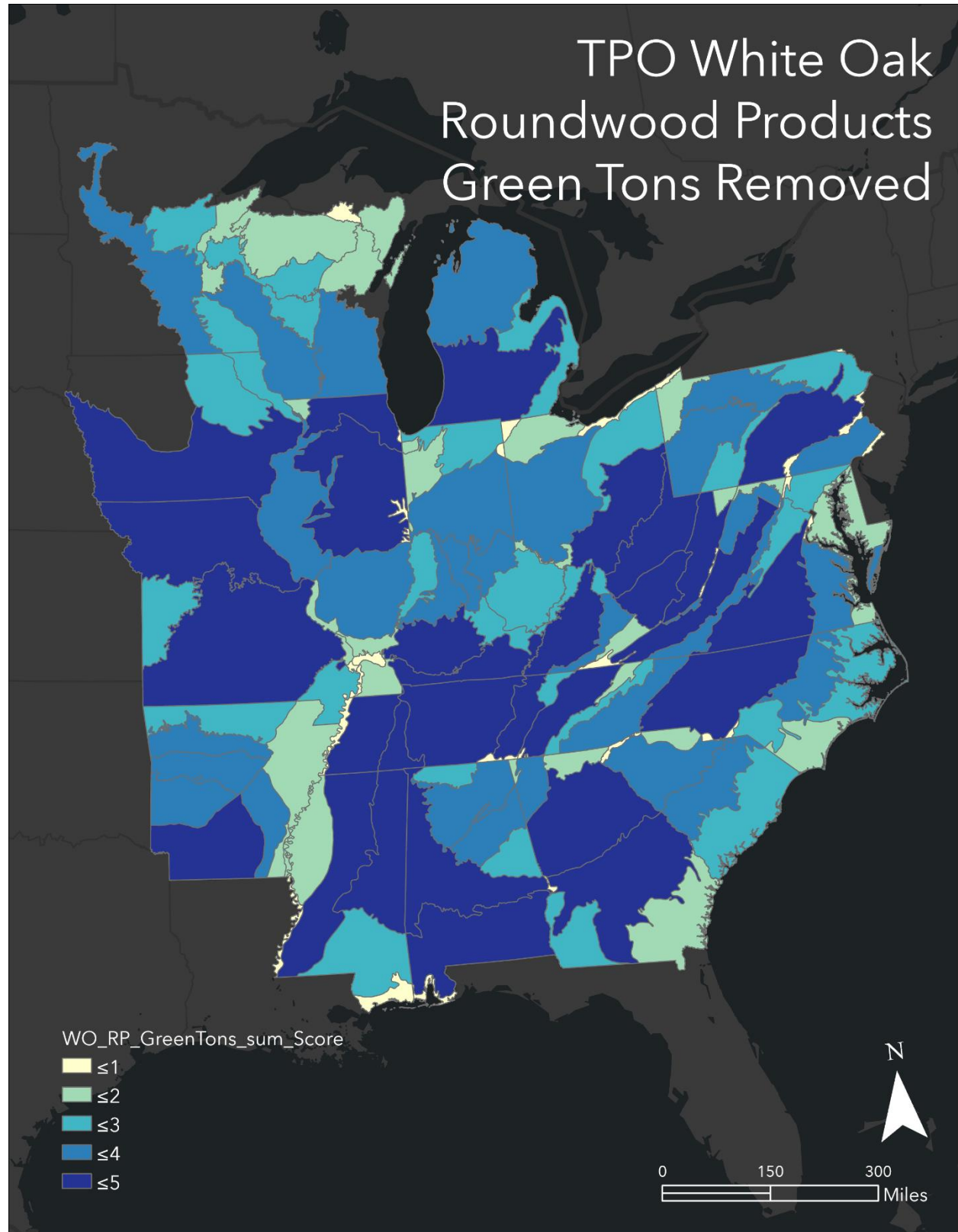


Deer Density

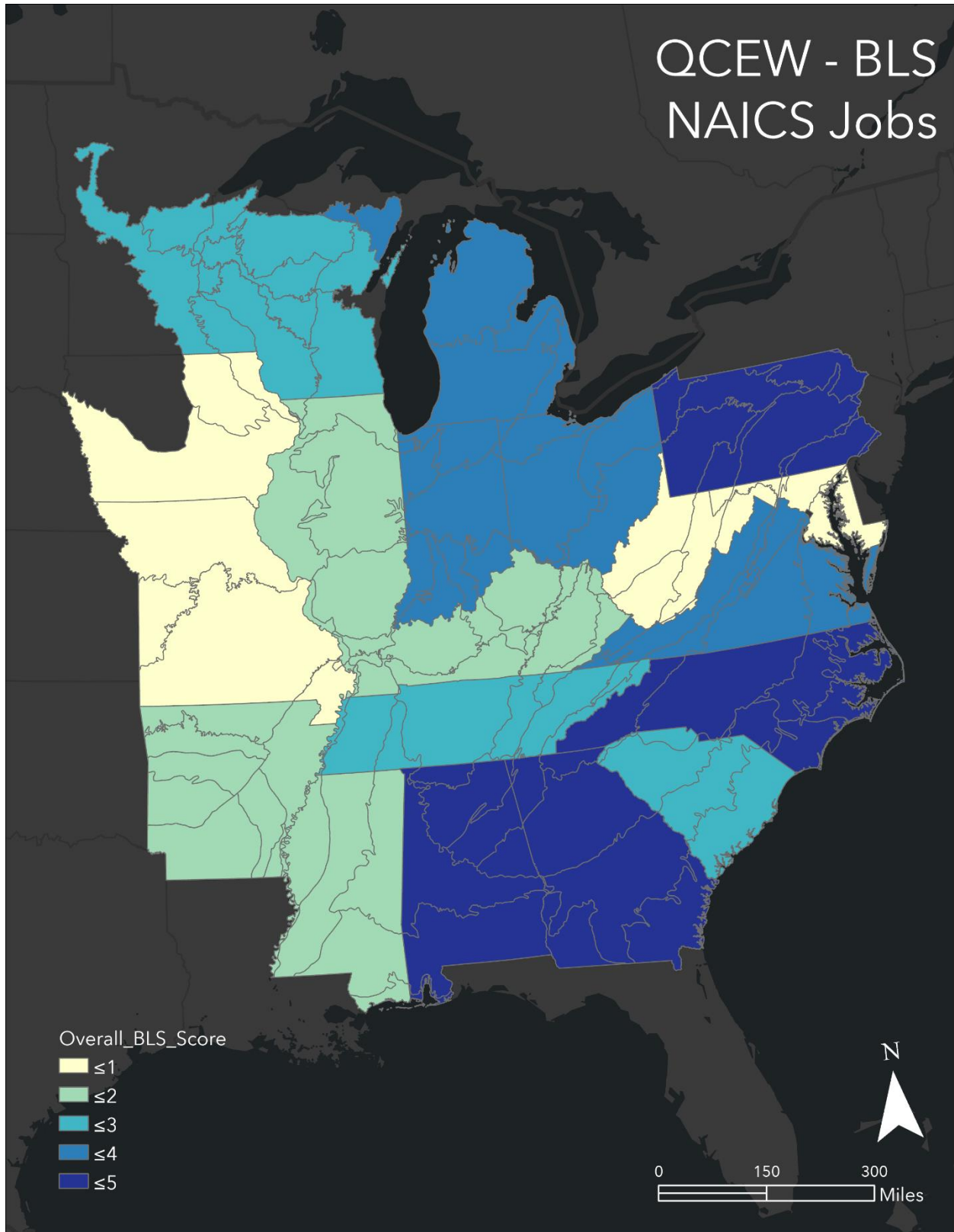


Forest Product Output (Timber Product Output)

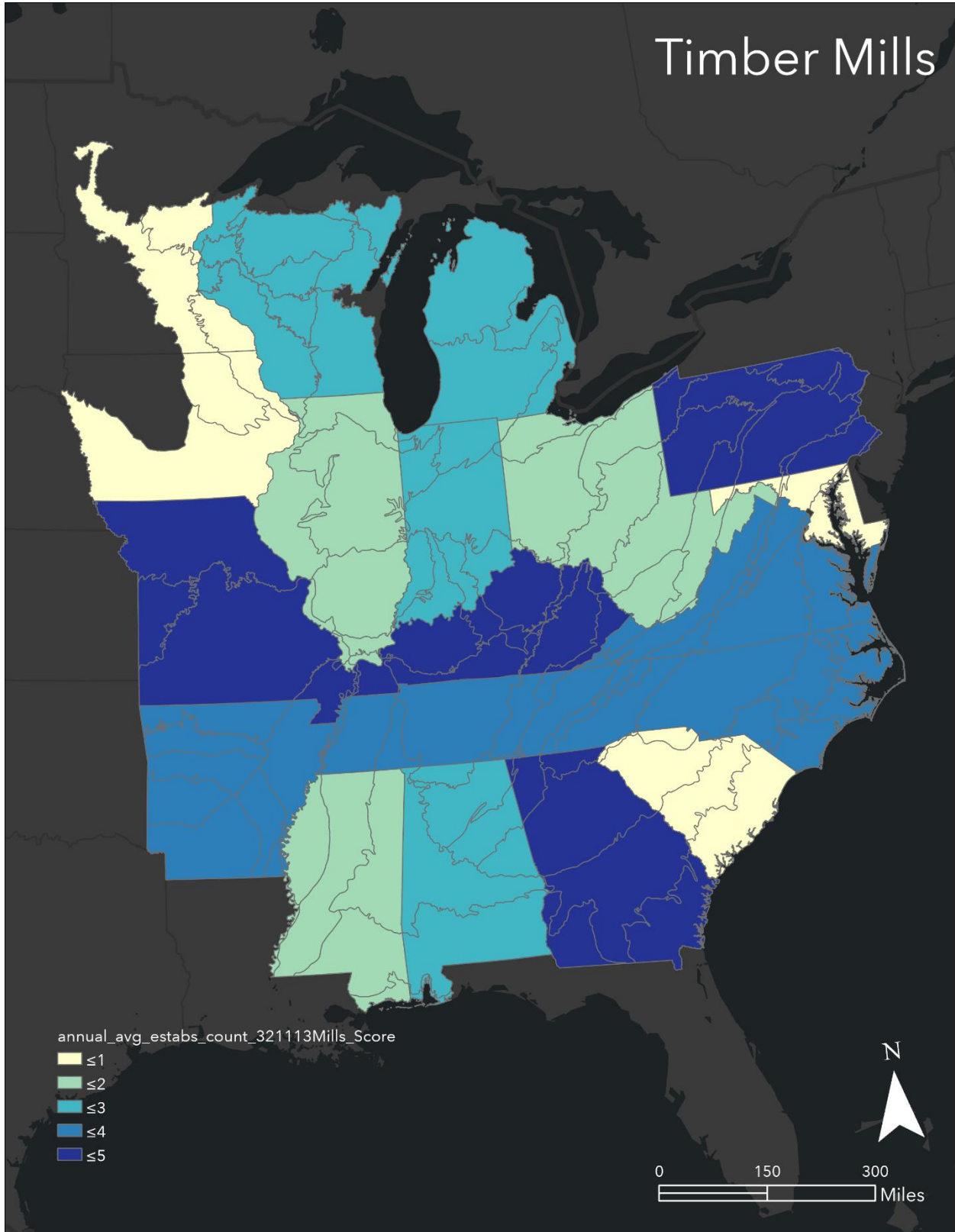
TPO White Oak Roundwood Products Green Tons Removed



BLS – Jobs per NAICS industry

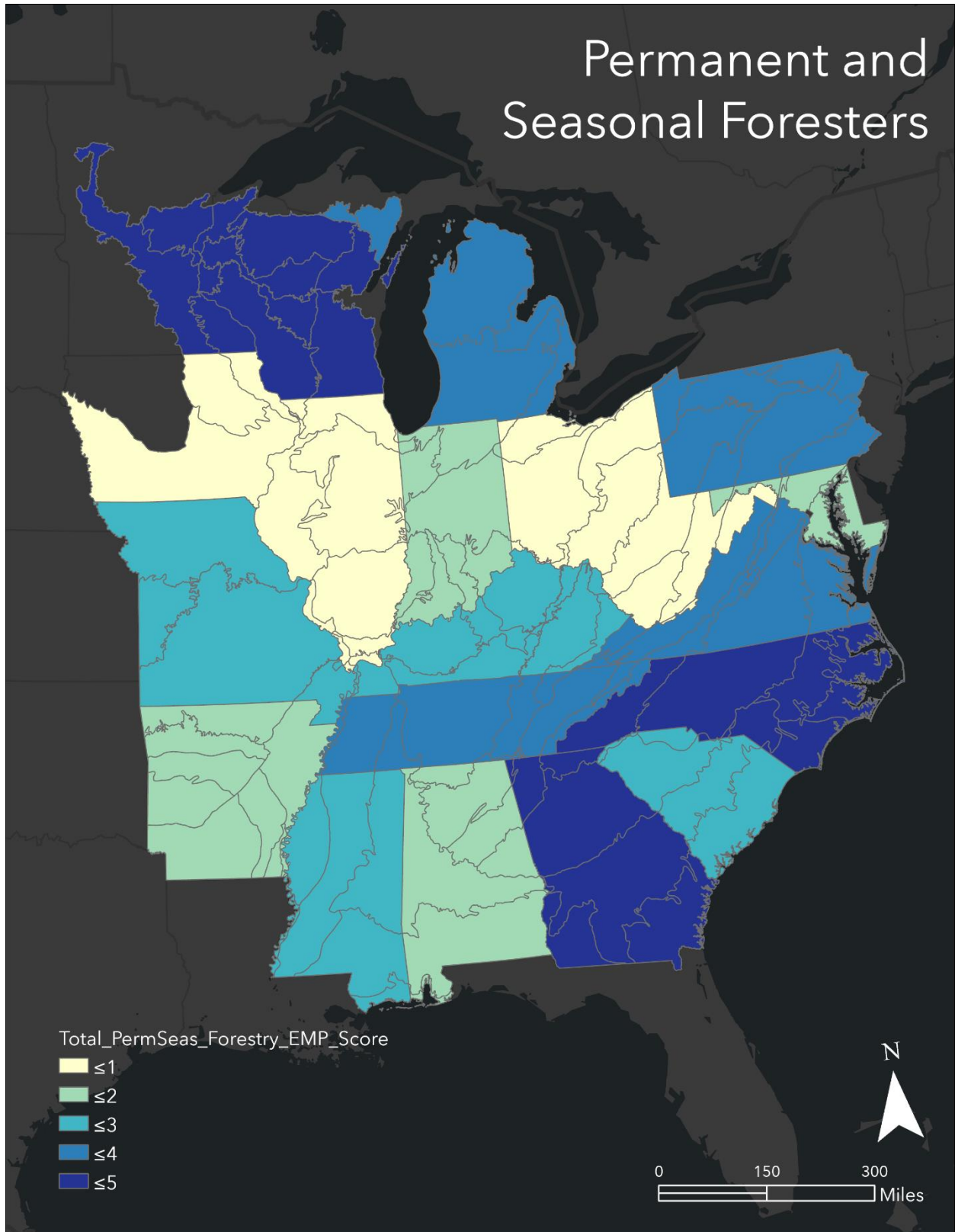


Timber Mills

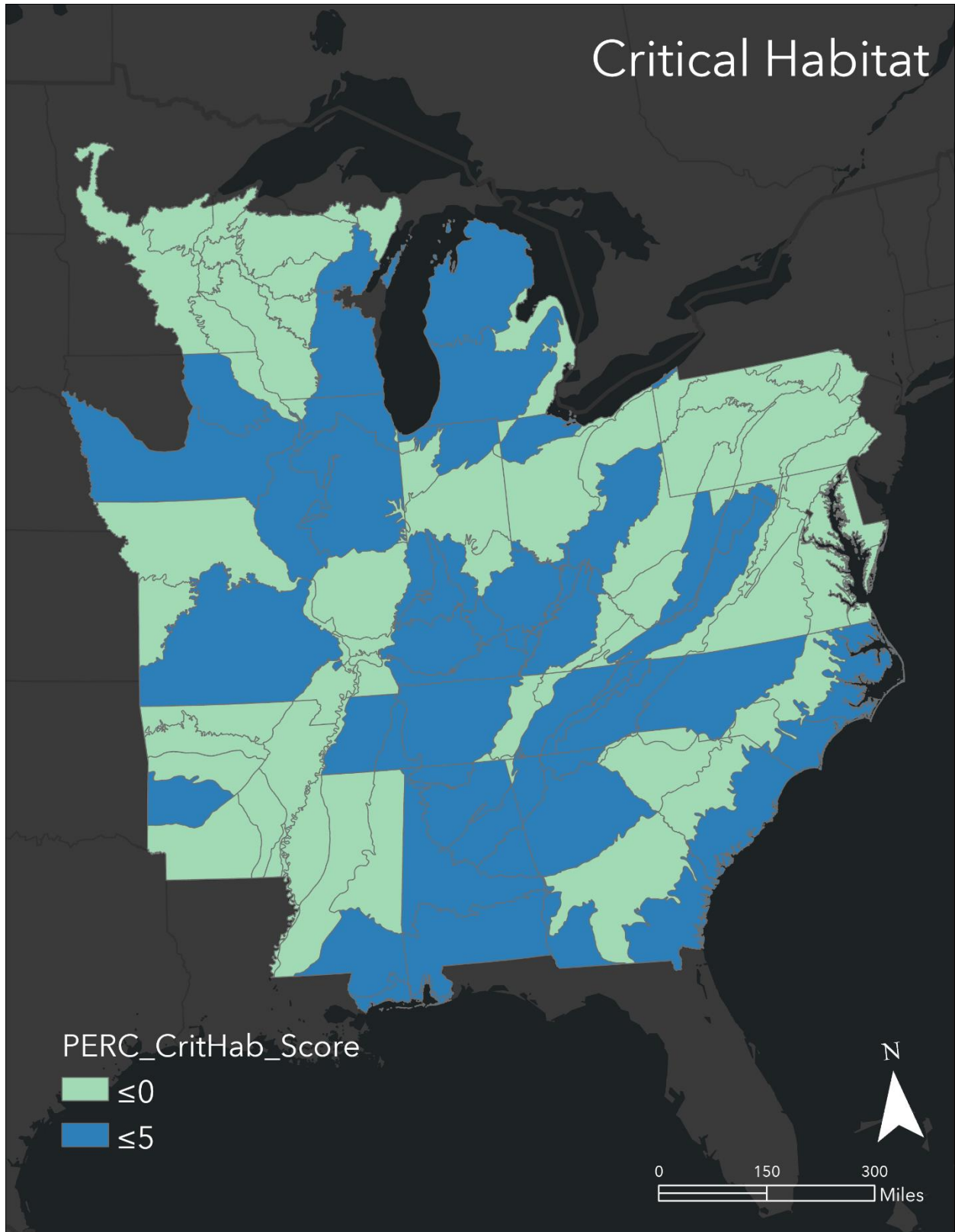


Foresters per state

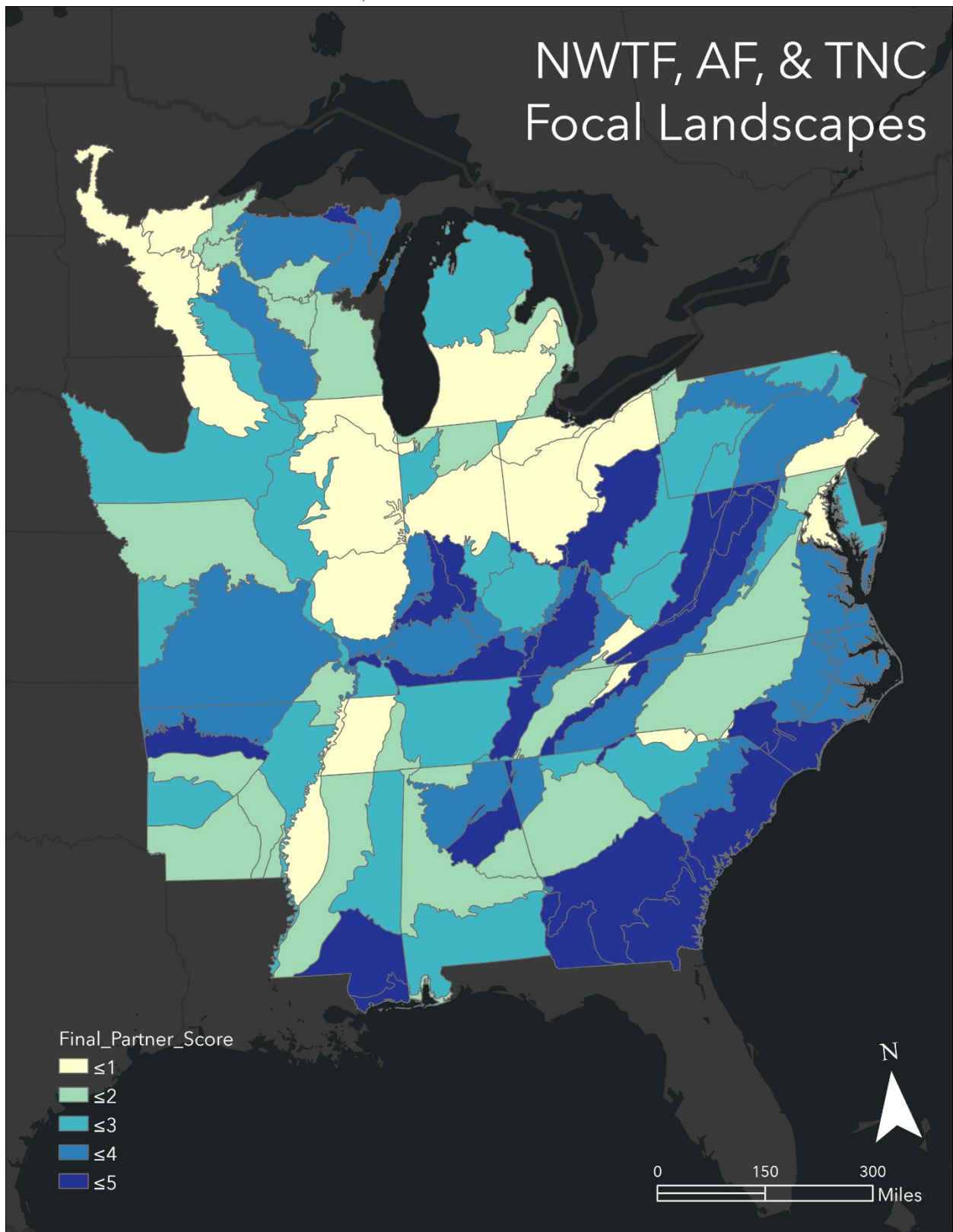
Permanent and Seasonal Foresters



Critical Habitat T&E Species

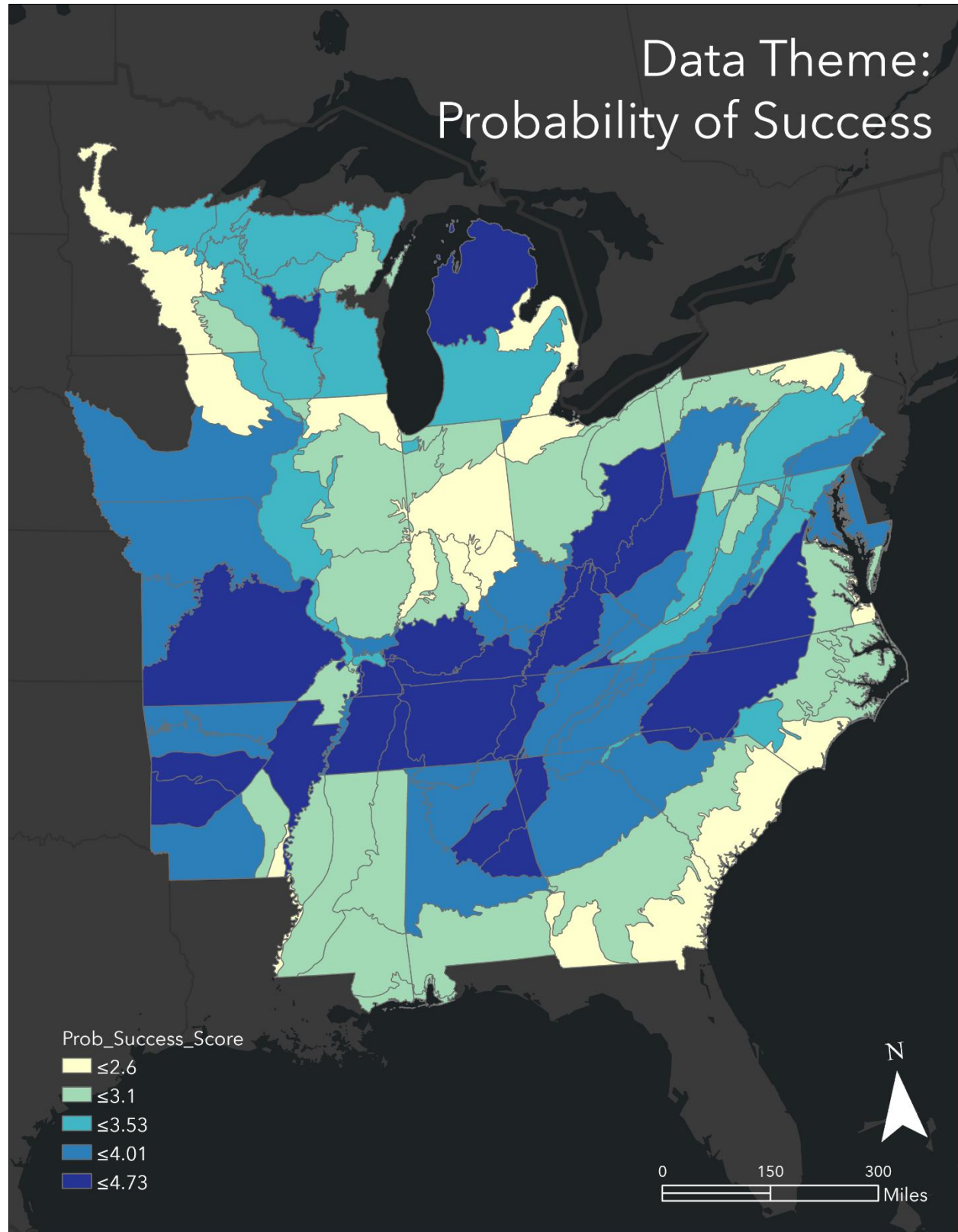


Partner Priorities & Focal Landscapes



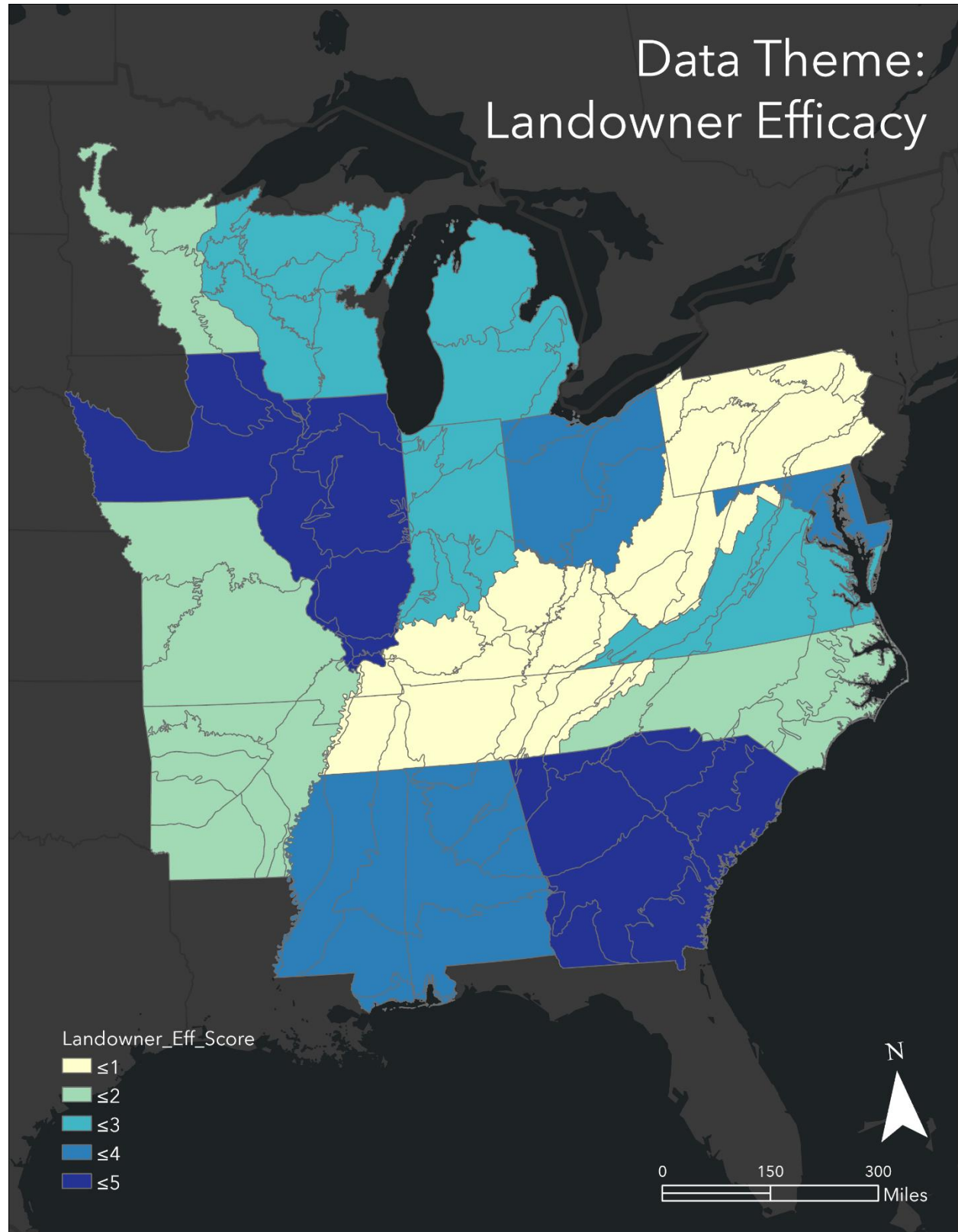
Data Theme: Probability of Regeneration Success

Data Theme: Probability of Success



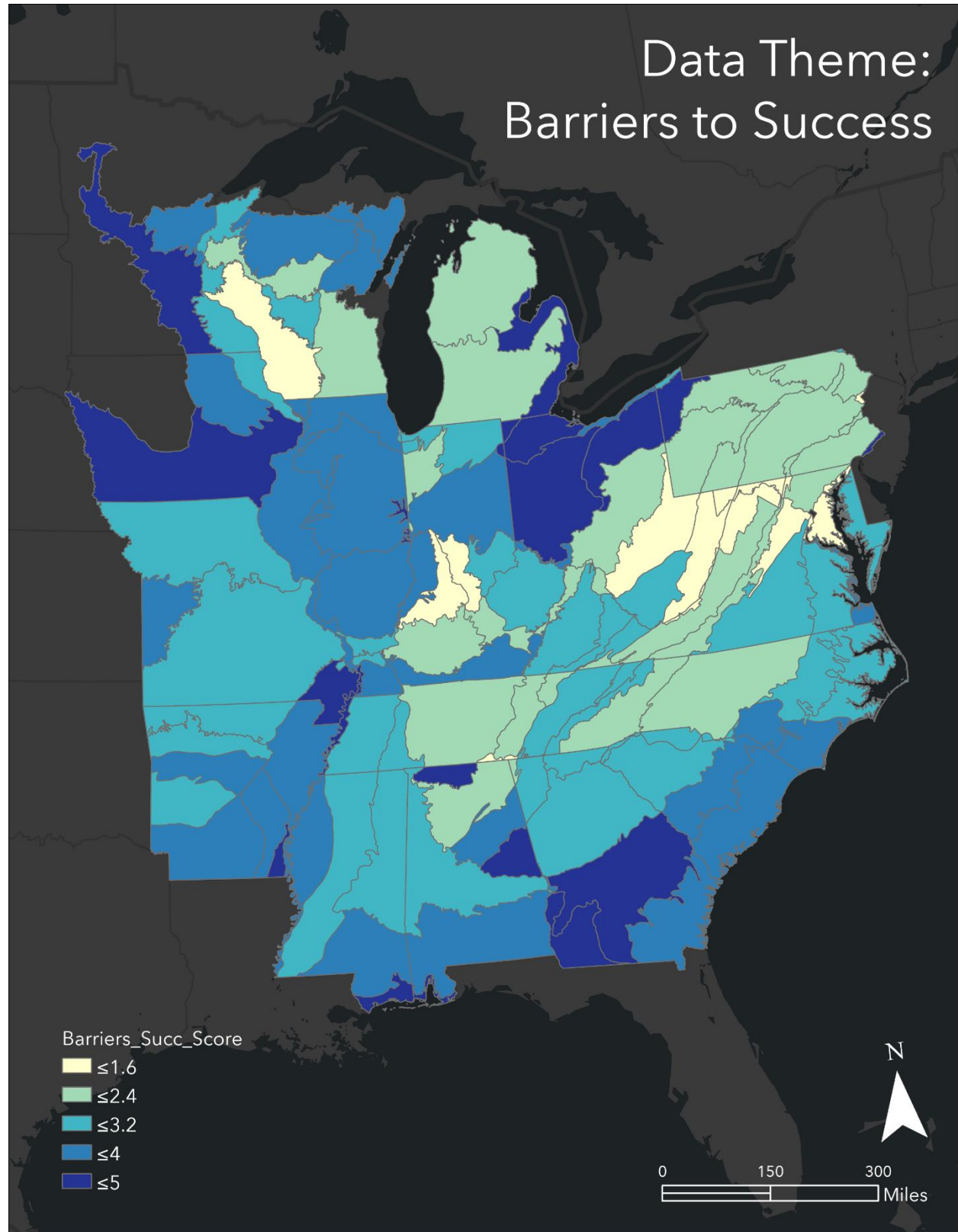
Data Theme: Landowner Efficacy

Data Theme: Landowner Efficacy



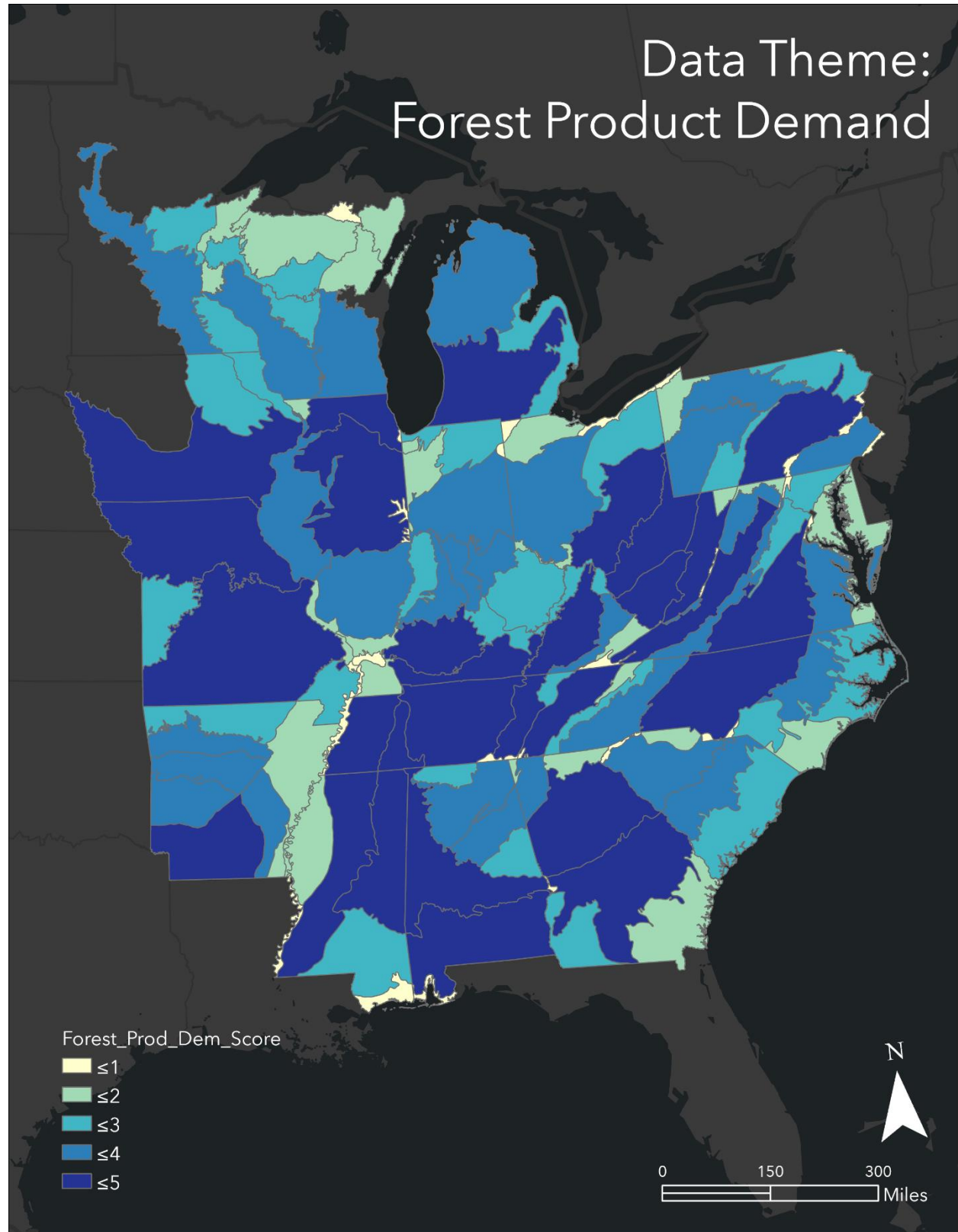
Data Theme: Barriers to Success

Data Theme: Barriers to Success



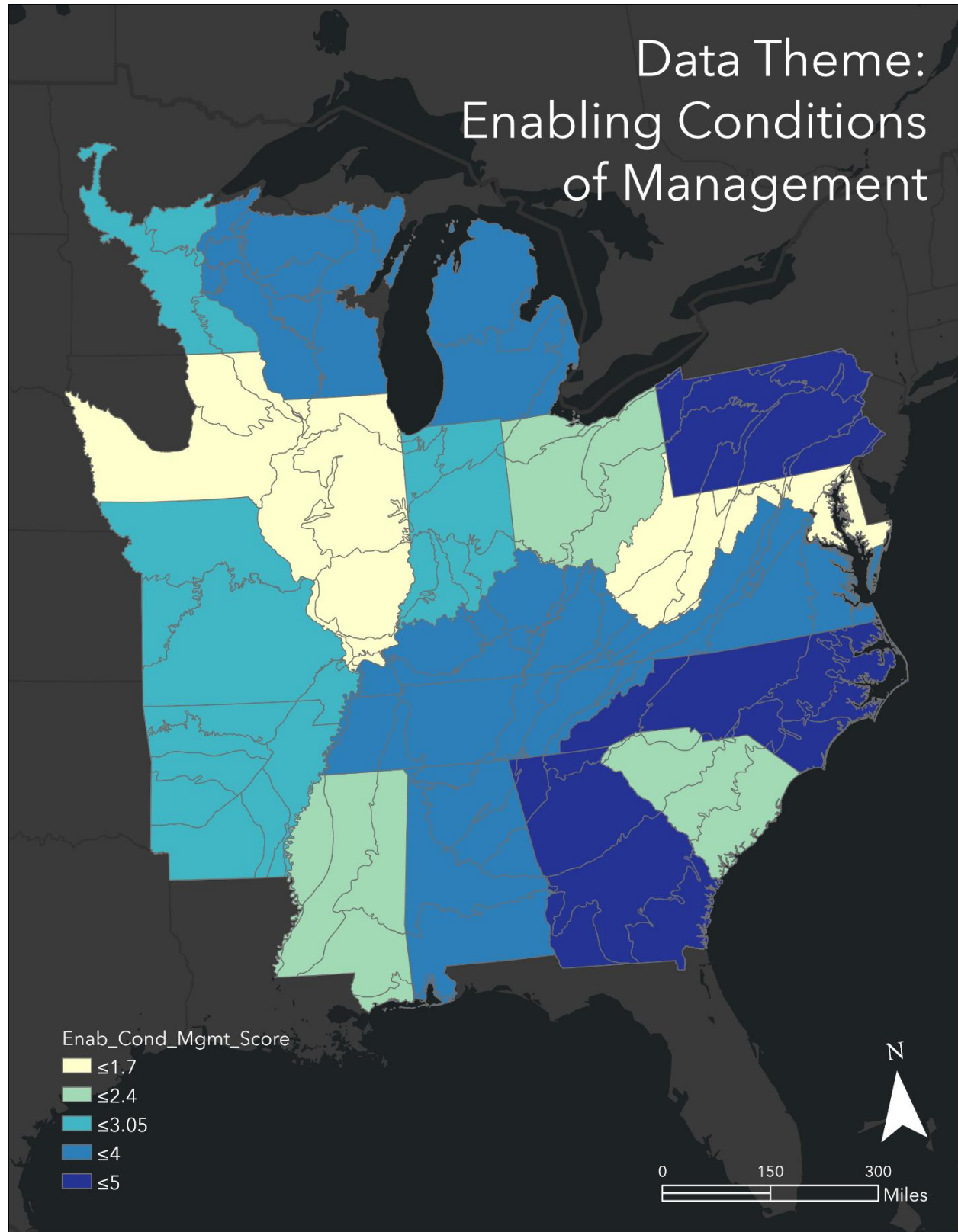
Data Theme: Forest Product Demand

Data Theme: Forest Product Demand



Data Theme: Enabling Conditions Management

Data Theme: Enabling Conditions of Management



Enab_Cond_Mgmt_Score

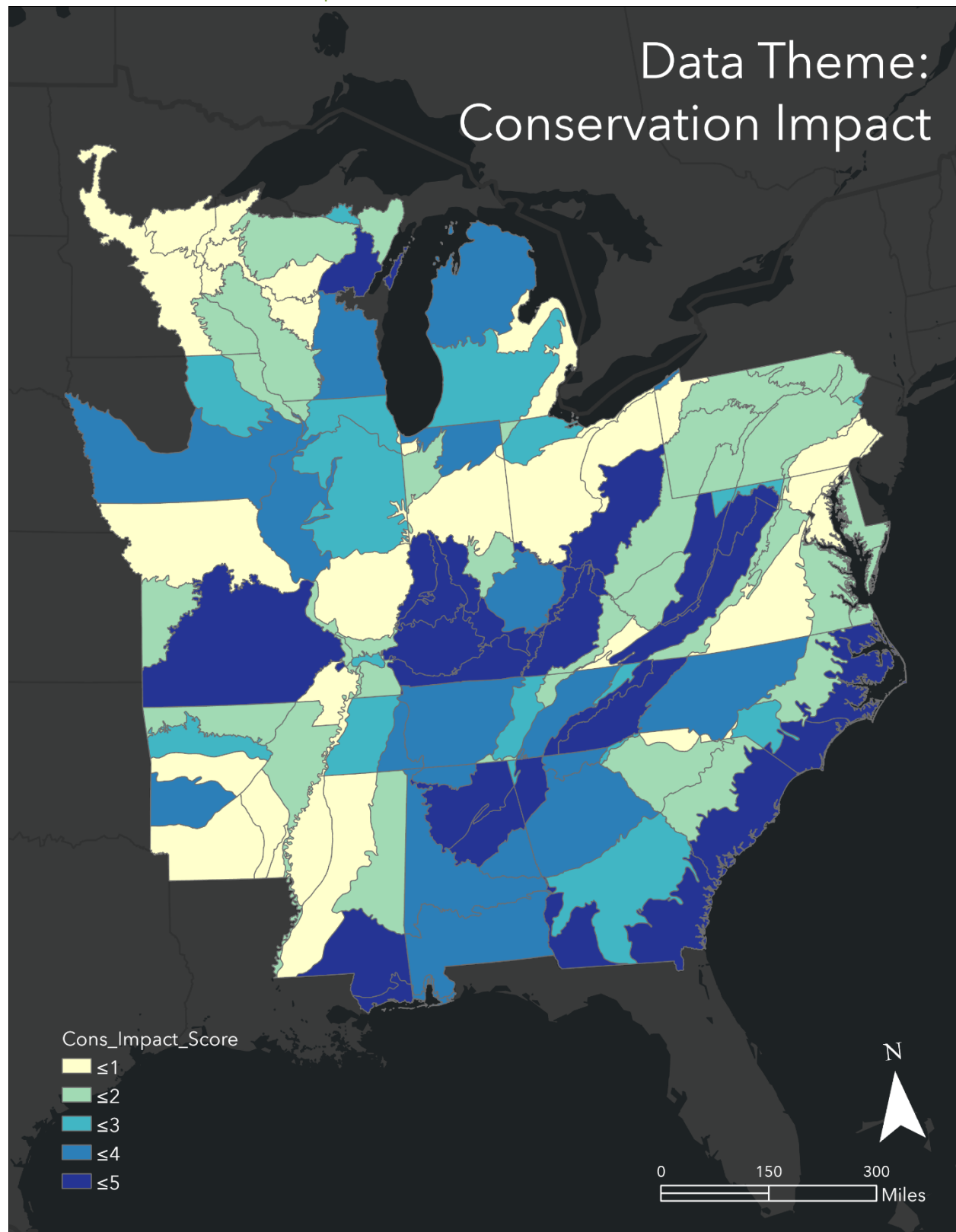
- ≤ 1.7
- ≤ 2.4
- ≤ 3.05
- ≤ 4
- ≤ 5



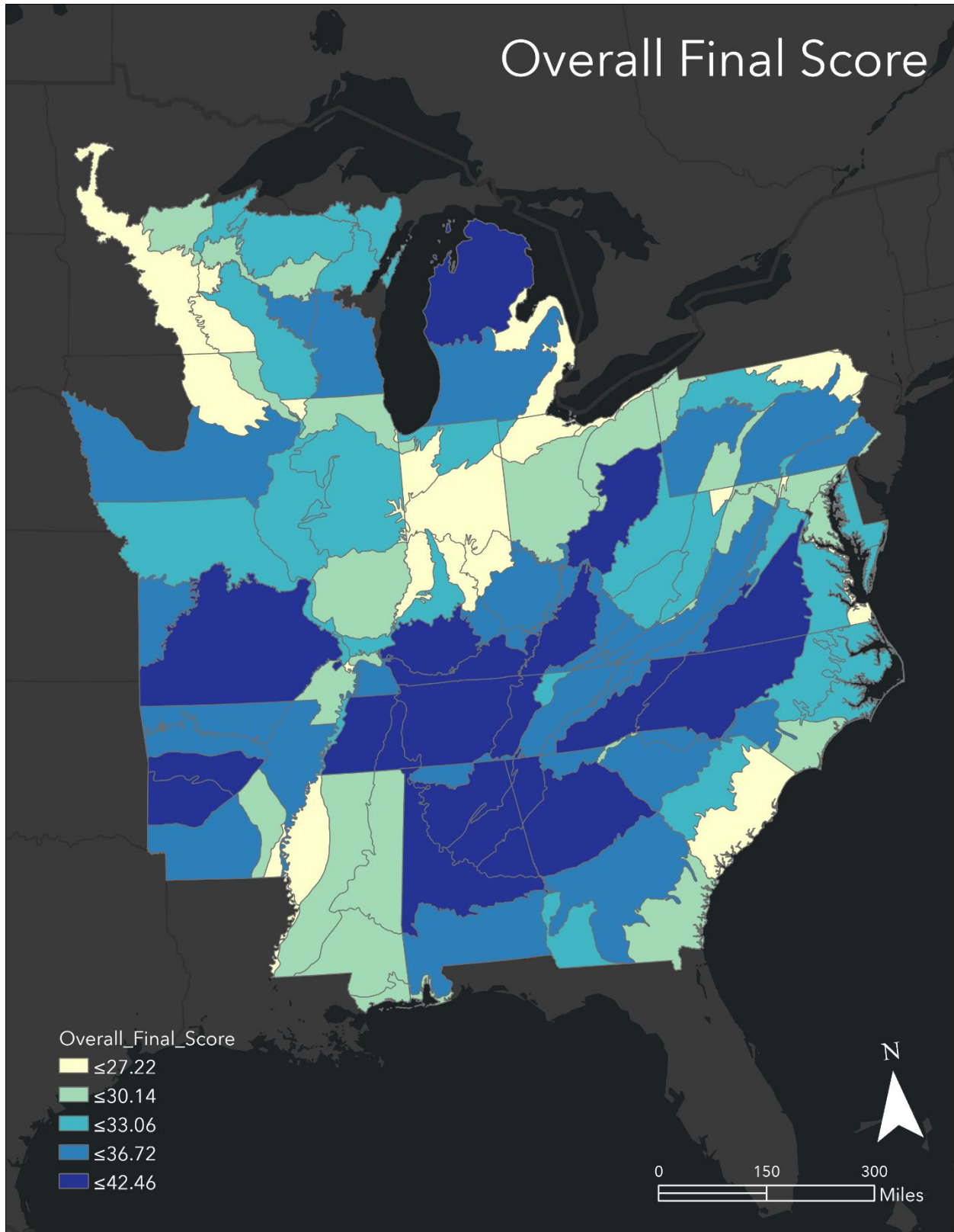
0 150 300 Miles

Data Theme: Conservation Impact

Data Theme: Conservation Impact



Overall Final Score



Appendix

Deliverable Inventory

Final Analysis Layer attribute-level metadata

The WOI_Data_Inventory – FINAL.xlsx Excel document contains a sheet that describes all attributes that are found on the final analysis layer.

Data

The WOI_Data_Inventory – FINAL.xlsx Excel document lists the data layers used in the Secondary Analysis.

- **Secondary Data sheet:** describes the data layers used for scoring as well as data layers included in the final data package as additional layers or that contributed attributes to the final analysis layer without contributing to scoring
- **WOI_EcoStates_AllData sheet:** describes the final analysis layer and all attributes found on it. Also notes which scores would be more difficult to adjust because they're calculated using FME ArcGIS Data Interoperability.
- **WOI_StateBoundaries_BLS_LOS_Com sheet:** describes the state boundary layer which includes some ancillary data and raw data used to calculate some scores.
- **Tools sheet:** describes the FME and Python tools that Timmons Group built to perform some of the data analysis. The Python tool generates a 1-5 score based on an attribute. The FME tools generally perform data transformation: reformatting it from the original data format and processing it into data that can be attached to the EcoState or state data, etc.
- **Secondary Data – Not Used sheet:** lists data that we reviewed and considered for inclusion in the Secondary Analysis, but that we ended up not using.

Tools

The Tools sheet of the WOI_Data_Inventory – FINAL.xlsx Excel document lists the tools that Timmons Group built to perform some of the GIS data processing tasks. It also notes which data layers these tools pertain to.

One of the primary tools Timmons Group built is the Python-based custom ArcGIS tool that generates the 1-5 score based on a selected attribute. This tool allows the user to decide whether to sort the attribute in an ascending or descending order, controlling whether low attribute values are scored as 1's or as 5's. This tool could be useful for AFF for reapplying 1-5 scores or creating new 1-5 scores based on new attributes.

The ArcGIS Data Interoperability tools are provided for reference only, and for documentation's sake. ArcGIS Data Interoperability is the Esri extension version of FME Desktop by from Safe Software. FME Desktop and ArcGIS Data Interoperability are powerful data transformation and manipulation tools. These tools support over 450 file formats, allowing you to take almost any file format and convert it into almost any other format. They have a visual drag-and-drop interface and do not require coding to

create sophisticated data transformation tools (similar to Esri's Model Builder, for those familiar with that tool).¹¹ ArcGIS Data Interoperability is an Esri extension and is used from within the Esri platform.¹²

Guide for Recalculating Scores

This section describes how to change weights and recalculate scores.

Adjusting weights and recalculating the Overall Final Score

Use case: All of the 1-5 scores for each individual data layer are fine as-is, but the overall final score needs to be recalculated after changing the weights for each data layer and/or data theme.

Example: You've gone back to the committee and stakeholders and have developed new weights to use for the final score calculation. You've filled in the weighting worksheet, and need to apply the new weights and calculate the final overall score.

Overall Guidelines:

- If you've adjusted all the weights for all data themes, you'll need to recalculate all data theme scores first, then recalculate the overall final score.
- If you've only adjusted the weights for the overall final score (only the weights at the data theme level), then you don't need to recalculate each individual data theme's score. You can just use the Overall_Final_Calc.cal expression and update that per the new weights.
- If you've adjusted the weights for a single data theme, then you need to recalculate that specific data theme score, and then recalculate the overall final score. You wouldn't need to recalculate each of the other data theme scores first.

Using the worksheet to calculate weights

At the data theme level, to calculate the weights we'll use from the worksheet, divide the weight given on the worksheet by 10.

Data Theme	Data Theme Weight (worksheet)	Weight (use in the Field Calculator expressions for Final Score)
Probability of Regeneration Success	60	6
Landowner Efficacy	6	0.6
Barriers to Success	6	0.6
Forest Product Demand	8	0.8
Enabling Conditions of Management	12	1.2
Conservation Impact	8	0.8

Figure 3 - Weights Across Data Themes - for calculating the Overall Final Score

The final overall score is capped at 50 points (each data theme score is a 1-5 value).

¹¹ Take Control of Your Data with FME Desktop. <https://www.safe.com/fme/fme-desktop/>

¹² ArcGIS Data Interoperability or FME Desktop. <https://www.safe.com/esri/arcgis-data-interoperability-extension/>

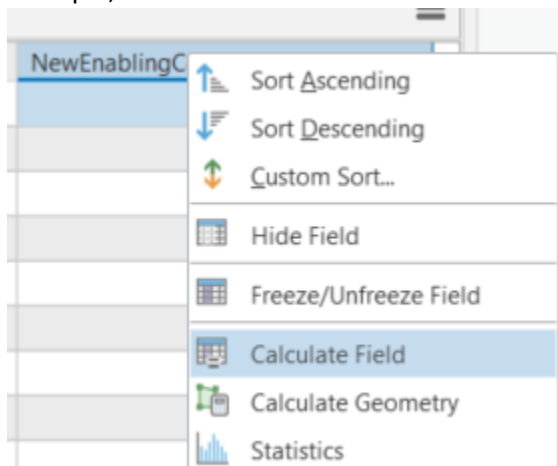
Layer Name	Weight (worksheet)	Weight (use in Field Calculator expressions for data theme score)
Timber Products Output (Mills)	35	0.35
Quarterly Census of Employment and Wages - NAICS (BLS)	35	0.35
Number of Foresters per State (Forest and Manager Capacity)	30	0.30

Figure 4 - Weights within a single data theme - for Enabling Conditions Management, as an example

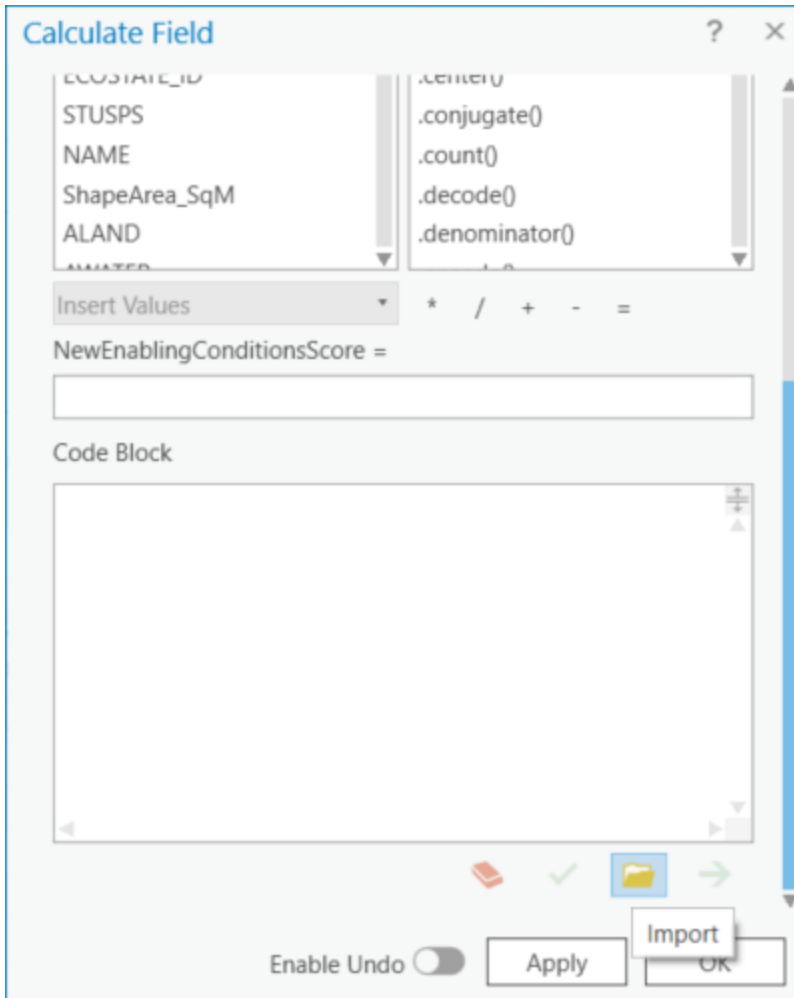
For weights within a single data theme, divide the worksheet weight by 100. These are the values that will be used to calculate the data theme score.

Step-by-step guide:

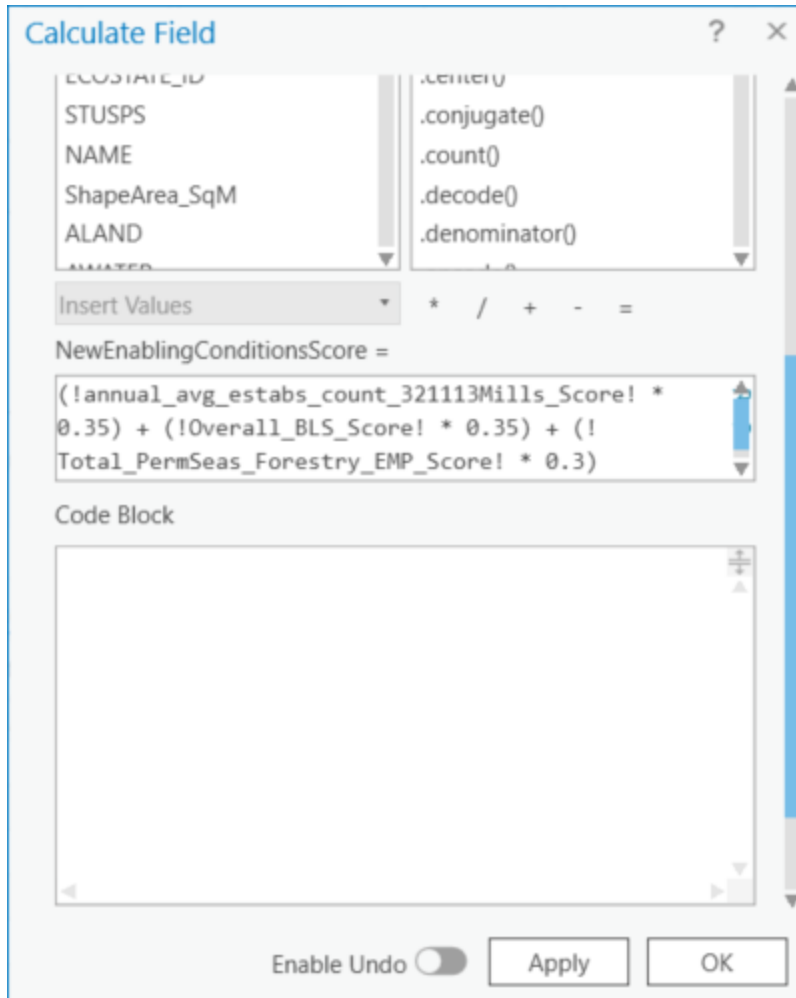
1. Open ArcGIS Pro. Open an existing Pro Project or create a new one using a Map template.
2. Add the final analysis layer to the map.
3. Open the Attribute Table by right clicking the layer in the table of contents and selecting Attribute Table.
4. Find the Data Theme Score fields you want to populate. Before doing this, we recommend saving a backup of the final analysis layer so you can compare the original scores to the new scores you're calculating now (save it as a new feature class). A different option would be to add new data theme score fields and a new overall final score field directly to the existing data layer; the only thing there is that you'll want to be careful when you go to calculate the new final overall score – you'll need to replace some field names in the calculator expressions.
 - a. You can use the Add Field geoprocessing tool to add a field. Be sure to use Double as the field type for the data theme scores and the final overall score.
5. Right click the score field that you want to populate and choose Calculate Field. For this example, I added a new field called "NewEnablingConditionsScore".



6. The Calculate Field pane has opened. Scroll down to the bottom of this pan and click the folder icon (hovering over it reveals the word "Import").

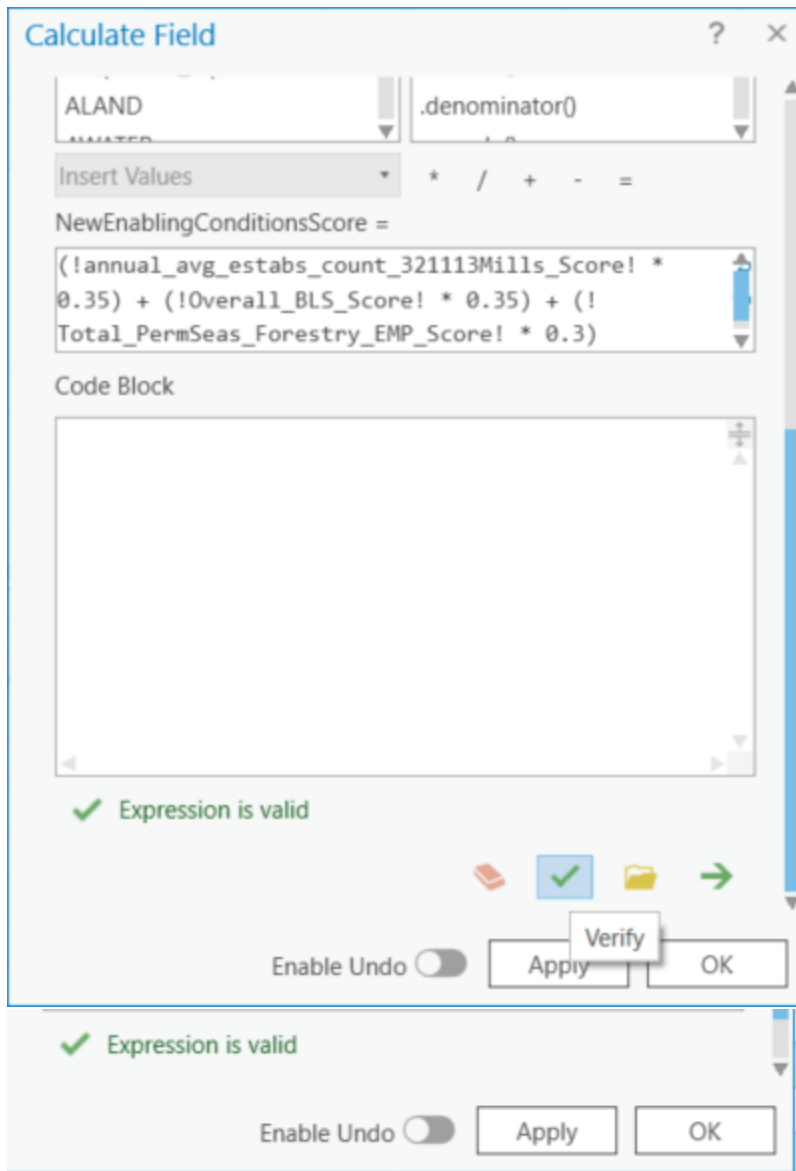


7. The Import dialog is open. Navigate to the data theme calculator expression file. For the Enabling Conditions Management one, that's Enab_Cond_Mgmt_Calc.cal. Select the file and click OK.
8. Importing this file has filled out the calculator expression.

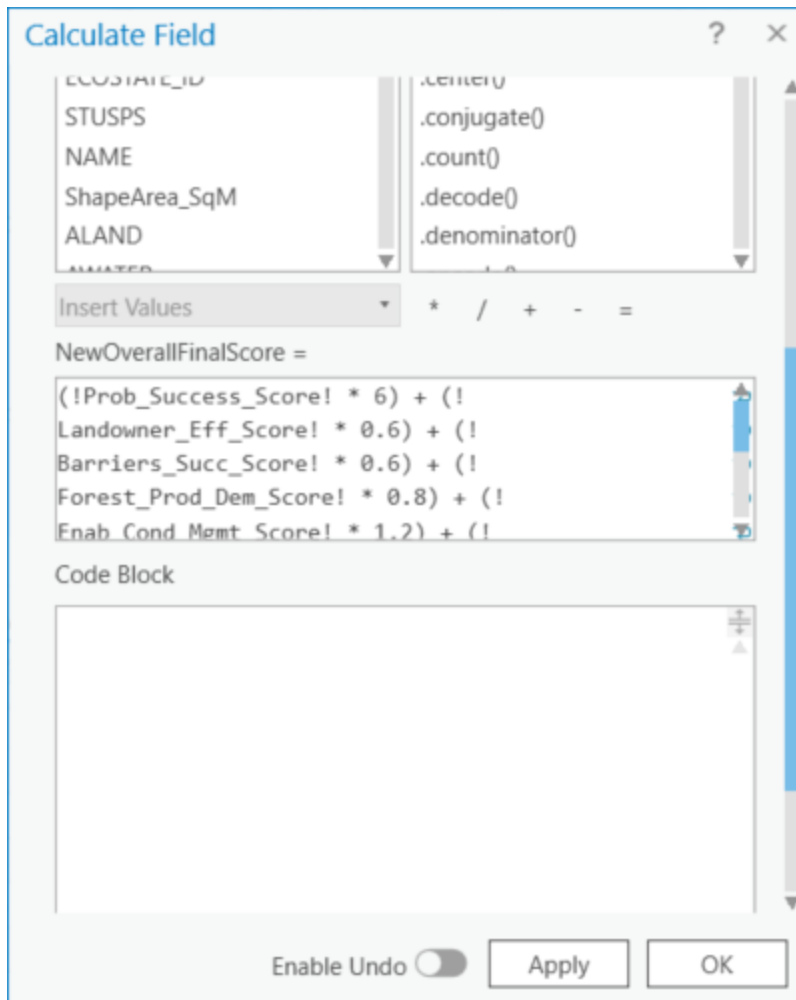


9. For ease of editing, you can copy out the expression into a Notepad file. For Enabling Conditions Management, the expression is as follows:

$$(!\text{annual_avg_estabs_count_321113Mills_Score!} * 0.35) + (!\text{Overall_BLS_Score!} * 0.35) + (!\text{Total_PermSeas_Forestry_EMP_Score!} * 0.3)$$
10. Between each set of exclamation marks you'll see the field name representing one of the data layer scores. Enabling conditions has three:
 - a. !annual_avg_estabs_count_321113Mills_Score!
 - b. !Overall_BLS_Score!
 - c. !Total_PermSeas_Forestry_EMP_Score!
11. You'll leave those field names as is. All you'll need to change are the weight values. For weights within data themes, this is simply the number on the worksheet divided by 100.
 - a. (!annual_avg_estabs_count_321113Mills_Score! * 0.35) + (!Overall_BLS_Score! * 0.35) + (!Total_PermSeas_Forestry_EMP_Score! * 0.3)
12. Once you've changed the weights, click the Verify button at the bottom of the Calculate Field dialog. The message **Expression is valid** should appear.



13. Now click OK to calculate the data theme score.
14. Follow those steps to calculate the other data theme scores (if needed). You'll need to do that if all weights have changed, except for data themes that still only have 1 data layer, as those don't need weights at this tier.
15. After all data theme scores have been appropriately calculated, find the overall final score field in the Attribute Table, right click it, and select Calculate Field.
16. Click the import button at the bottom of the Calculate Field window. Navigate to and select the Overall_Final_Calc.cal file and click OK to import this expression.



17. The full expression reads as follows for the original weighting scheme:
 - a. $(!Prob_Success_Score! * 6) + (!Landowner_Eff_Score! * 0.6) + (!Barriers_Succ_Score! * 0.6) + (!Forest_Prod_Dem_Score! * 0.8) + (!Enab_Cond_Mgmt_Score! * 1.2) + (!Cons_Impact_Score! * 0.8)$
18. Change the weight values. If you added new fields for new versions of the data theme scores, you'll also have to change the expression to use those new fields (for example, replace !Prob_Success_Score! With !New_Prob_Succ_Score!, or whatever you called the field, etc.). Click OK to calculate the final overall score.

Recalculating a 1-5 equal quintile score for a typical layer

Use case: You need to recalculate a 1-5 equal quintile score for a data layer, or you've found a new data layer that you want to calculate a 1-5 score for.

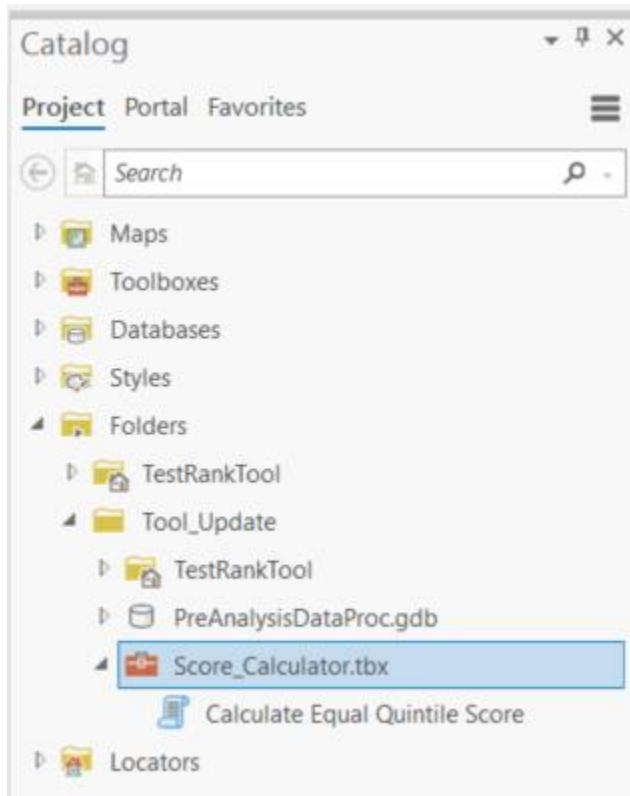
Example 1: You want to recalculate a 1-5 score in the opposite direction, as descending instead of ascending.

Example 2: You have a new data layer, you've done processing to get a value per EcoState, and you want to calculate a brand new 1-5 score based on that data layer.

Example 3: You have a new data layer representing statewide data. You've done any needed work to get an attribute that represents a sum or average, etc. per state. This data lives on the state polygon boundary. You can then use this tool to calculate a 1-5 score for the states. Then you can take that score field and join it to the final analysis layer.

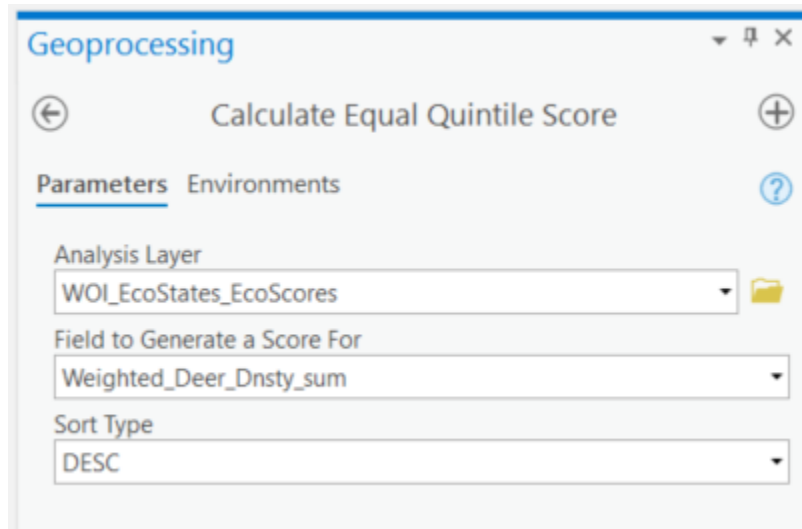
Step-by-step guide:

1. Open ArcGIS Pro. Open a Pro Project, or create a new one with a Map template.
2. Add the correct data layer to your map. Which layer is correct depends on which score you want to calculate. If the score is calculated on the EcoStates, then the final analysis layer is correct. However, if the score is calculated on the states, you'll need the state data layer.
3. Ensure the Score_Calculator.tbx is available in your Catalog pane. An easy way to add the toolbox is to add a connection to the Folder where that toolbox is housed. In the Catalog pane, right click Folders and choose Add Folder Connection. Then navigate to the location of the Score_Calculator.tbx.

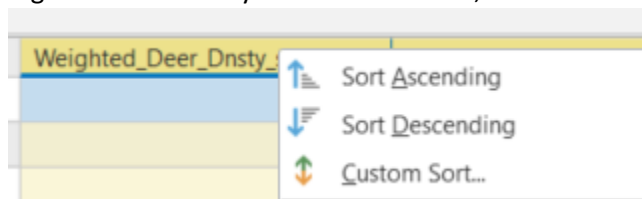


4. Expand the Score_Calculator.tbx to see the Calculate Equal Quintile Score tool. Double click the tool to open it in the Geoprocessing pane.
5. In the Geoprocessing pane, set the parameters for the tool. Select the "Analysis Layer" that the tool will run on. Then select the field that will be used to generate the score. Then select either ASC or DESC for the Sort Type.
 - a. For example, if we want to recalculate the Deer Density score, we'll use the final analysis layer because this score is calculated at the EcoState level.

“Weighted_Deer_Dnsty_sum” is the field to generate a score for. And the Sort Type is DESC because this layer is scored in a descending manner (more deer, higher value in the field corresponds to a lower score).



6. Click Run. The tool will check if there's already a field in the Analysis Layer called (whatever field you picked)_Score. If it already exists, it will recalculate that field. If it doesn't exist, it will add that field. So in our Deer Density example, it will automatically recalculate or add a field called Weighted_Deer_Dnsty_sum_Score. This (fieldname)_Score field will be populated with the 1-5 value.
7. You can check the results of the tool by sorting the data layer on the field you scored against. For this example, that means sorting the Analysis Layer using the Weighted_Deer_Dnsty_sum field, descending.
 - a. Open the Attribute Table for the analysis layer. Right click the layer in the table of contents and choose Attribute Table.
 - b. In the Attribute Table, scroll over until you find the Weighted_Deer_Densty_sum field.
 - c. Right click the field you want to sort on, and choose Sort Descending or Sort Ascending.

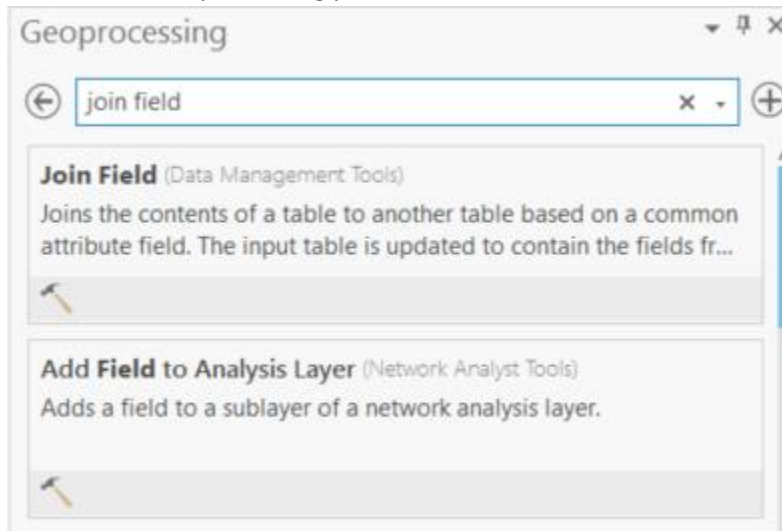


- d. Now that the table is sorted, look at the values in the _Score field. Because we scored these features in a descending direction, the highest Deer Density sum values should correspond to the lowest score values. And indeed that appears to be the case – the highest values are associated with scores of 1. You can scroll down through the table and see that all records are broken into 5 groups, and as you scroll along you'll see scores of 2, 3, 4, and 5 in the score field.

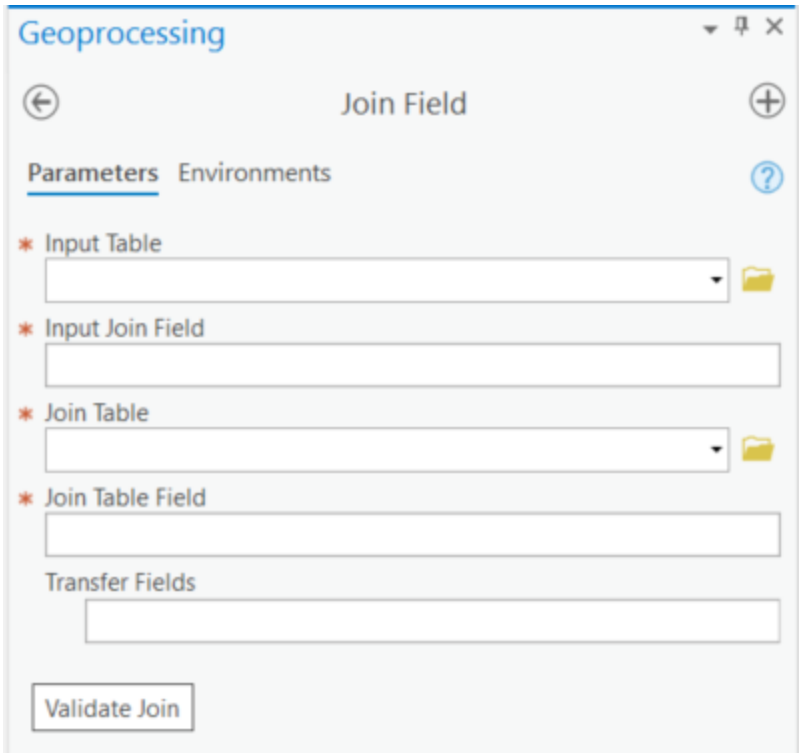
Weighted_Deer_Dnsty_sum	Weighted_Deer_Dnsty_sum_Score
146	1
145	1
144	1
143	1
142	1
141	1
140	1
139	1

e. Success! You can move on.

8. If you recalculated a score at the EcoState level on the final analysis layer, you're done! But if you calculated a score at the state level on the state polygon boundary feature class, then you'll need to add that field to the final analysis layer. You can accomplish that using the Join Field tool. In the Geoprocessing pane, search for the Join Field tool, then open it.



9. Fill out the Join Field parameters.
- Input Table will be the final analysis layer. This is the layer that you're adding the resultant score field to.
 - Input Join Field will be the field in the final analysis layer denoting the state.
 - Join Table is the state boundary feature class where you created the new `_Score` field.
 - Join Table Field is the state boundary feature class's field denoting the state.
 - Transfer Fields – select only the new `_Score` field that you want to add to the final analysis layer.



10. Click Run to run the tool.
11. Now your final analysis layer has the new `_Score` field on it. You can move on to recalculating the overall final score, etc.

Recalculating a 1-5 score for Site Productivity based on new ranges

Site productivity was scored in a unique way. We can't use the Calculate Equal Quintile Score tool to recalculate those field values. However, we can use the ArcGIS Field Calculator and a field calculator expression.

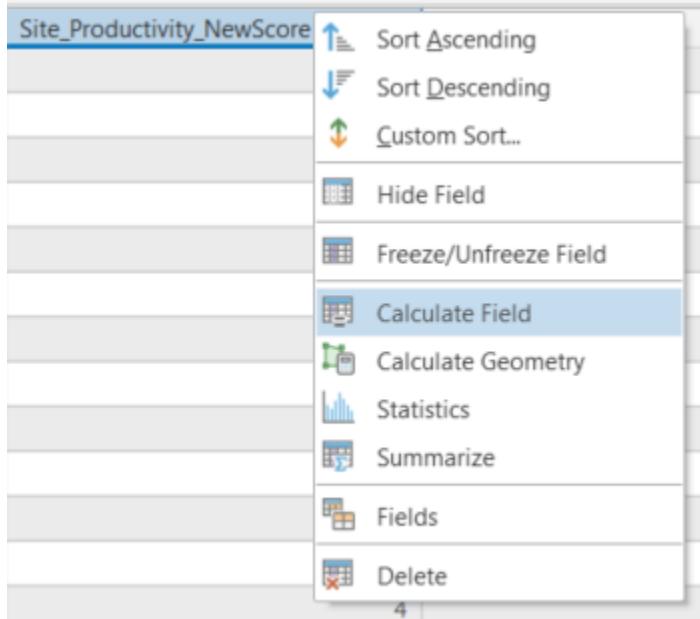
Conveniently, ArcGIS Field Calculator expressions can be saved out to a file. We've provided a file called `Calculate_SiteProductivityScore_Expression.cal`. This shows the exact expression that was used to calculate the Site Productivity Score as we've calculated it for this analysis. You might be interested in changing the ranges of the values in the calculator expression to calculate a different version of this score. To do that, you'll just need to load in the calculator expression and change the numbers it's using.

Step-by-step guide:

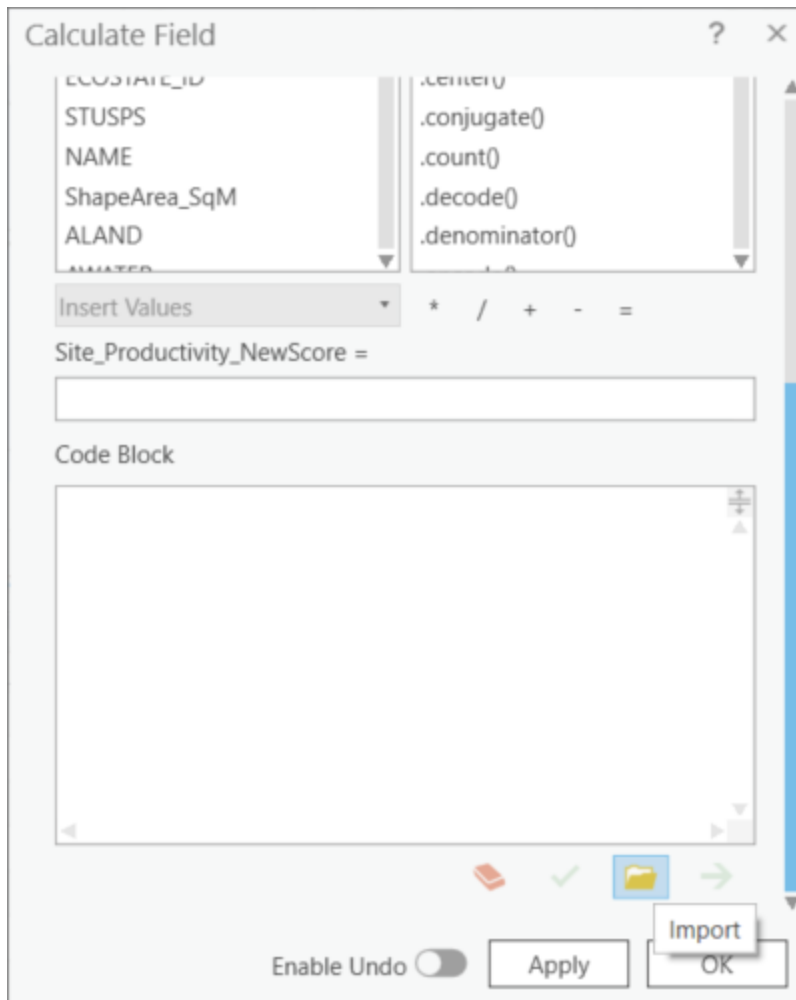
1. Open ArcGIS Pro. Open an existing Pro Project or create a new one using a Map template.
2. Add the final analysis layer to the map.
3. Open the Attribute Table by right clicking the layer in the table of contents and selecting Attribute Table.
4. Find the Site Productivity Score field, or add a new field to contain the new score field you'll calculate (you might want to add a new field if you're changing the calculation ranges; that will

let you compare the original version of the productivity score to the new score you're calculating).

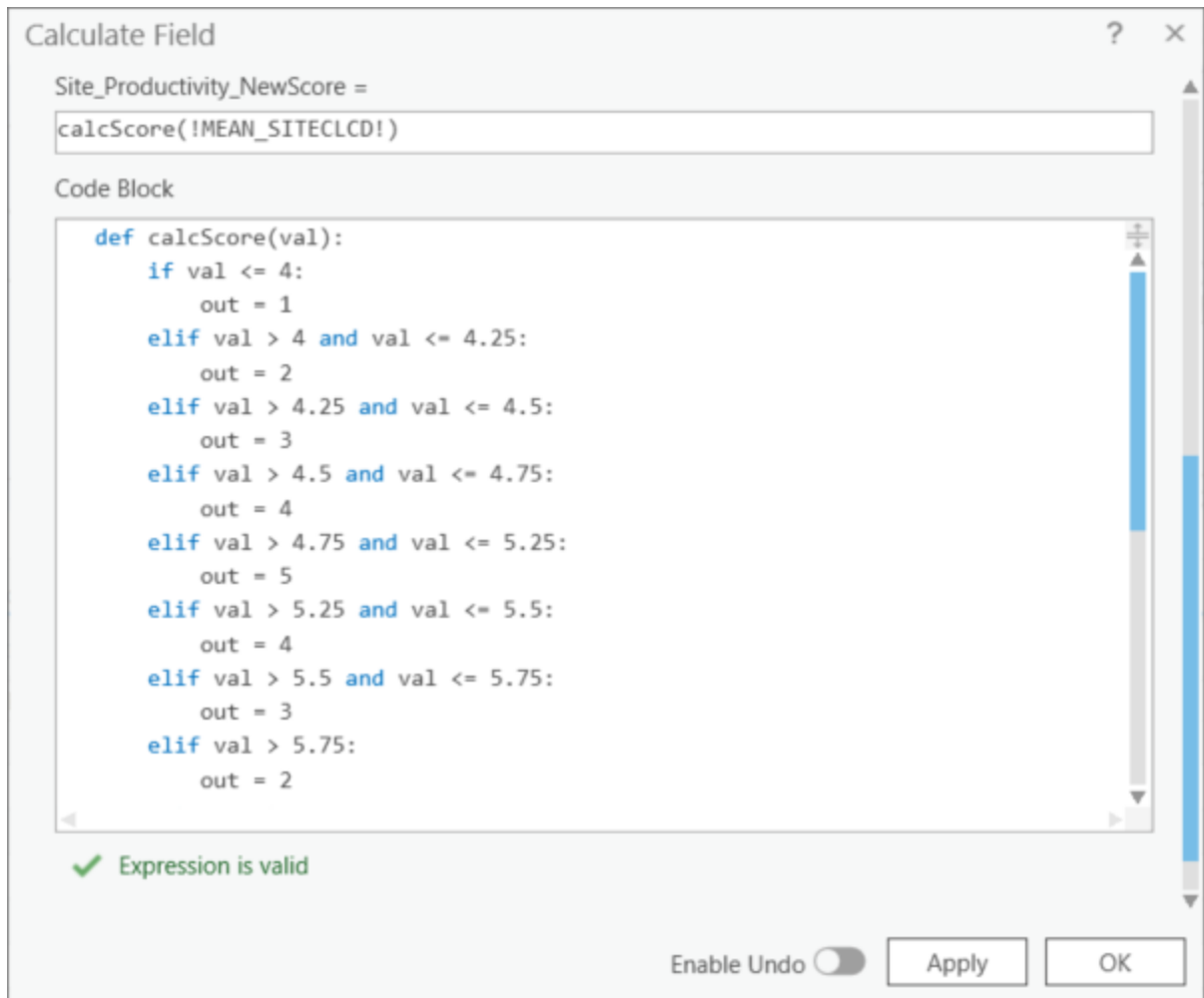
- a. You can use the Add Field geoprocessing tool to add a field. Be sure to create an integer field (Long or Short type) for the score.
5. Right click the score field that you want to populate and choose Calculate Field. For this example, I added a new field called "Site_Productivity_NewScore".



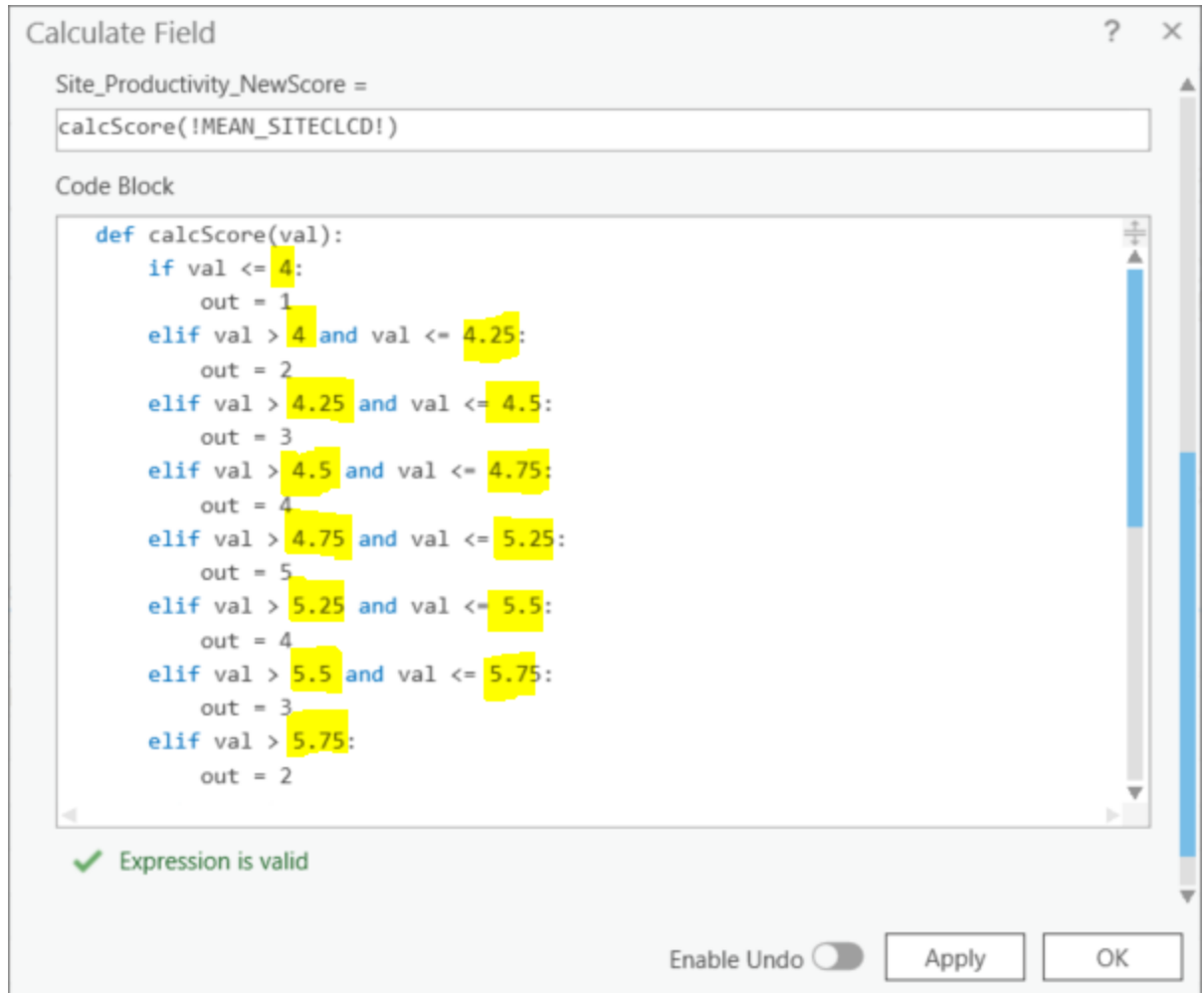
6. The Calculate Field pane has opened. Scroll down to the bottom of this pane and click the folder icon (hovering over it reveals the word "Import").



7. The Import dialog is open. Navigate to the Calculate_SiteProductivityScore_Expression.cal file, select it, and click OK.
8. Importing this file has filled out the Code Block section of the dialog (and the box immediately above it). Great!



9. If you don't want to change any of these ranges, then all you need to do is click OK, and it will apply the calculations and populate the Score field.
10. If you do want to change the ranges, then you simply have to change all if/elif lines to update all the ranges. You don't have to edit any of the other lines.
 - a. Edit all the values highlighted in the screencap below. For clarity's sake, this expression converts the average site productivity value into a 1 through 5 score. In the expression, "val" is the site productivity value (it points to the MEAN_SITECLCD field) and "out" is the score it receives. So, a site productivity value less than or equal to 4 will receive a score of 1. Likewise, a site productivity value greater than 4.75 and less than or equal to 5.25 will receive a score of 5. I'm assuming here that you do want to keep the 1-5 score values, but of course you could change those too if you change the out = # lines; for example, if you wanted to have a score of 0 instead of 1, you could change out = 1 to out = 0.



- b. Click OK. Check the Attribute Table to verify that the tool and your modified calculator expression functioned as expected.

WOI_EcoStates_EcoScores				
Fields: WOI_EcoStates_EcoScores				
Field: Add Calculate Selection: Select By Attributes Zoom To Switch Clear Delete Copy				
ECOSTATE_ID	NAME	MEAN_SITECLCD	SiteProductivity_Score	Site_Productivity_NewScore
IN223G	Indiana	3.575	1	1
MO234D	Missouri	3.666667	1	1
IL234D	Illinois	3.666667	1	1
MS234A	Mississippi	3.75	1	1
MS234D	Mississippi	3.857143	1	1
MS231B	Mississippi	3.929539	1	1
IN223D	Indiana	3.946078	1	1
MS231H	Mississippi	3.956679	1	1
IN223B	Indiana	3.986111	1	1
AR234A	Arkansas	4	1	1
GA232B	Georgia	4	1	1
GA231B	Georgia	4	1	1
VA232I	Virginia	4.052632	2	2
MS232B	Mississippi	4.072727	2	2
GA232C	Georgia	4.1	2	2
SC232C	South Carolina	4.108527	2	2
IL223A	Illinois	4.108696	2	2
GA232J	Georgia	4.121495	2	2

Figure 5 - Shows the Site_Productivity_NewScore side by side with the original SiteProductivity_Score (the calculations weren't changed, so the values match)