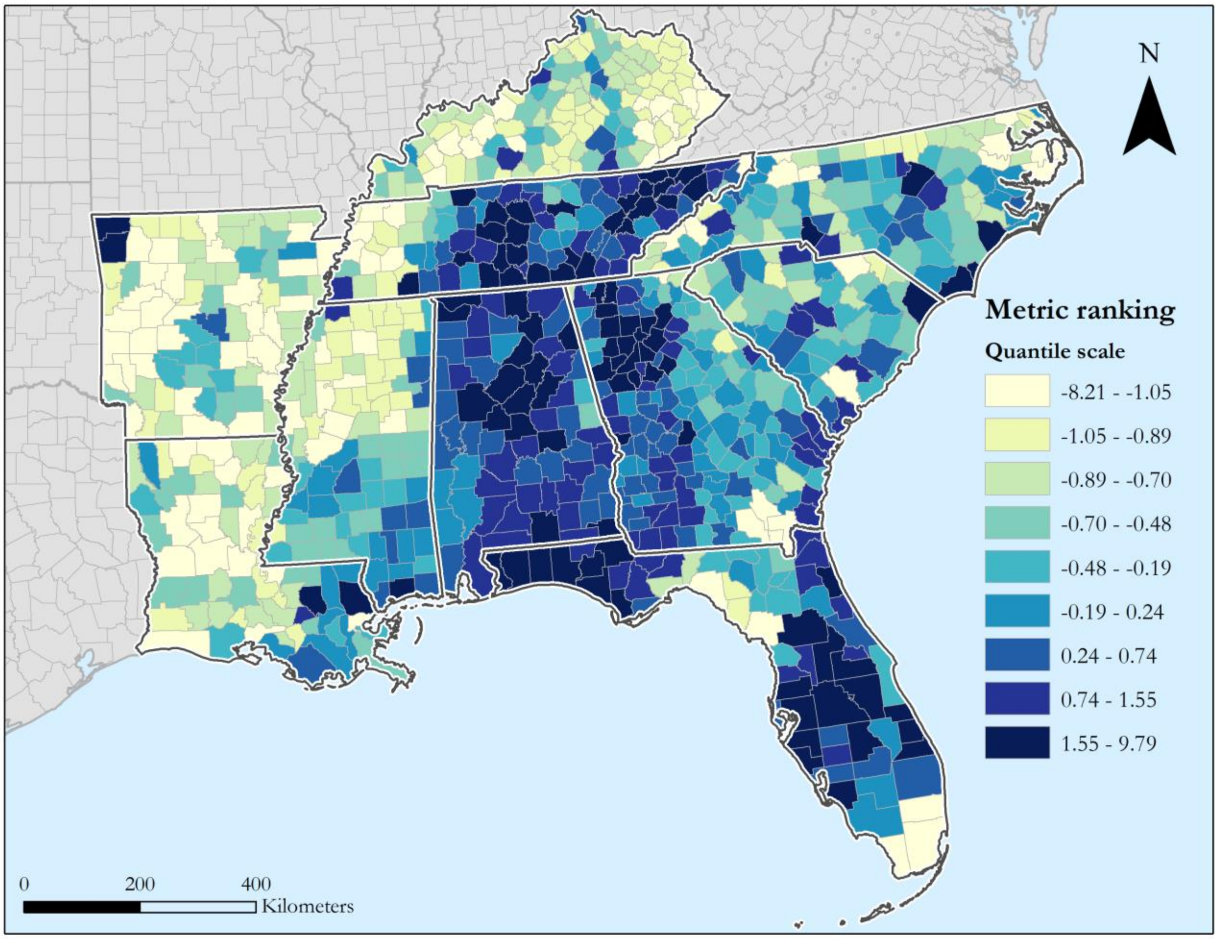
Prioritizing Counties for Imperiled Species Conservation in the Southeast United States

By Andrew A. Pericak, Jacob Malcom, and Ya-Wei Li



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ABSTRACT

Imperiled species are threatened by a variety of factors, many of which stem from human population growth and concomitant habitat loss. The biodiversity of the Southeastern United States is of particular concern because of the combination of the high number of imperiled species and high projected human population growth in the coming decades. Conservation planning for imperiled species requires identifying the areas where efforts are most likely to avert extinction, but determining those areas is challenging because planners must consider many variables that may affect species. Here we address that challenge by ranking each of the 875 counties of the Southeast using a score that combines the number of species listed under the Endangered Species Act, projected population growth through 2040, and the area of currently protected land. The analysis reveals that the counties surrounding some of the Southeast's largest cities—including Orlando, Atlanta, and Charlotte—have the highest scores because of the combination of many listed species, high projected growth, and limited protected lands. Some areas that are currently less-developed than the big cities, such as most counties in Alabama and Tennessee, are also of high concern because they harbor a large number of listed species. In contrast, most counties in Louisiana, Arkansas, and Kentucky are of the least concern. Beyond the Southeast, future research can easily adapt this study's methodology to inform conservation planning for imperiled species in other regions.

Introduction

The Southeast region of the United States—defined here as the states encompassing the United States Fish and Wildlife Service's (FWS) Region 4[1]—faces the perfect storm. There are currently 371 species in the region listed as threatened or endangered under the U.S. Endangered Species Act (ESA), a number exceeded only by Hawaii.[2] Many more species will likely be listed in the coming years as part of FWS's listing work plan.[3] The Southeast contains three of the six states with the highest net population growth between the 2000 and 2010 censuses (Florida, Georgia, and North Carolina); the fourth-fastest growing city by percent growth (Raleigh, NC); and two major US cities with a double-digit population growth rate (Miami, FL, 11.1%; and Atlanta, GA, 24.0%) (Mackun and Wilson 2011). The combination of these factors presents huge challenges for imperiled species conservation now and into the future. The extinction of listed species is all too likely absent strong conservation planning and actions. Prior research has investigated expected human population growth in the region (Terando et al. 2014), but no previous work of which we are aware has examined the intersection of such growth with threatened and endangered species.

Here we synthesize data on listed species occurrence, human population projections through 2040, and currently protected lands for all 875 counties of the ten Southeastern states. We identify "hot spots" that need the attention of conservation planners and practitioners to ameliorate threats to species in these areas before they become unmanageable. In addition, our analysis—conducted exclusively with freely and readily available public datasets—provides a template that can be extended to other areas of the country. Such approaches can help conservation planners make informed decisions about habitat preservation in the face of rapid human development.

Methods

Testing Background Assumptions

Projections of habitat loss and degradation caused by human development are largely lacking but needed for conservation planning decades into the future. We hypothesized that projected human population growth—for which data are readily available—is a good proxy for habitat loss in the absence of detailed habitat loss projections. If this hypothesis is supported then we expect past human population growth data to be strongly correlated with habitat loss, and we can assume that population growth projections are a suitable proxy. To test our hypothesis, we calculated the Pearson's correlation between county-level human population changes and land cover changes over a ten-year period. County-level human population data came from the 2000 and 2010 Censuses (U.S. Census Bureau 2015). Land cover data came from the National Land Cover Database (NLCD) 2001

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[1] Specifically, Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee.

[2] The FWS includes Hawaii in its Pacific Northwest / Pacific Islands Region (Region 1). The state of Hawaii itself has 434 listed species; subtracting that number from the overall total in Region 1 places the Southeast Region ahead of Region 1. However, if Hawaii were its own region, it would still have more listed species than the entirety of Region 4. See "Listed U.S. Species by Responsible (Lead) Region," U.S. Fish and Wildlife Service Environmental Conservation Online System, last accessed July 17, 2015, http://ecos.fws.gov/tess_public/.

[3] See "Listing Workplan, United States Fish and Wildlife Survey, last updated February 16, 2016, http://www.fws.gov/endangered/improving_esa/listing_workplan_actions.html.

to 2011 Land Cover "from-to" Change Index (Homer et al. 2015)[4], with county-level habitat loss calculated as the sum of areas of newly developed land and cultivated crops between 2001 and 2011. Our hypothesis was supported by analyzing past data: there is a strong, positive correlation between the two variables (Pearson's $r = 0.7164$, $p < 0.0001$). We therefore assume that population growth projections are a good proxy for habitat loss and degradation into the future.

Data Acquisition and Sources

We used both FWS's Environmental Conservation Online System (ECOS)[5] and United States Geological Survey's (USGS) Biodiversity Information Serving our Nation (BISON)[6] databases to obtain county-level species occurrence data for ESA-listed species in the Southeast. From each dataset we extracted the number of species found in each of the 875 counties in the region (Figure 1).

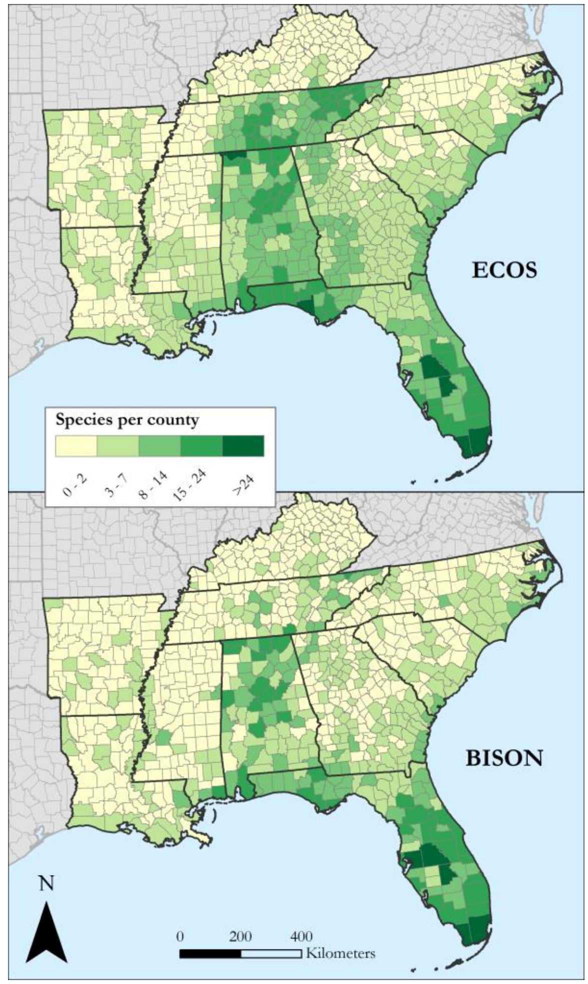

Figure 1 Comparison of the number of unique listed species per county from the ECOS and BISON databases.

Next, we identified a set of factors that we expect will affect the survival of imperiled species in the coming decades, then identified sources of freely available data for each variable (Appendix Table 1). We used spatial analysis tools available through ArcGIS 10.2.1 to subset raster datasets per county and to calculate the total area of each dataset per county. A small number of manual changes were required for certain datasets:

- Not all states' official population projections extended through 2040. For those states (Mississippi, whose projections extend through 2025; Georgia, Louisiana, and South Carolina, through 2030; and North Carolina, through 2035), we used the "Forecast" function in Microsoft Excel to perform simple linear regressions over the given projected population at a five-year interval to

[4] This dataset compares the NLCD classifications from the 2001 dataset and the 2011 dataset, indicating per raster cell if there was no change in that cell over the ten year time period or, if land cover did change, what the land cover was in 2001 and what it became by 2011.

[5] See "Environmental Conservation Online System," United States Fish and Wildlife Survey, last accessed July 10, 2015, http://ecos.fws.gov/ecp/.

[6] See "Biodiversity Information Serving Our Nation (BISON)", United States Geological Survey, last modified April 13, 2015, http://bison.usgs.ornl.gov/.

estimate the future population for the missing years. Of the 451 counties for which we estimated future population, 405 had R^2 values greater than 0.95 (Appendix Figure 1).

- Because the Protected Areas Database (PAD) includes multiple entries for a defined protected area when attribute information (e.g., land ownership or legal status) changes, we removed entries that exactly overlapped with one another in PAD.
- Determining land area for some coastal counties initially presented anomalous results. We calculated the area of each county, then subtracted both the area of water bodies and the area of protected areas inside that county. The resulting area represents the theoretical amount of land per county that could become or already is urbanized or agricultural land. Three counties (Dare County, NC; Cameron Parish, LA; and Plaquemines Parish, LA), however, resulted in negative human habitable areas after performing this calculation, likely resulting from overestimation of the area of water in ArcGIS.[7] For those counties, we retrieved the total land area per county from the U.S. Census Bureau's State and County QuickFacts[8] and only subtracted the protected area within that county.

Modeling "Hot Spots" for Conservation

To account for the different data sources and variation in their associated scales,[9] we first standardized all the variables to a mean of zero and unit variance. We then used principal components analysis (PCA) with package `FactoMineR` (Husson et al. 2015) to evaluate the correlations among variables. The first three principal components explained 73.0% of the data's variance. We chose three variables that were roughly orthogonal to each other (i.e., uncorrelated) to calculate the index: the number of species per county ($n_{species}$),[10] the absolute change in population ($\Delta_{population}$), and the sum of protected area per county.

To create a single "metric score" that combined information from each variable, we used the formula

$$Score = n_{species} + \Delta_{population} - area_{protected\ land}$$

to calculate each of the 875 counties' relative importance for imperiled species conservation. Higher values resulting from this formula indicate greater threats to more species, whereas lower scores indicate fewer threats and/or fewer species. Last, we ran an optimized hot-spot analysis using ArcGIS (Esri 2014) weighting the county polygons by the score, to determine any significant clustering of similar scores.

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[7] These three counties are all located on the coast and have extensive water area. Dare County includes North Carolina's Outer Banks; both Cameron and Plaquemines Parishes have large areas of wetlands. To determine the area of water bodies per county, we converted the National Hydrography Dataset, originally in vector format, to a raster. This conversion into raster likely overestimated water areas in these counties because of all their wetlands and the varying shapes those wetlands could have.

[8] See http://quickfacts.census.gov/qfd/index.html.

[9] For instance, imperiled species richness per county ranged from 0 to 33, whereas the population change per county ranged from -138,550 to 597,400 people.

[10] Data from ECOS and BISON were highly correlated per county; we chose to use the ECOS data for subsequent analyses. See "Results" below.

RESULTS

We collected or calculated data at the county level for fourteen variables (Appendix Table 2). The core data for this project can be found at figshare. We found that although BISON records indicated fewer species per county on average than ECOS, the number of imperiled species per county was highly correlated between the datasets (Pearson's $r = 0.7481$, $p < 0.001$). From the base datasets we derived additional variables per county using spatial analysis tools in ArcGIS:

- *Population density in 2040:* The projected population in 2040 divided by the human-inhabitable land (Appendix Figure 2).
- *Human population change from 2015 to 2040:* Expressed as the expected number of humans (Appendix Figure 3, top) and as percent population change (Appendix Figure 3, bottom).
- *Land characteristics:* Total area and percent of county that is protected from habitat destruction (Appendix Figure 4), total projected urbanized area and percent of county projected to be urbanized in 2040 (Appendix Figure 5), and total area and percent of county that is human-inhabitable land (Appendix Figure 6).
- *Net forest change from 2000 to 2012:* Forest loss subtracted from forest gain per county (Appendix Figure 7). While this metric describes the past rather than the future, we include it here for completeness of our analysis.

The PCA (Appendix Figure 8) revealed correlations among a few sets of variables, such as the species counts according to ECOS and BISON; the percent and the total area of protected land; and area of urbanization, population change, and population density. The protected lands and the population change variables' vectors are roughly orthogonal (i.e., at right angles) to each other, with the species counts variables roughly bisecting those vectors.

The metric score rankings of all 875 counties ranged from -8.2046 to 9.7888 (mean = 0, standard deviation = 1.5586; Table 1 and Figure 2, next pages). The optimized hot-spot analysis map shows significant clustering of both high and low metric values across the region. A large, significant hot spot (i.e., high scores) covers most of Alabama, most of Georgia, and substantial portions of Tennessee and Florida. A large, significant cold spot (i.e., low scores) covers Louisiana and Arkansas and half of Mississippi (Appendix Figure 9).

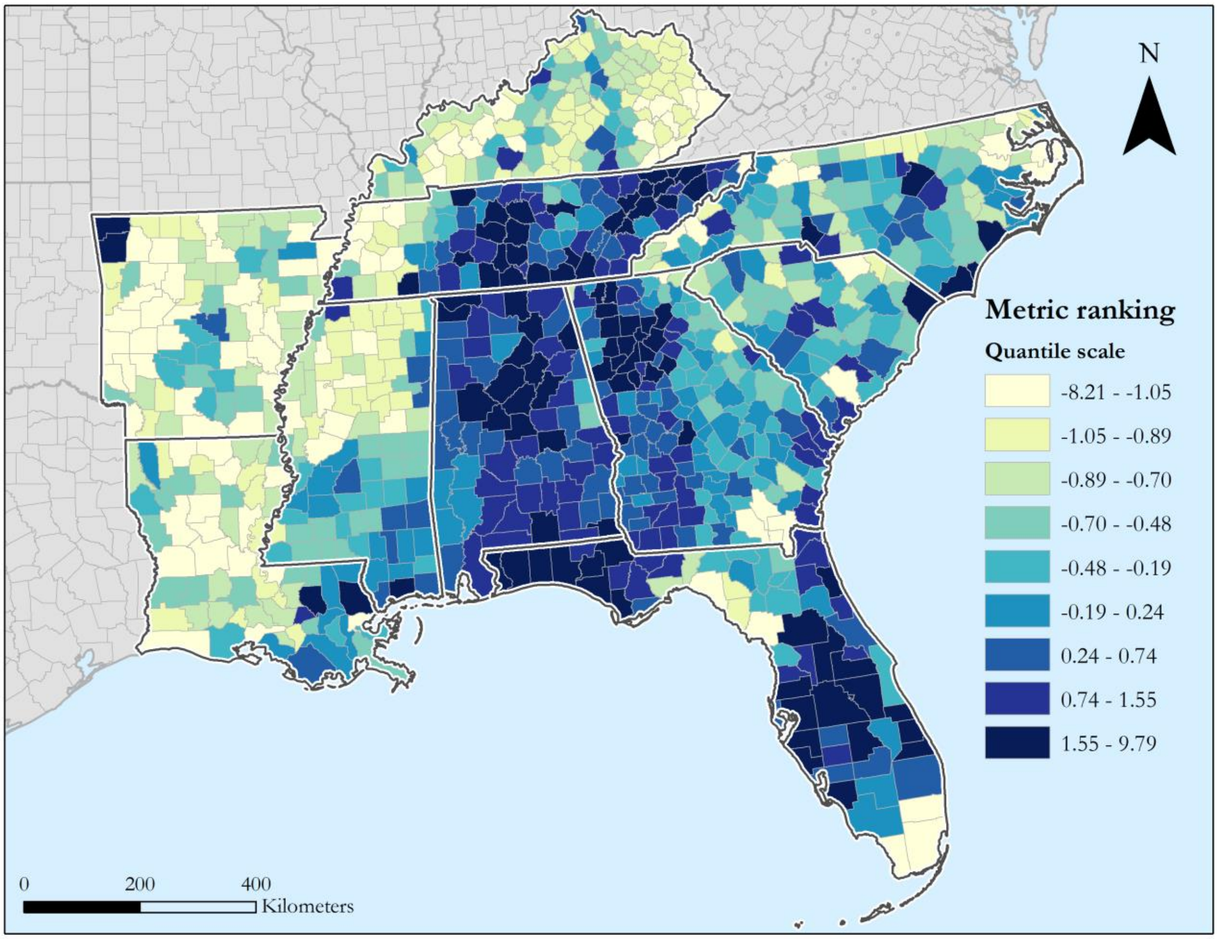

Figure 2. Metric scores for all 875 counties of the Southeast. High values (darker colors) are areas of greatest concern, whereas low values (lighter colors) are areas of least concern. See Methods for a detailed explanation of how the score is calculated.

Table 1. Top ten and bottom ten counties according to the prioritization metric. Here, "top" means those counties attaining the highest score, which indicates the greatest potential for harm to species and thus the most immediate targets for conservation. "Bottom" means those counties with the lowest score, places where little attention is needed. The metric scores are relative, so a score of 2 does not necessarily mean twice as much attention is needed as a score of 1, for example.

County and State (Associated Urban Area)	Metric Score	Metric Ranking
Orange County, Florida (Orlando)	9.7888	1
Mecklenburg County, North Carolina (Charlotte)	7.9933	2
Fulton County, Georgia (Atlanta)	7.881	3
Hillsborough County, Florida (Tampa)	7.5046	4
Gwinnett County, Georgia (Atlanta)	7.4923	5
Polk County, Florida (Lakeland)	7.3411	6
Wake County, North Carolina (Raleigh)	6.7650	7
Lee County, Florida (Cape Coral / Fort Myers)	6.3372	8
Rutherford County, Tennessee (Murfreesboro)	6.2745	9
DeKalb County, Georgia (Atlanta)	6.1600	10
…	…	…
Charlton County, Georgia	-3.7194	866
Polk County, Arkansas	-3.9865	867
Swain County, North Carolina	-4.1332	868
Broward County, Florida (Fort Lauderdale)	-4.2234	869
Cameron Parish, Louisiana	-4.7538	870
Ware County, Georgia	-5.0361	871
Yell County, Arkansas	-5.7822	872
Monroe County, Florida	-6.6789	873
Montgomery County, Arkansas	-7.2518	874
Scott County, Arkansas	-8.2046	875

Discussion

The Southeastern U.S. is a region of significant conservation interest because of the convergence of a high number of imperiled species and high projected human population growth rates. By gathering, processing, and analyzing publicly available datasets covering the 875 counties of the Southeast, we have shown a way to prioritize areas for imperiled species conservation. The metric for ranking individual counties is calculated from the number of listed species, the current amount of protected land, and projected future human population growth per county. Under this metric, counties with the highest scores correspond to the greatest concern and should be the focus of near-future conservation efforts because of anticipated long-term threats.

The areas of greatest concern in the Southeast tend to fall around the region's fastest-growing metropolitan areas, including Orlando, Tampa, Atlanta, Birmingham, Charlotte, and Raleigh. How these locations achieved their high scores varies, however. Orange County, Florida (Orlando), has an above-average number of imperiled species (15 unique species) and very high projected population growth (over 587,000 people by 2040), but it has an average amount of protected land (about 110 km^2). This contrasts with Mecklenburg County, North Carolina (Charlotte), which is also projected to experience high population growth (about 570,000), but has few currently listed species (4 species) and little protected land (about 7.5 km^2). Even though these two counties have the highest scores, conservation planners may choose to focus on only one component of the score to achieve specific conservation goals. For example, if the goal is to protect as many imperiled species as possible, then a conservation planner might opt to focus efforts on Orange County. If the goal is to increase the amount of protected land that could serve as habitat for both currently listed species *and* species that may require listing in the future, Mecklenburg County may represent the better target.

Not all metropolitan areas have high concern. Miami-Dade County, Florida, for instance, has a score that is surprisingly in the lowest tenth percentile. Even though this county has the greatest projected population growth of all Southeast counties (~600,000 additional humans by 2040) and the third-highest number of listed species (32 unique species), it also has the most protected area of any county (over 3,000 km^2) because a large proportion of Everglades National Park overlaps with the county. Subtracting the value for protected area in the metric decreases the metric score for counties with extensive protected land; in the case of Miami-Dade, this subtraction was large enough to counteract the strong pull from the high values for population and species.[11]

Alabama, Georgia, Tennessee, and Florida contain most of the counties of greatest concern. This results both from the number of listed species in this region and from the extensive growth associated with Atlanta. A relatively high number of imperiled species live in the region extending approximately north from the Florida panhandle into Alabama and through the northern border of Tennessee (see Figure 1). Georgia contains fewer species, but the entire ring of counties surrounding Fulton County (Atlanta) are expected to have large population increases. This represents an important characteristic of the scoring formula: it weights all the standardized variables equally, meaning that outlying data points found in one component variable (i.e., large population growth in the Georgia counties) can "pull" the metric toward an extreme value, despite relatively normal values for the other component variables.

On the opposite end of the spectrum, Louisiana and Arkansas contain most of the counties of least concern. Both states have substantial protected areas and are projected to lose human population in many of their counties, resulting in lower scores. Scott County, Arkansas, places last on the prioritization list: it only has two ESA-listed species, a projected population growth of 256 people by 2040, and almost 1500 km^2 of protected land. In contrast to counties further east, there is relatively little reason to prioritize conservation efforts on listed species in Scott County or surrounding areas.

Future analyses

The simple analysis presented here paints a clear picture, at both the county and regional level, of where we expect to witness extensive land use change from current conditions. Because the method has built-in flexibility, future applications could incorporate different datasets in order to help address specific conservation goals, to look at species at differing spatial scales, or to include updated information. Future applications could tailor the score to fit a specific conservation goal, for

[11] This also shows how the metric, as formulated it here, "balances" the three competing conservation goals of greater species richness, more protected area, and minimized habitat loss (via minimized human population growth). Future use of this method might weight these variables differently.

example by weighting certain variables higher than others. Future research could also expand or modify this analysis to include other variables, such as species uniqueness, which we excluded from this study. We included counts of the total number of imperiled species per county, but that variable excludes which exact species are found in those counties. If an imperiled species is only found in one county, conservation work in that county might be particularly important. Future research might therefore include a variable that accounts for a species' overall range or phylogenetic uniqueness.

Additionally, future research could incorporate remotely-sensed data to further improve the metric model. As the spatial and temporal resolution of remotely-sensed data continues to improve, those data could help reveal areas of rapid land or topographical change, low primary productivity, and fine-scale habitat fragmentation, all factors that also may harm imperiled species. Given the often monumental storage size of remotely-sensed datasets, such analyses may only be possible for small regions, perhaps covering only a few counties. Nonetheless, if a conservation planner takes the results from this study or from a modified version of it, identifies certain counties most in need of conservation action, and then looks at remotely-sensed data products for those counties, that planner could even potentially identify exact parcels of land in need of conservation efforts. This study provides a general indication of where conservation efforts may be needed, but remotely-sensed data could help target those efforts to a high degree of specificity.

Conclusion

Future human population growth presents many threats to imperiled species, including loss of habitat, increased pressure for resources, and greater habitat fragmentation. The species of the Southeast United States will acutely feel these effects. By examining the current distributions of listed species and future projections of several environmental variables, we show that specific counties in the Southeast—especially those centered around or near the fastest-growing metropolitan areas—will be some of the most challenging places for imperiled species to exist.

Conservation planners can use the results of this study, or expand on its methods, to prioritize areas for the most immediate conservation action. If the areas at greatest risk are protected today, then the imperiled species living there may experience better chances of survival into the future. This study, however, is merely a snapshot of today's current conditions and best available data. It assumes that the population and urbanization projections will come to pass, that the size and extent of protected areas will not change, and that the number of imperiled species per county remains constant. These are likely false assumptions, as projections of the variables analyzed in this study will undoubtedly change over the next 25 years. Conservation planners should continually update these analyses as conditions change or as more accurate data becomes available. Such work will be crucial to protecting imperiled species in the face of extensive human development expected to occur across much of the Southeast.

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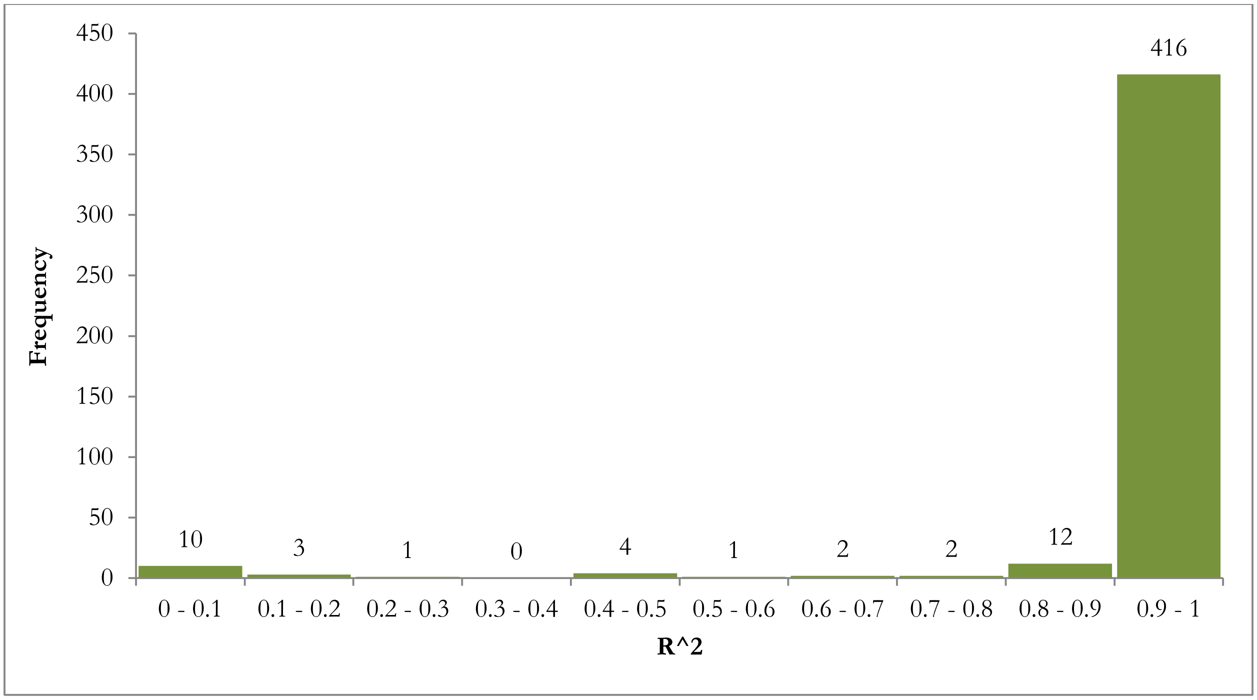
APPENDIX

Appendix Table 1. Data variables and sources used for creating the prioritization metric. This does not include some of the derived variables. For full citations, see the Works Cited.

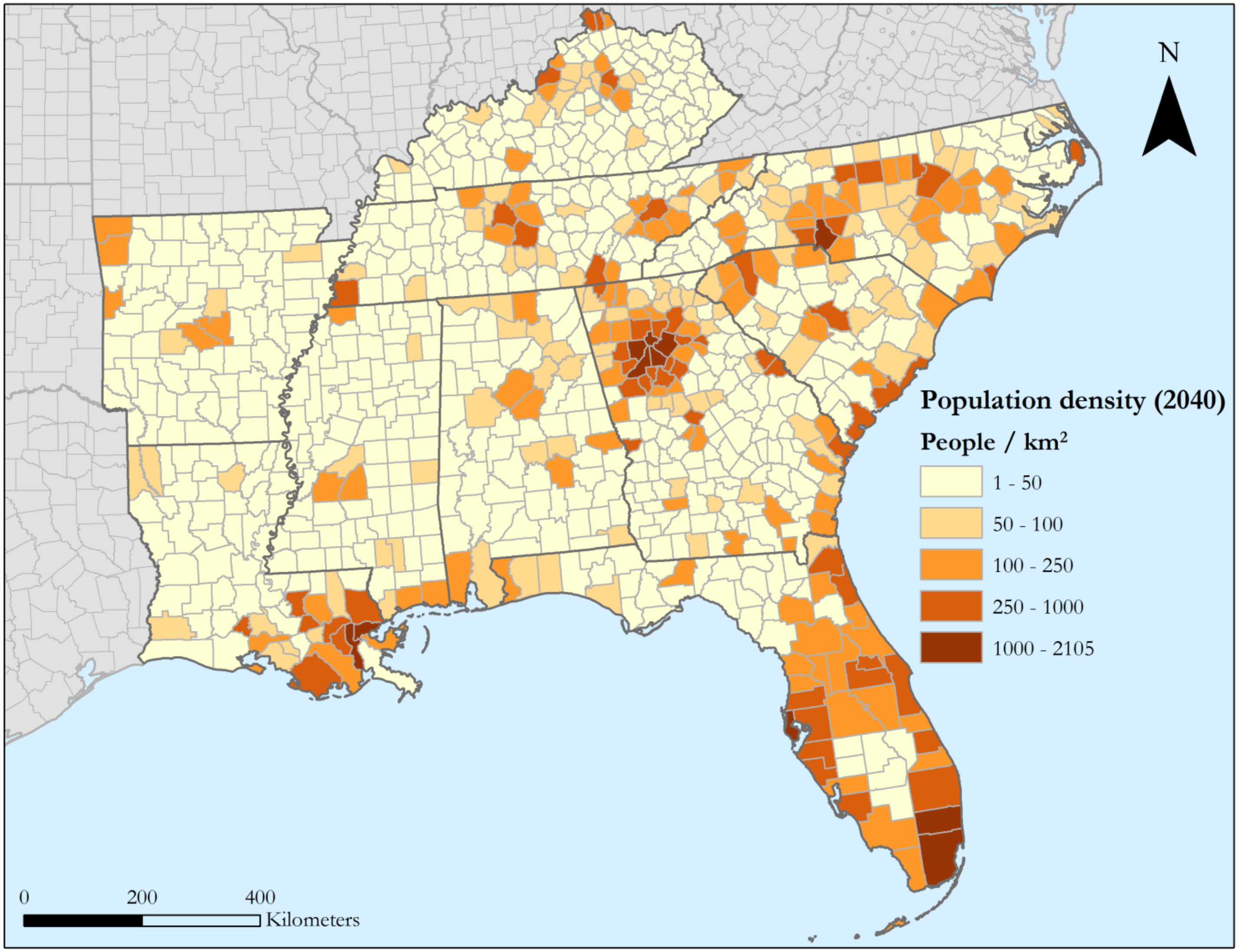
Variable (per county)		Source
Number of listed species		United States Fish and Wildlife Service Environmental Conservation Online System database (ECOS)
Number of listed species		United States Geological Survey Biodiversity Information Serving Our Nation database (BISON)
Protected area (GAP classes 1 and 2 only)		United States Geological Survey Protected Areas Database of the United States version 1.3 (PAD)
Projected urban area in 2040		Terando et al. 2014
Waterbody area		United States Geological Survey National Hydrography Dataset (NHD)
Forest loss and gain from 2000 to 2012		Global Forest Watch
Population projections through 2040	Alabama	University of Alabama – Center for Business and Economic Research
	Arkansas	University of Arkansas at Little Rock – Institute for Economic Advancement
	Florida	The Florida Legislature – Office of Economic & Demographic Research
	Georgia	State of Georgia – Governor's Office of Planning and Budget
	Louisiana	State of Louisiana
	Kentucky	University of Louisville – Kentucky State Data Center
	Mississippi	Mississippi Institutions of Higher Learning – Office of Policy Research and Planning
	North Carolina	State of North Carolina – Office of State Budget and Management
	South Carolina	State of South Carolina – Revenue and Fiscal Affairs Office
	Tennessee	State of Tennessee – Tennessee Advisory Commission on Intergovernmental Relations

Appendix Table 2. Summary statistics for raw and derived variables. All variables' units are per county; *n* = 875 unless otherwise noted.

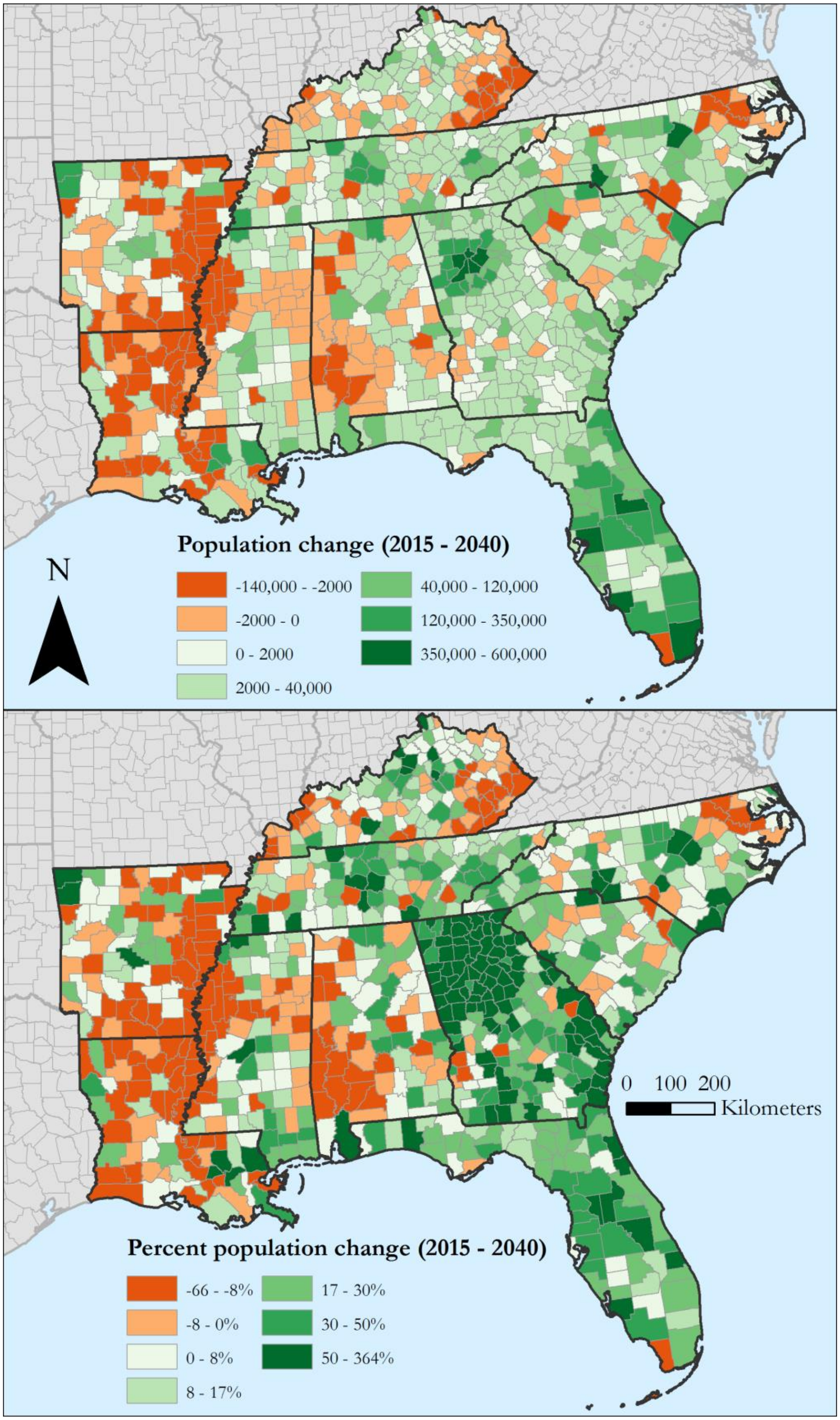
Variable	Mean	Standard Deviation	Minimum	First Quartile	Median	Third Quartile	Maximum
Species (ECOS)	5.3257	5.4086	0	1	3	7.25	33
Species (BISON)	3.6960	4.8508	0	0.75	2	4	47
Human population, 2040	105,566.5051	237,863.7622	1273	13,817.25	32,206	50,459.25	3,260,274
Human population change, 2015 – 2040	24,207.1954	68,462.3660	-138,550	-943.25	2504	11,683	597,400
% human population change, 2015 – 2040	19.1742	38.4422	-65.5183	-4.3681	10.8010	27.1702	364.0157
Urbanized area, 2040 (km^2) (*n* = 806)	93.3537	150.5672	0.6084	13.7907	40.8096	70.47	1182.035
% urbanized area, 2040 (*n* = 806)	6.7370	9.4575	0.0366	0.9807	3.4086	6.7954	79.4464
Inhabitable area, 2040 (km^2)	1265.3204	591.4078	92.2375	906.6986	1212.9269	1721.1187	4589.8910
% inhabitable area, 2040	91.5374	17.3132	5.7906	87.4391	95.6522	97.5898	328.0494
Population density (people/km^2), 2040	90.5421	192.4694	1.2346	13.0696	29.9056	68.8270	2104.1998
Protected area, 2015 (km^2)	64.1868	197.6573	0	0	4.5979	90.9143	3043.8328
% protected area, 2015	3.4536	7.9703	0	0	0.4004	5.2359	85.3495
Forest change area, 2000 – 2012 (km^2)	-87.0884	191.2805	-2046.1445	-68.8267	-26.8157	-6.9689	52.2729
Water area, 2015 (km^2)	111.7917	278.1987	0.5142	6.9759	40.1486	71.2142	3701.9385



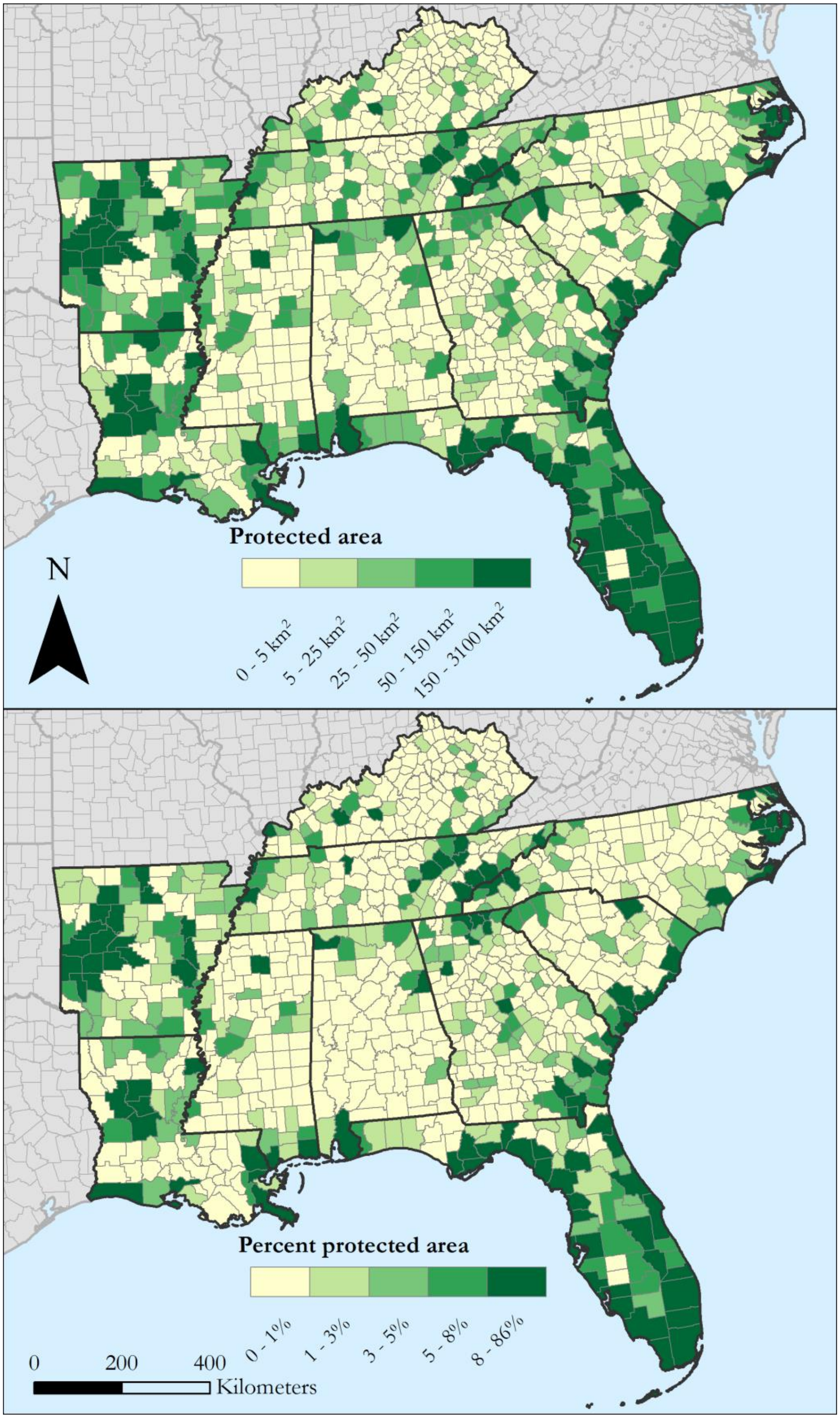
Appendix Figure 1. Histogram of R^2 values for study-estimated (linear regression) future populations of counties without official population projections extending to 2040 (n = 451). Projection fit was very high for 92% of counties evaluated.



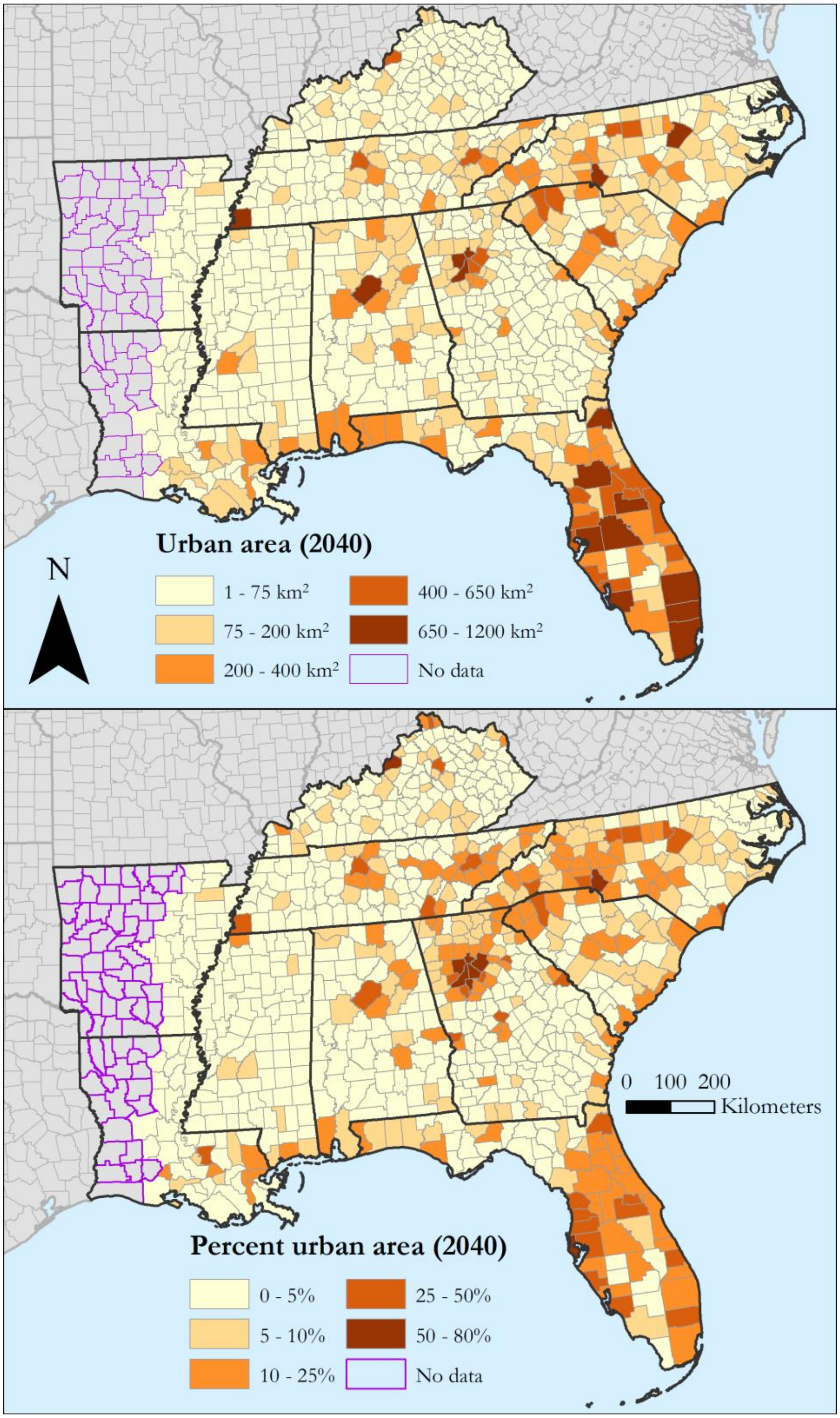
Appendix Figure 2. Projected human population density in 2040.



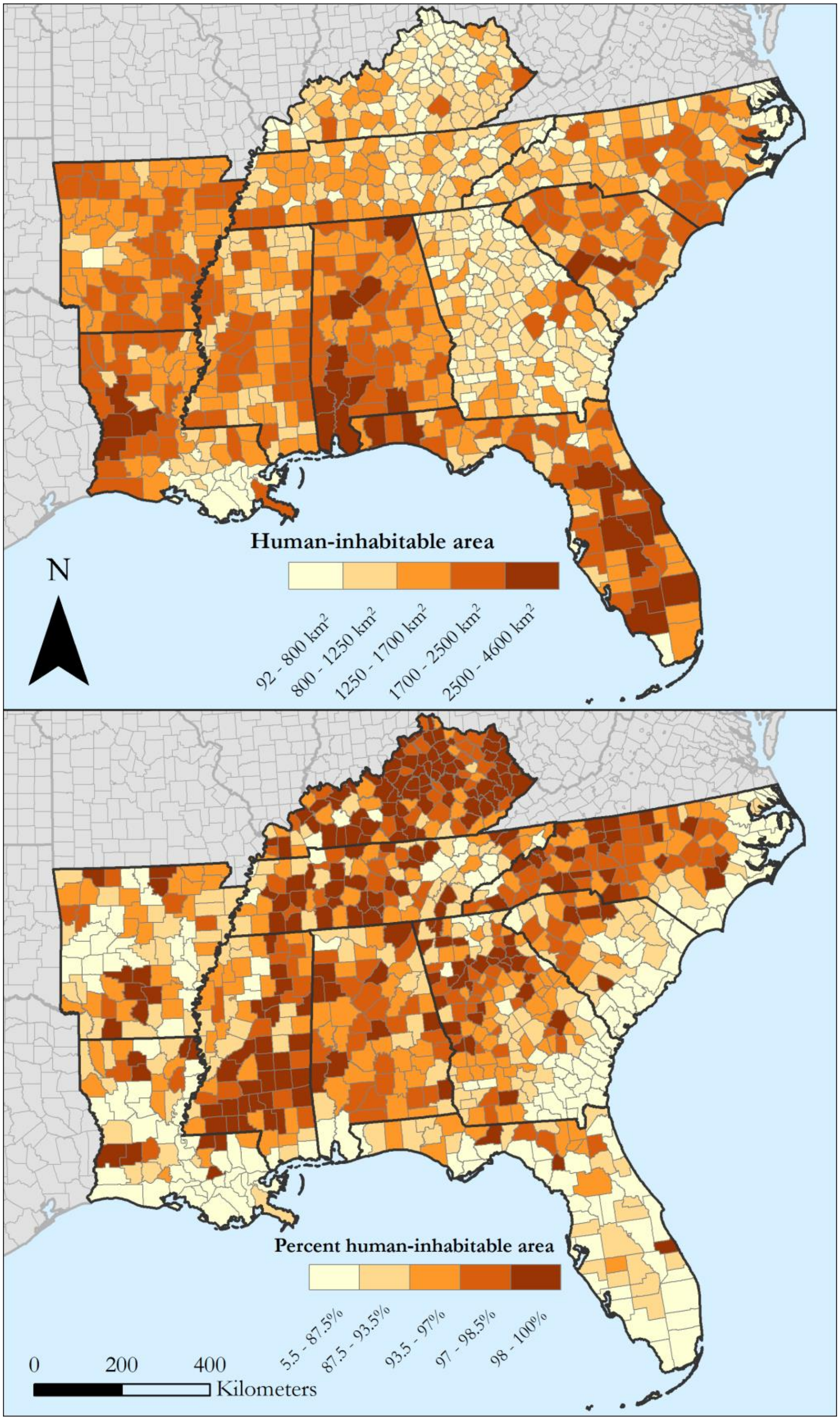
Appendix Figure 3. Projected population change (top) and percent population change (bottom), from 2015 to 2040.



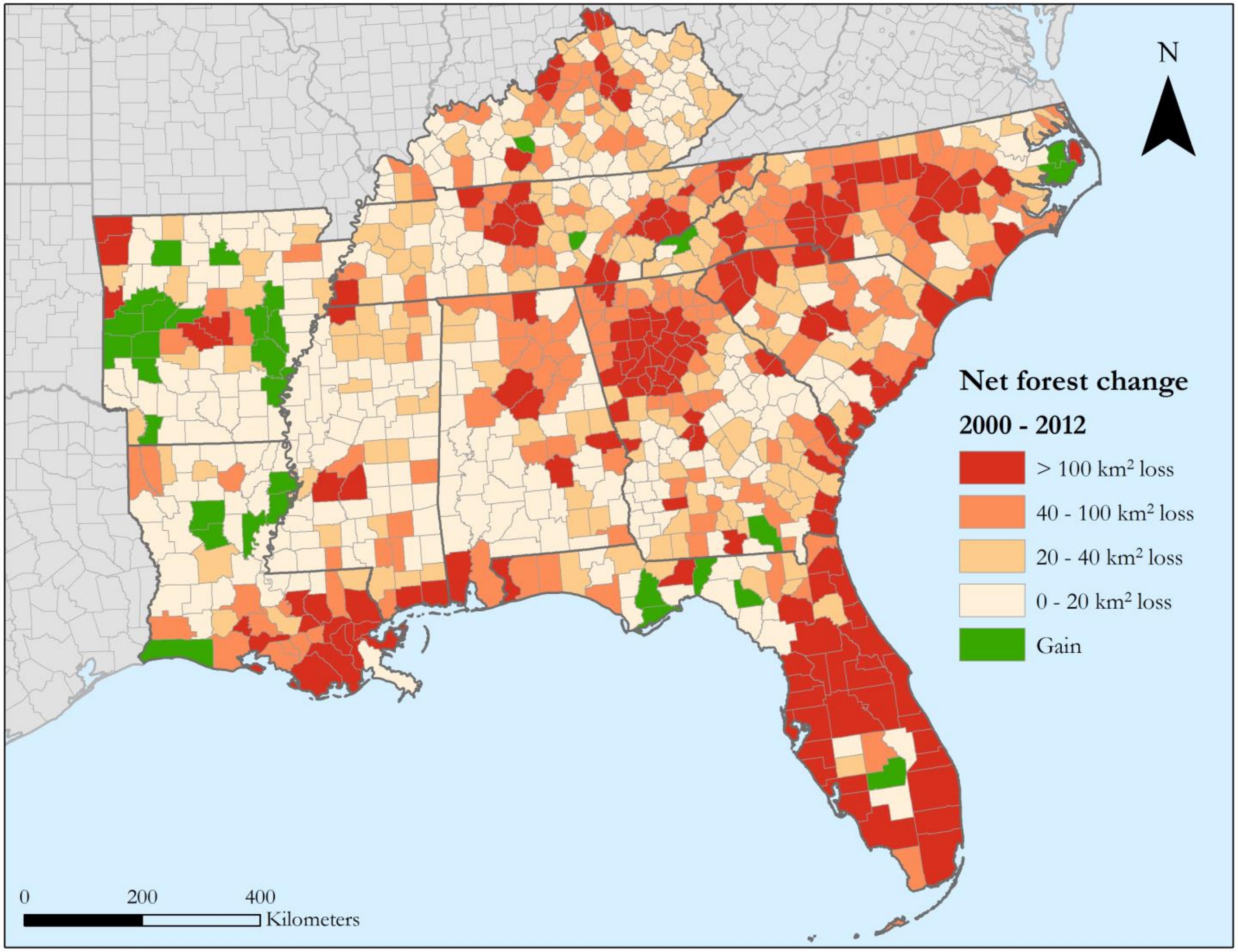
Appendix Figure 4. Total protected area (top) and percent protected area bottom, as of 2015.



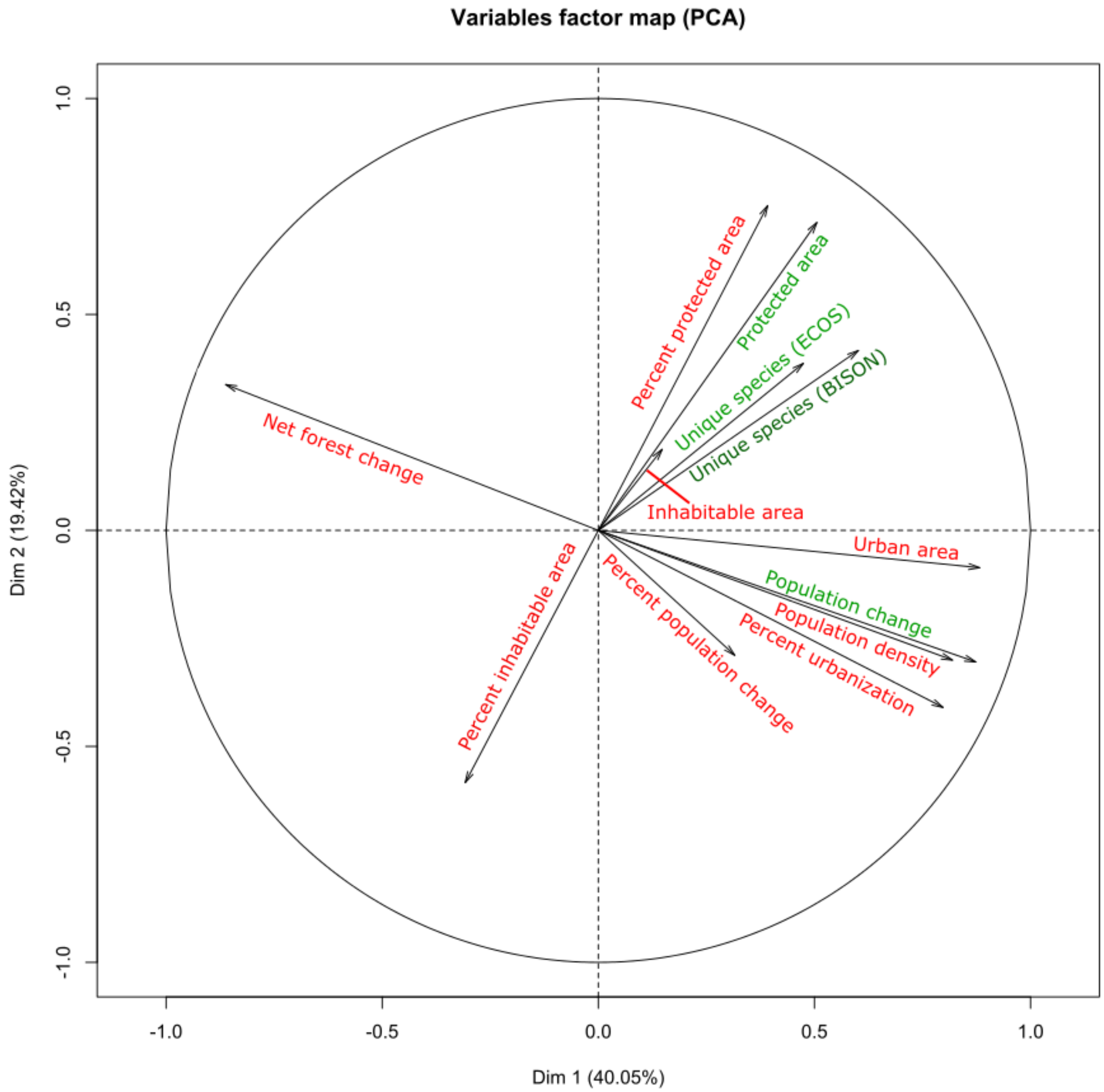
Appendix Figure 5. Projected urban area (top) and percent urban area (bottom) by 2040. Note that the data source (Terando et al. 2014) did not perform urbanization projections for counties in the western halves of Arkansas and Louisiana.



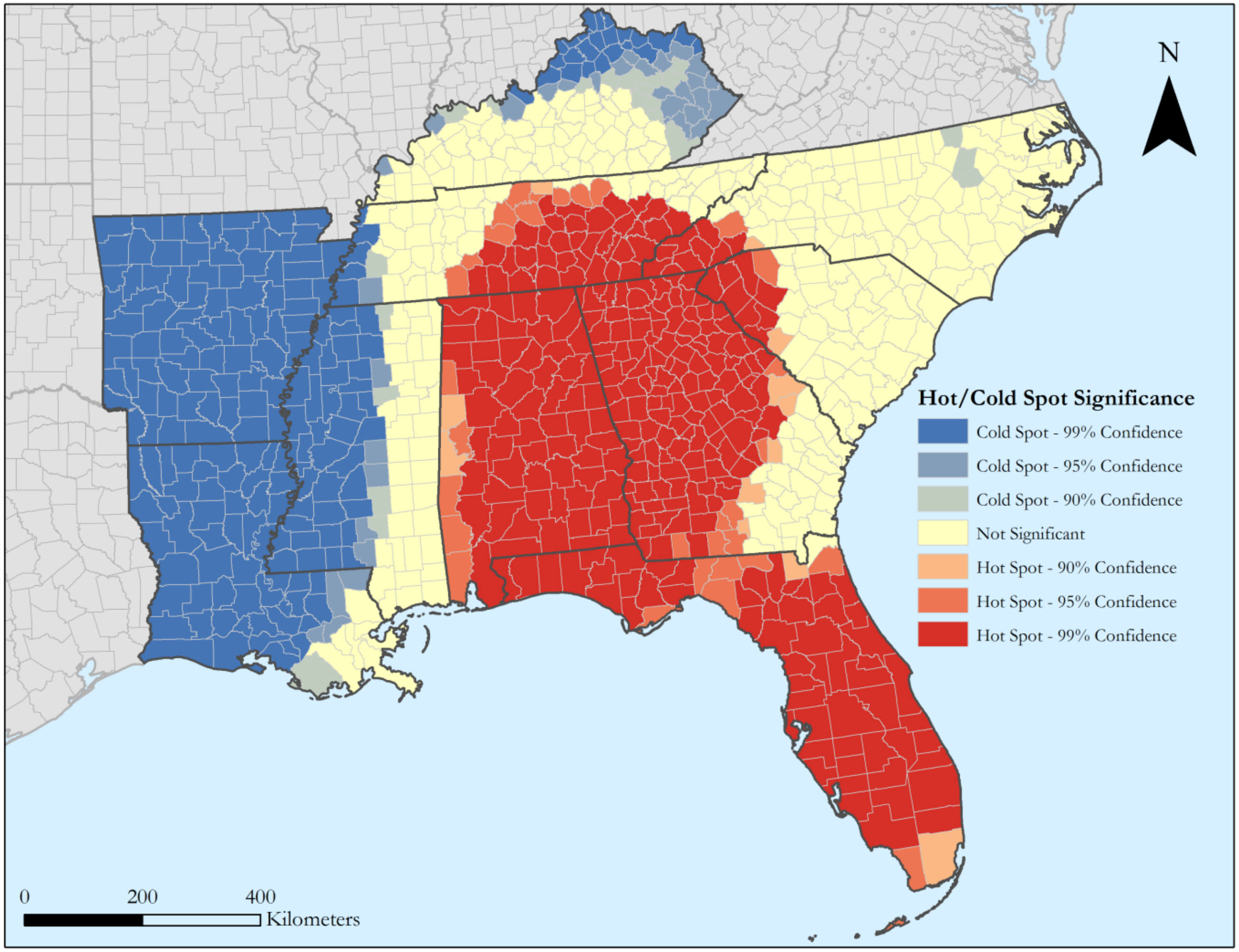
Appendix Figure 6. Human-inhabitable area and percent human inhabitable area in 2015.



Appendix Figure 7. Net forest change area from 2000 through 2012.



Appendix Figure 8. PCA plot of standardized variables. The three standardized variables used in the metric model are in green and the variables not used are in red. The number of unique species per county according to BISON is colored in dark green to indicate that we could have opted to use that variable instead of the species according to ECOS.



Appendix Figure 9. Optimized hot-spot analysis of the metric value per county. The hot spot analysis compared the metric value in a target county to the values of nearby counties, looking for a significant spatial distribution of those values. In this case, the "hot" spots (red) indicate a significant clustering of counties with high metric values. Similarly, the "cold" spots (blue) indicate a significant clustering of counties with low metric values. The yellow color indicates a non-significant distribution of metric values.

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