# Elk Habitat Suitability Index Map for North Carolina

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Executive Summary

Rocky Mountain elk (*C. e. nelson*) were introduced in the North Carolina's portion of the Great Smoky Mountains National Park in the early 1900s, an attempt to restore elk populations in the Carolinas. The North Carolina Wildlife Resources Commission is considering the possibility of conducting additional reintroductions outside the Park. The success of such attempts is intimately related to habitat quality. Therefore, a state-wide habitat suitability assessment was conducted to help the Commission identify potential sites for elk reintroduction and explore the feasibility of developing a strategy to achieve a successful reintroduction elsewhere in the State. Suitability herein was defined as habitat that provided the core biological requirements to sustain an elk population taking in consideration sociological constraints (e.g., proximity to roads, agricultural fields). We used fine scale data sets and a two-stage approach to remove areas where elk-human conflicts were more likely (minimize), while retaining areas based on biological indicators of elk habitat quality (maximize). The extent of habitat deemed suitable for elk in North Carolina was categorized as 41% unsuitable, 30% low suitability, 29% medium suitability, and <1% high suitability. The coastal plain and piedmont offered the best suitability throughout the State; however, it was largely eliminated from the habitat suitability pool due to extensive agricultural activities and the pervasiveness of secondary roads. There is plenty of forest and open habitat throughout the state, but successional scrub and shrub was a limiting factor and critical in identifying highly suitable habitat. This work provides a basis to evaluate some of the consequences and the trade-offs associated with alternative actions that would be considered in the reintroduction strategy. Our assessment underscores that any proposed reintroduction site, be it in the mountains or piedmont, will quickly lead to elk-human interactions. As such, a reintroduction strategy should be coupled with a well-coordinated outreach and education campaign.

## INTRODUCTION

Eastern elk (*Cervus elaphus canadensis*) were plentiful in the Carolinas prior to European development in the 1700's (Brickell 1737, Van Doren 1955). Populations began to decline with the advent of large-scale habitat loss, unregulated hunting, and competition from domestic livestock (Christensen 1998, O'Gara and Dundas 2002), eventually leading to their extirpation by the mid 19th century. Since the early 1900's, several eastern states have attempted to reintroduce the Rocky Mountain elk (*C. e. nelson*) (Bryant and Maser 1982, Larkin et al. 2003, McClafferty and Parkhurst 2001). These reintroductions led to the current population located in the North Carolina's portion of the Great Smoky Mountains National Park (GSMNP; Murrow 2007).

The North Carolina Wildlife Resources Commission (NCWRC) is considering the possibility of conducting additional reintroductions outside the GSMNP. Because the success of such attempts is intimately related to habitat quality, the NCWRC tasked the Biodiversity and Spatial Information Center at the North Carolina Cooperative Fish and Wildlife Research Unit to conduct a state-wide habitat suitability assessment. The goal of this project was not to develop a new habitat suitability model, but to use existing models to conduct a rapid assessment of habitat. The NCWRC would use this product to identify potential sites for elk reintroduction and explore the feasibility of developing a strategy to achieve a successful reintroduction elsewhere in the State.

Suitability herein is defined as habitat that provided the core biological requirements to sustain an elk population taking in consideration sociological constraints (e.g., proximity to roads, agricultural fields). While many models of elk habitat suitability have been developed (Wisdom et al. 1986, Thomas et al. 1988, Van Deelen et al. 1997, Beyer 1987, Long 1996, Edge et al. 1987, Lyon 1979, Coe et al. 2011), few have been based on data from eastern United States. Of these studies, we felt that those by Didier and Porter (1999) and Zysik (2010) provided a better foundation to conduct a state-wide assessment of elk habitat suitability. Didier and Porter (1999) developed a suitability model for eastern New York, whereas Zysik (2010) used telemetry data collected in Kentucky to assess and refine Didier and Porter's model. The assessment presented here was based on Zysik's (2010) refined model with some additional modifications.

## STUDY AREA

The study extent includes the entirety of North Carolina. Elk were known to inhabit much of the eastern Appalachian Mountains and piedmont prior to European settlement. As vast amounts of their habitat was converted to agriculture and unregulated hunting pressure increased, elk were extirpated from North Carolina in the late 1700's. With the increase in forest woodlots and the decline of agricultural clearings since the highpoint in the early 20th century, what is believed to be viable elk habitat permeates throughout much of the state.

## METHODS

Our analytical approach followed procedures outlined in Didier and Porter (1999) and Zysik, (2010). These studies outlined a two-stage modeling approach which included; 1) a coarse, low-resolution stage to remove areas where elk-human conflicts were less likely, and 2) a fine, high-resolution stage-based on biological indicators of elk habitat quality. Our approach differs from these previous studies in that we utilized fine scale data to delineate areas of high probability of elk-human conflicts. Therefore, we defined the two-stage approach used in this study as: 1) eliminating areas from consideration based on sociological constraints, and 2) biological factors supporting elk habitat utilization.

Sociological Constraints -- Three sociological constraints were assessed to identify areas of low potential of human-elk conflicts. These were urban land use, agricultural production, and proximity to 4 land highways. Urban land use was defined by the Southeast Gap Analysis Project (SE-GAP) Urban Avoid dataset (USGS SE-GAP, 2007) by compiling secondary road density (U.S. Census Bureau, 2007) and buffered urban development from the SE-GAP land cover data set (USGS SE-GAP, 2010). We removed areas from consideration by utilizing the medium and high exclusion setting from the SE-GAP Urban Avoid dataset (i.e. portions of the landscape identified as being *highly or moderately* influenced by human disturbance). Areas of high agricultural activity were also removed from consideration due to the inherent conflict with potential crop depredation. The fine scale approach utilized for this assessment used the percentage of row crops within 20,000 acres to set a suitability value. We applied the scale of a functional relationship to rank suitability, where 0% - 5% results in full suitability (1), 5% - 20% is a linear function from full suitability (1) to no suitability (0), and greater than 20% represented no suitability (Figure 1). The third and final component of sociological constraints relates to the proximity to 4-lane divided highways. We applied a fine scale filter on 4-lane highways of a functional relationship to rank suitability, where distances of < 1 km provides no suitability (0), 1 km – 8 km is an increasing linear function from 0 to 1, and > 8 km represented full suitability (1) (Figure 2). The composite suitability value for sociological constraints is the product the three components.

$$SV_{sc} = [\ SV_{rc} * SV_{hwy} * SV_{urban}\ ]$$

The final step in the suitability assessment was to remove contiguous areas < 500 km$^2$ as these are not thought large enough to sustain a viable population (Witmer 1990).

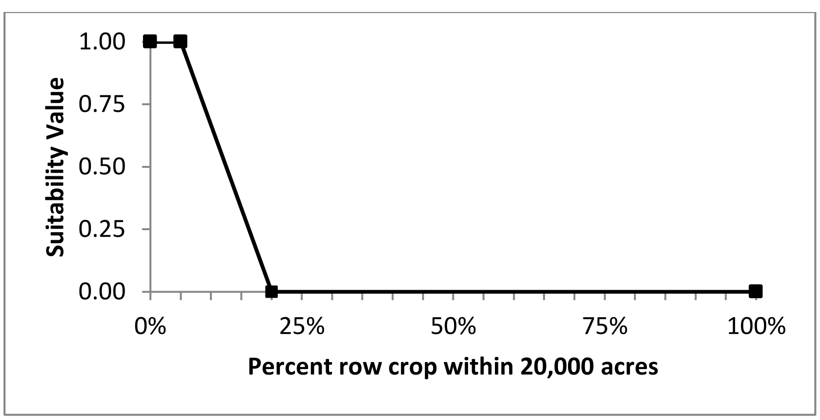


Figure 1. Relationship used to calculate suitability values for percent row crops.

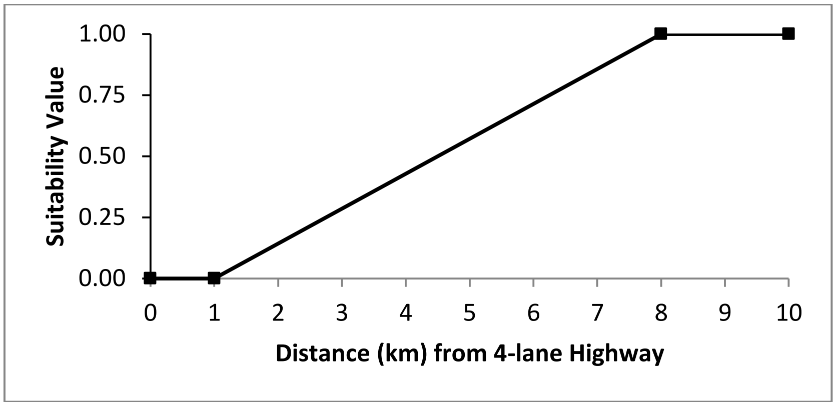

Figure 2. Relationship used to calculate suitability values for distance from 4-lane highways.

<u>Biological Parameters</u> - The modeling of biological parameters was based on Zysik's (2010), which utilized telemetry data to refine Didier and Porter's (1999) model. Five components were incorporated into the biological parameters: 1) food and cover habitat, 2) hardwood forest habitat, 3) successional scrub/shrub habitat, 4) open habitat, and 5) secondary road density. Land cover from SE-GAP was used to estimate these habitat categories. SE-GAP land cover is based on 2001 Landsat Thematic Mapper imagery. We aggregated the 82 land cover classes present in North Carolina into 10 classes to match the thematic grain of Zysik's (2010) model (Appendix A). There are newer NLCD data (i.e., 2006; Wickham et. al, 2013); however, the aggregation of woodland and forest classifications in the latter dataset were deemed incompatible with the thematic classification required to pick up habitat affinities of elk. Spatial analyses were conducted using ArcGIS 10.0 and Model Builder 10.0 (ESRI, Inc.).

Table 1. Suitability values for food and cover.

| Code | Cover Type | HSI Food | HSI Cover |
|---|---|---|---|
| 1 | Deciduous | 0 | 1 |
| 2 | Coniferous | 0 | 1 |
| 3 | Mixed Deciduous/Coniferous | 0 | 1 |
| 4 | Shrub/Successional | 1 | 1 |
| 5 | Open | 1 | 0 |
| 6 | Urban | 0 | 0 |
| 7 | Barren | 0 | 0 |
| 8 | Water | 0 | 0 |
| 9 | Wetland | 0 | 0 |
| 10 | Other | 0 | 0 |

Each land cover type was assigned a food and cover suitability value as per Zysik's (2010) refined model (Table 1). Land cover was reassigned to a corresponding suitability value ($SV_{cv}$, $SV_{fd}$). Distance modifiers ($MOD_{df}$, $MOD_{dc}$) were applied to both cover and food suitability values to assess the degree of interspersion of habitats resulting in corresponding modified suitability values ($MSV_{cv}$, $MSV_{fd}$).

$$MSV_{fd} = SV_{fd} * MOD_{dc}$$

$$MSV_{cv} = SV_{cv} * MOD_{df}$$

Distance functional relationships (Figures 3 and 4) developed by Zysik (2010) are based on the movement behavior of elk in Kentucky (Wichrowski 2001) and seasonal movements reported by Didier (1998). The high distance afforded to food that received a full suitability value is due to the limitation of remotely sensed data to discern small forest openings which provide forage opportunities for elk.

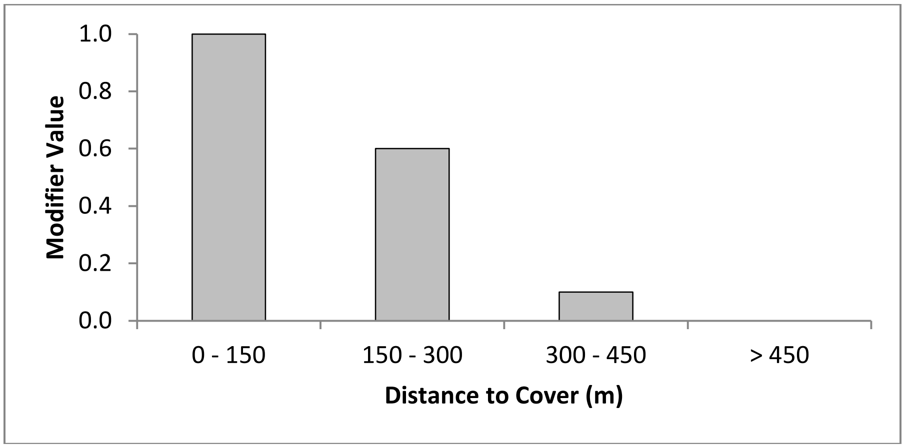


Figure 3. Functional relationship for distance to cover modifier.

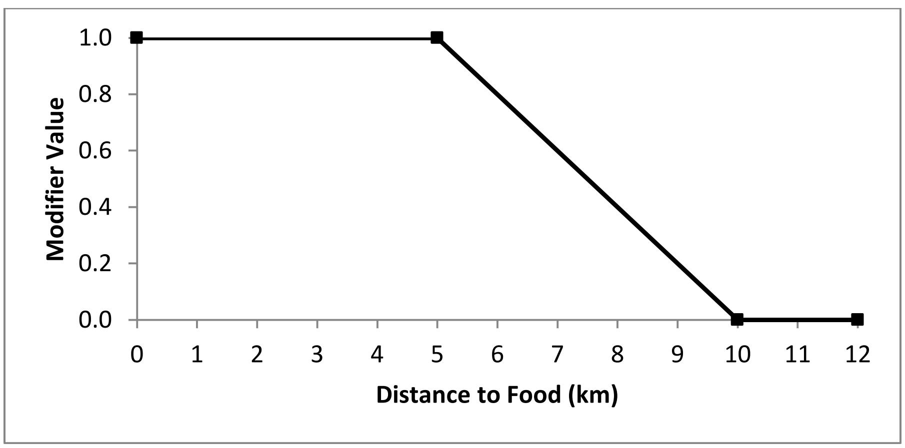


Figure 4. Functional relationship for distance to food modifier.

The combined cover/food suitability value was based on the greater modified suitability value except where both are > 0, in which case the suitability value was set at 1.

$$SV_{cvfd} = IF(MSV_{dc} = 1 \text{ and } MSV_{fd} = 1, THEN\ 1, ELSE$$
$$IF(SV_{fd} > 0 , THEN\ MSV_{dc}, ELSE$$
$$IF\ (SV_{cv} > 0, THEN\ MSV_{df}, ELSE\ 0)))$$

Habitat diversity was characterized by the percentage of three distinct habitat types: forest, successional scrub/shrub, and open habitats. Functional relationships defining suitability were taken from Didier and Porter (1999; Figure 5).

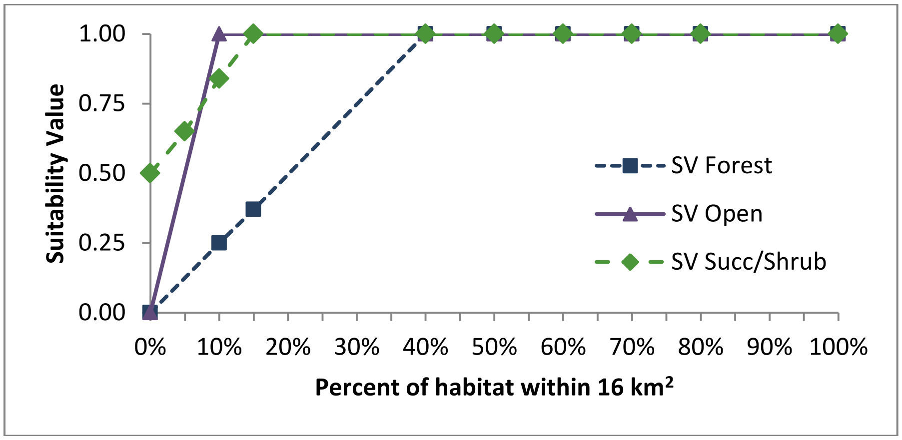


Figure 5. Functional relationships used to calculate suitability values based on percent of habitat type present within 16 $km^2$.

Elk avoids habitat adjacent to roads in numerous studies (Lyon 1983, Rost and Bailey 1979, Edge 1982, Edge et al. 1987, Rowland 2000). Thus, the potential influence of roads on habitat quality was incorporated by developing a suitability value based on the density of secondary roads (Figure 6) taken from Zysik (2010). The analysis window was based on a 55 km2 average elk home range in Kentucky (Wichrowski 2001).

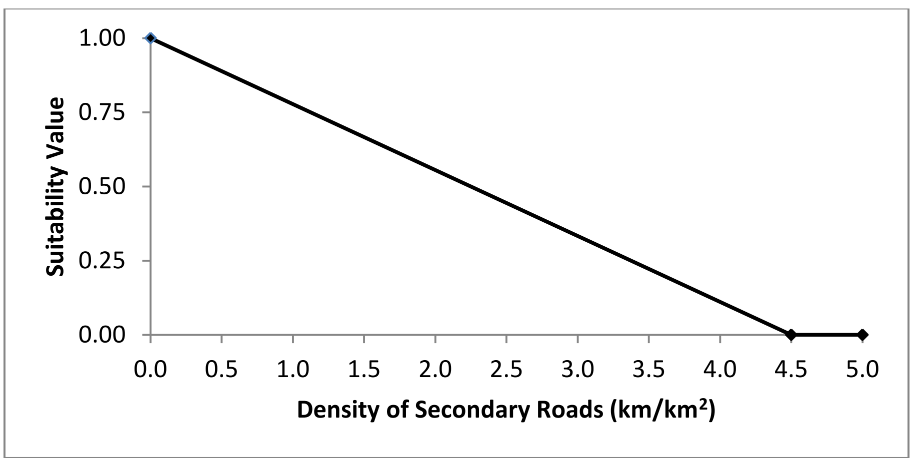


Figure 6. Functional relationship used to calculate suitability value based on secondary road density within 55 $km^2$.

The five biological parameters were then combined into a single suitability value (SVbp) using a geometric mean, thereby ensuring that each component is present in all SVbp scores greater than 0.

$$SV_{bp} = [\ SV_{cvfd} * SV_{forest} * SV_{open} * SV_{shrub} * SV_{roads}\ ]^{1/5}$$

The final suitability value (FSV) is the product of the suitability values from sociological constraints ($SV_{sc}$) and biological parameters ($SV_{bp}$).

$$FSV = [ SV_{sc} * SV_{bp} ]$$

RESULTS

Sociological Constraints – To reduce human-elk conflicts, previous efforts by Zysik (2010) and Didier and Porter (1999) excluded counties with populations >100,000 people. This coarse scale approach in North Carolina excludes 27 counties, accounting for 31.8% of the total land area within the state (U.S. Census Bureau, 2012) (Figure 7). The fine scale approach used in this assessment to delineate human activity by the Urban Avoid dataset (USGS SE-GAP, 2007) excluded only 5.8% of the total land area of the State (Figure 8).

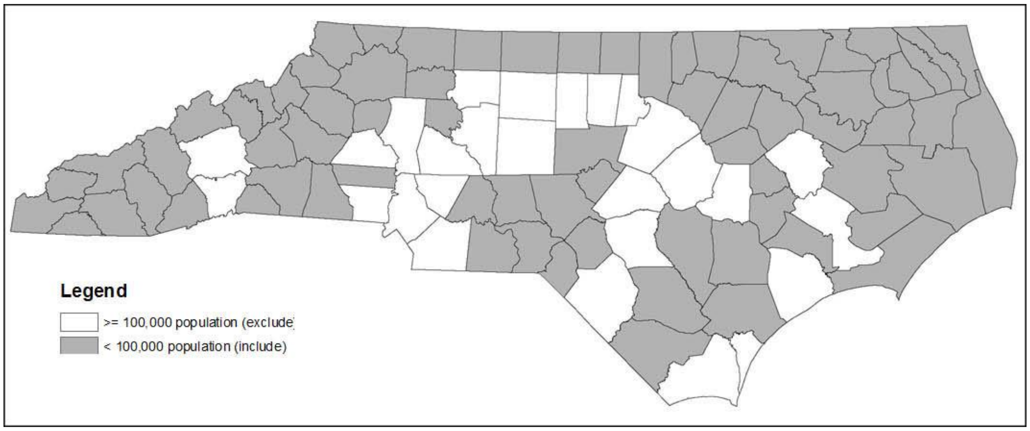


Figure 7. Counties with human population > 100,000.

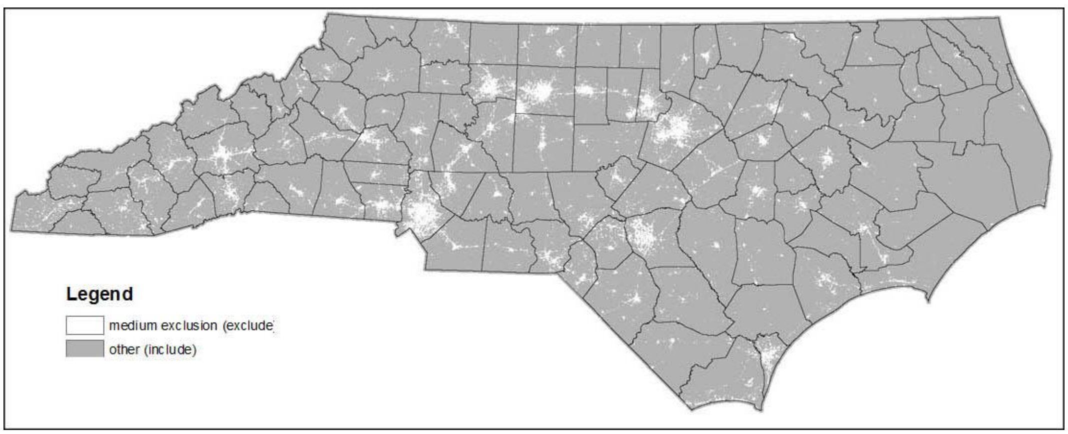


Figure 8. Medium exclusion value of the SE-GAP Urban Avoid dataset.

Previous efforts at identifying areas with high potential for crop depredation excluded counties with > 15% of land cover as row crops (Zysik, 2010 and Didier and Porter, 1999). There are 36 counties in North Carolina that fall into this category (Figure 9), all of which are in the coastal plain eco-region and comprise 39.0% of the total land area. The fine scale approach utilized for this effort excluded 27.0% of the total land area outright and suppressed suitability scores for another 17% (Figure 10).

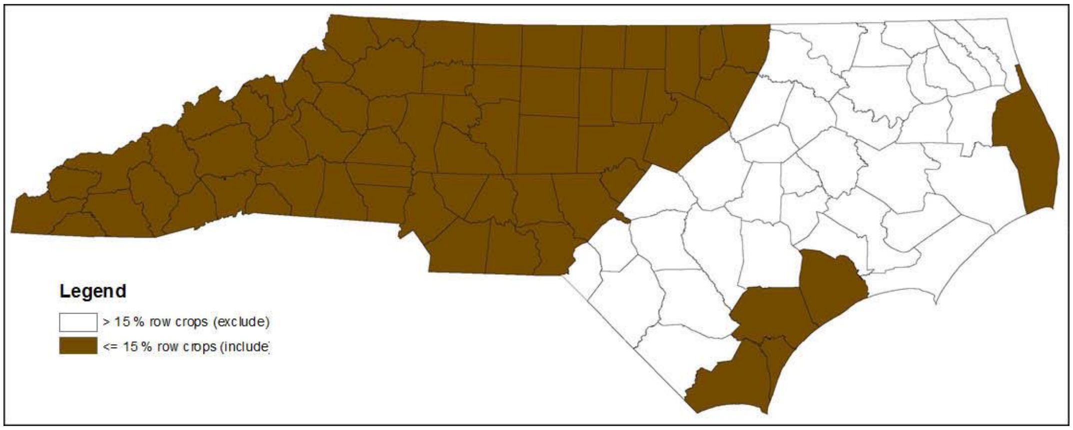

Figure 9. Counties with > 15% of the land cover as row crops.

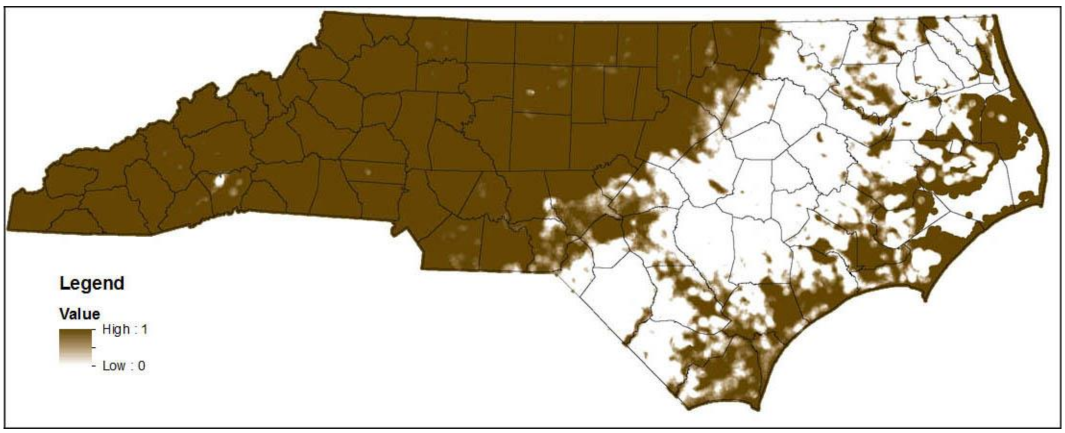

Figure 10. Suitability value based on percent of row crops within 20,000 acres.

Zysik (2010) and Didier and Porter (1999) identified an exclusion zone associated with 4-lane highways with an 8 km buffer (Zysik, 2010 and Didier and Porter, 1999) (Figure 11). In North Carolina, this would remove 53.0% of the land area. The fine scale approach used in this assessment excluded 27.0% of the total land area outright plus suppressing suitability for another 17.0% (Figure 12).

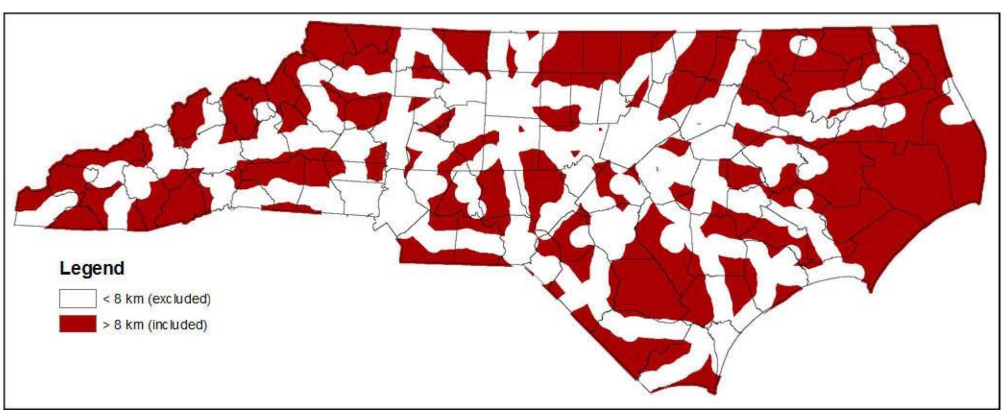

Figure 11. 8 km buffer on 4-lane highways.

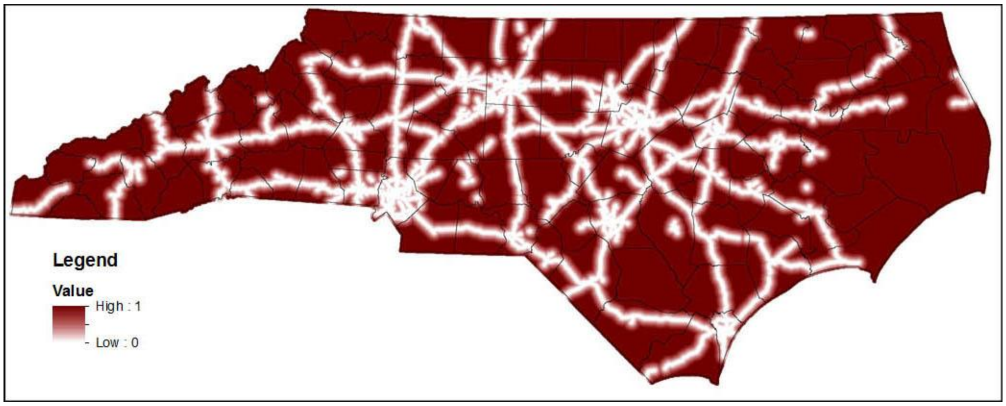


Figure 12. Suitability value based on distance from 4-lane highways.

After filtering out contiguous habitat inclusion patches < 500 km$^2$, the application of the Zysik (2010) and Didier and Porter's (1999) stage 1 "exclusion masks" result in over 80% of the land area in the State being excluded (Figure 13). In contrast, the fine scale approach utilizing suitability values for row crop percentage and distance from 4-lane highways result in 43.8% of the land are being excluded outright, with an additional 31.4% having suppressed suitability value (Figures 14 and 15).

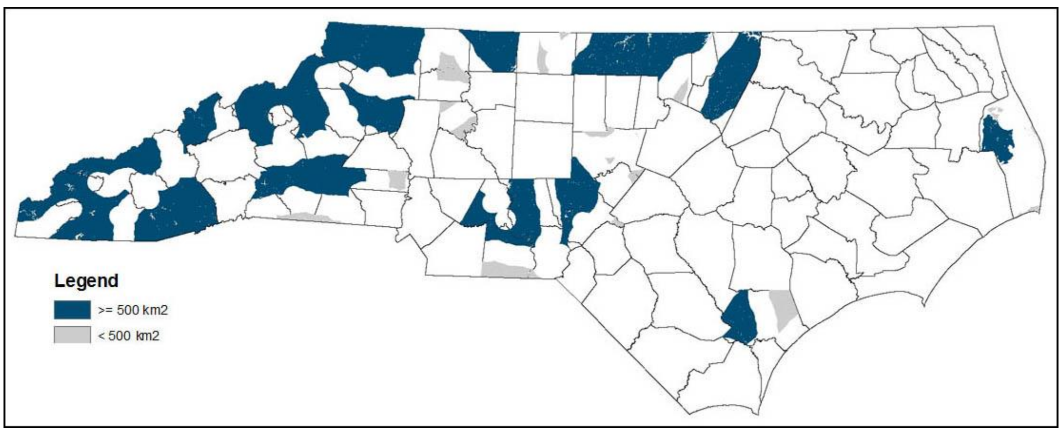


Figure 13. Composite of coarse sociological constraints highlighting contiguous areas > 500 km$^2$.

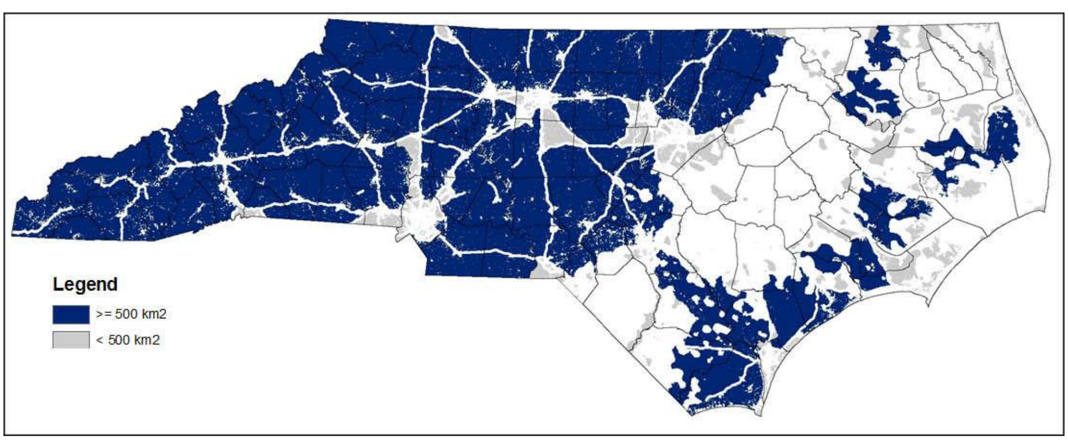


Figure 14. Composite of sociological constrains highlighting contiguous areas > 500 km$^2$.

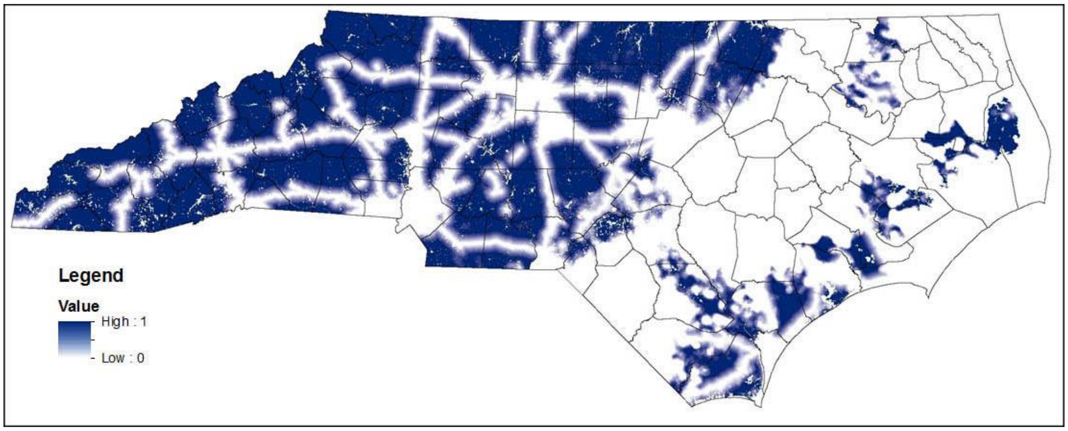

Figure 15. Suitability value of sociological contraints ($SV_{sc}$).

Biological Parameters - The suitability value depicting food and cover ($SV_{cvfd}$) had over 80% of the total land area with the highest suitability value (1.0). Lower suitability values of 0.6 and 0.1 represented less than 3% and remaining land area of 16.5% was fully unsuitable (0.0) (Figures 16 and 17). The suitability values of both forest and open habitat were also dominated by the preponderance of full suitability values, 57% and 28%, respectively (Figures 18, 19, 20, and 21). Successional and scrub/shrub suitability values, on the other hand, had very little suitability values over 0.5 (Figures 22 and 23). Secondary road suitability values had less than 1% of the total land area excluded outright, 81% had suppressed suitability, and 18% received full suitability value (Figures 24 and 25).

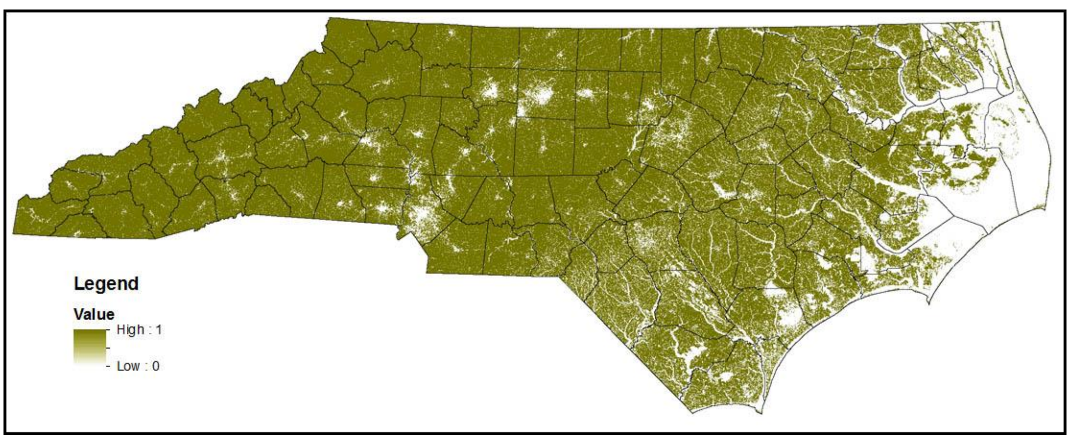

Figure 16. Suitability value of food and cover composite.

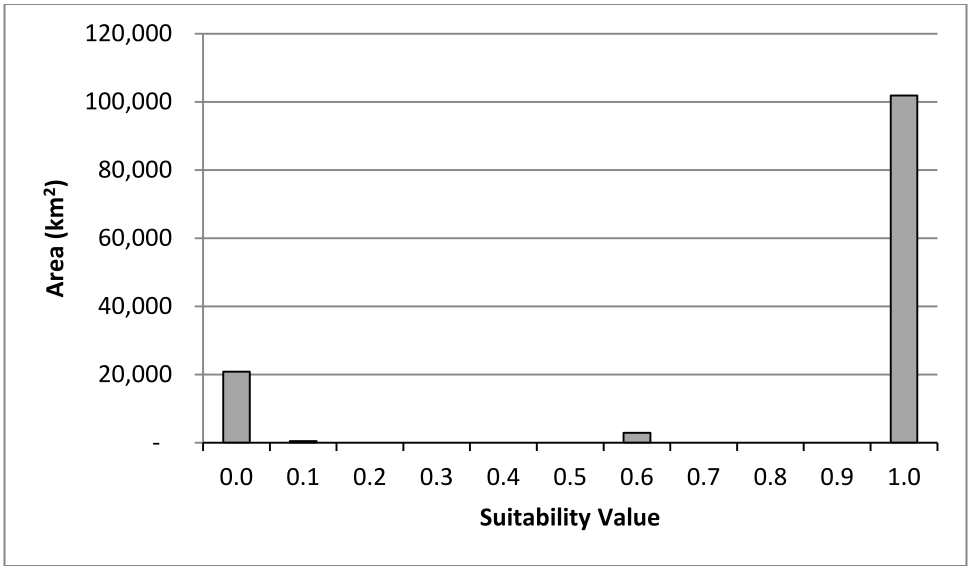

Figure 17. Distribution of food and cover suitability value.

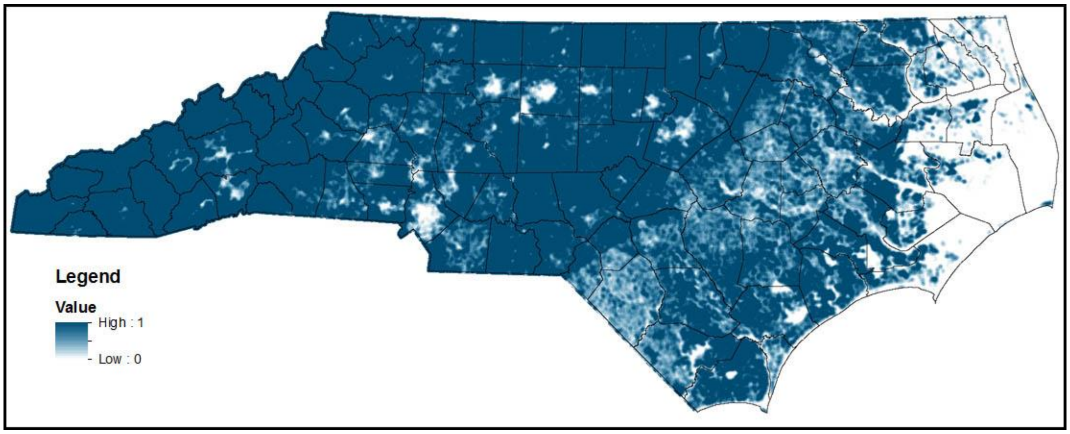

Figure 18.  Suitability value of forested habitat percent cover.

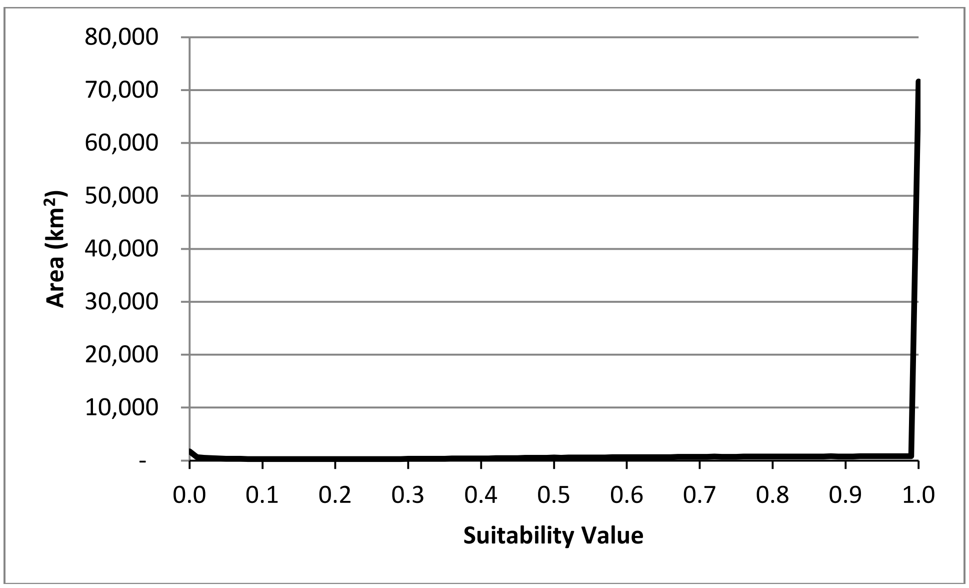

Figure 19.  Distribution of forest habitat suitability value.

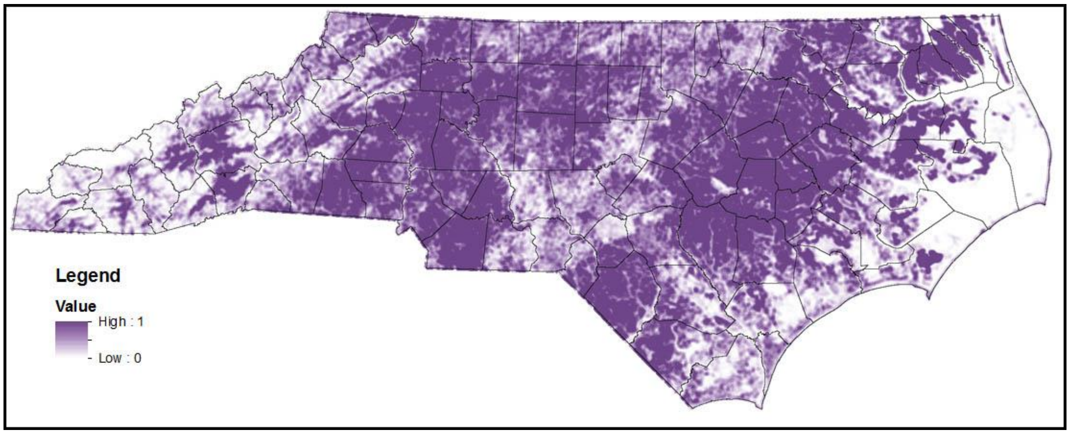

Figure 20. Suitability value of open habitat percent cover.

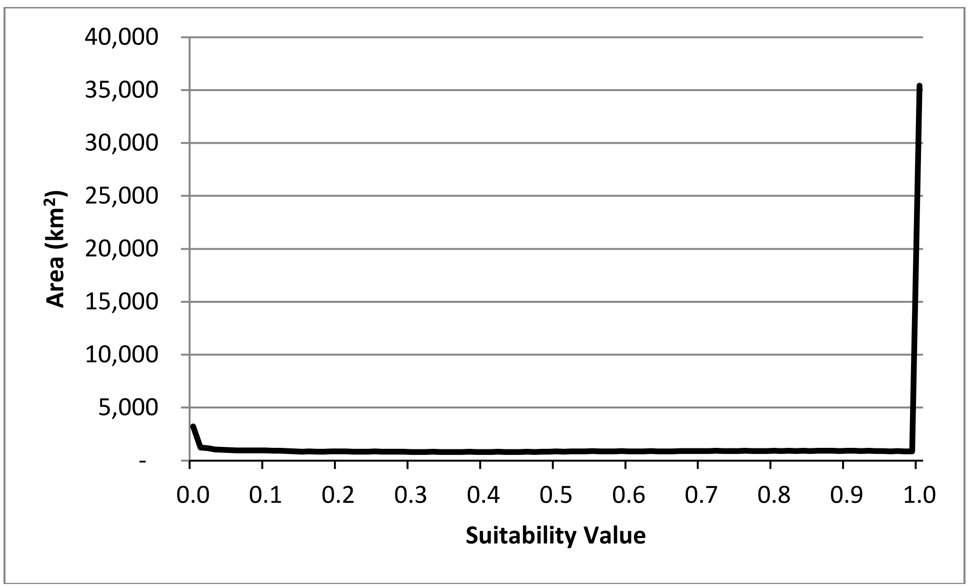

Figure 21. Distribution of open habitat suitability value.

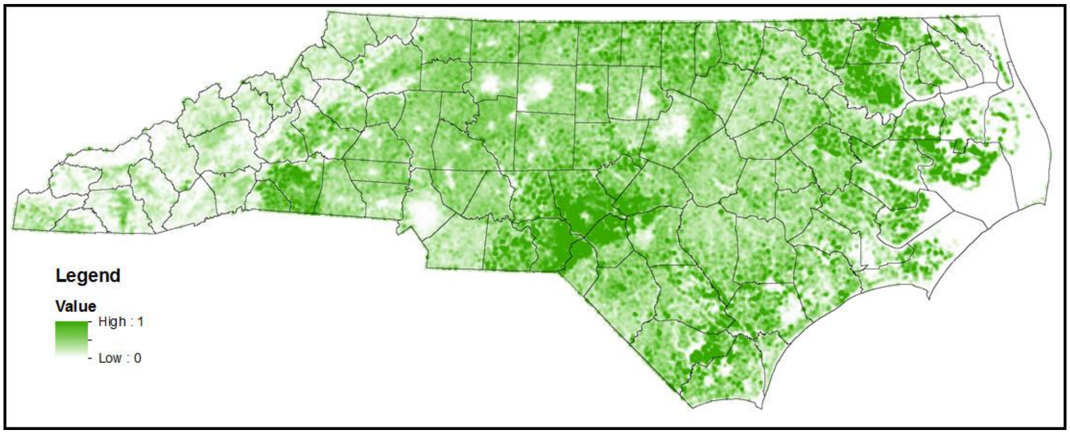


Figure 22. Suitability value of successional scrub/shrub habitat percent cover.

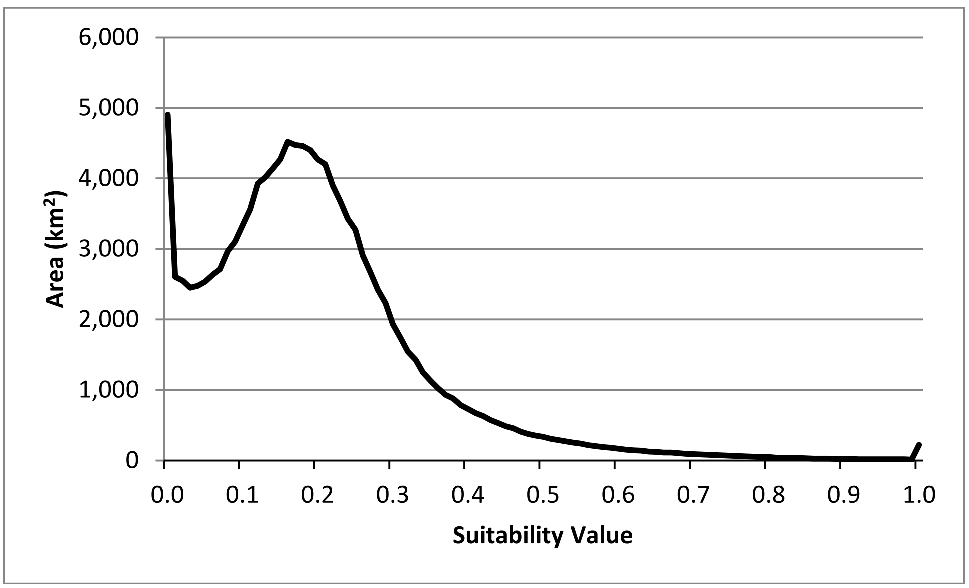


Figure 23. Distribution of successional scrub/shrub habitat suitability value.

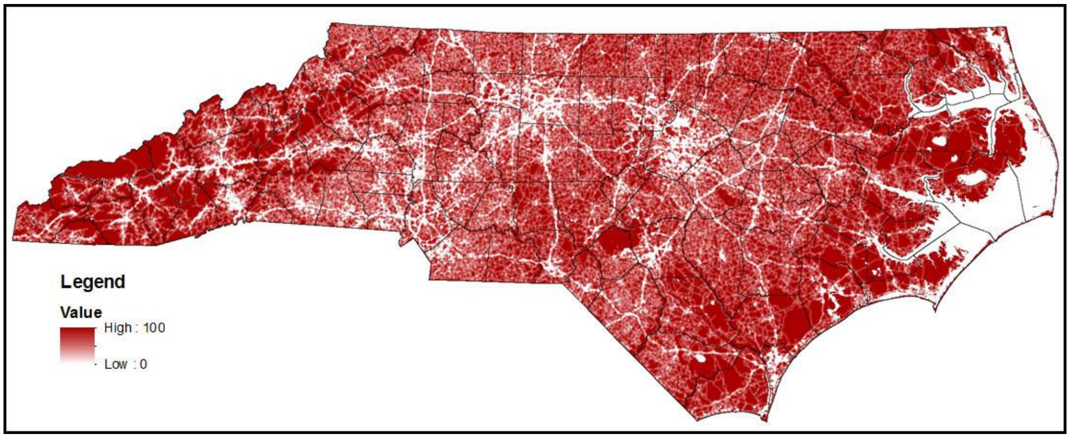

Figure 24. Suitability value of secondary roads density.

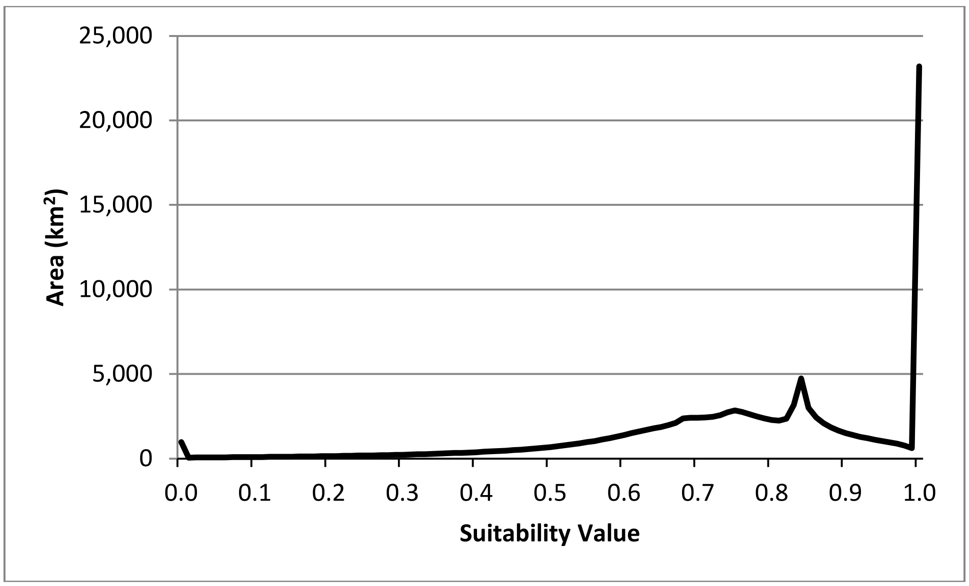

Figure 25. Distribution of secondary road density suitability value.

The final suitability value is reported in four categories; unsuitable (0-0.25), low (0.25 – 0.5), medium (0.5 – 0.75), and high suitability (0.75 – 1.0). Prior to the application of sociological constraints, 21% of the total land area within North Carolina was unsuitable, 19.0% low suitability, 58.2% medium suitability and 1.7% highly suitable (Figures 26 and 27). When sociological constraints are applied, a large proportion of medium and high suitability areas are masked out resulting in 41% unsuitable, 30% low suitability, 29% medium suitability, and <1% high suitability (Figures 28 and 29).

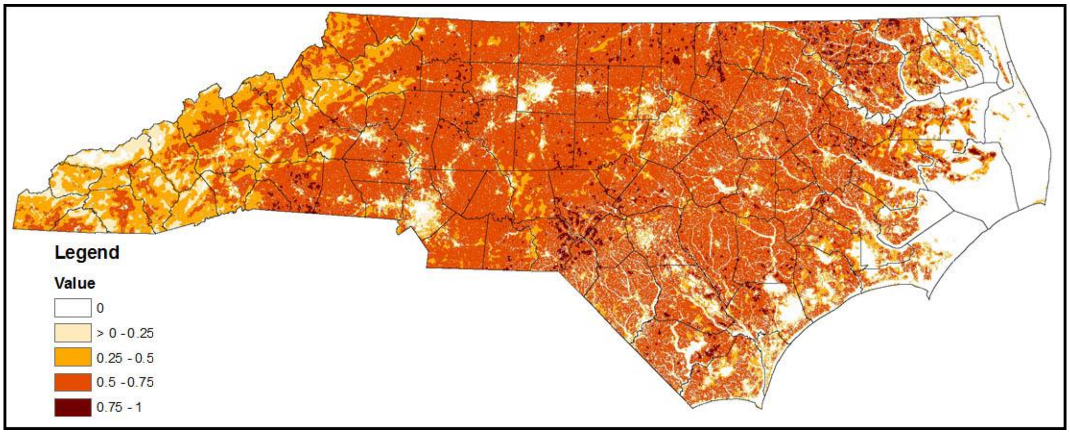

Figure 26.  Final suitability value with no sociological constraints.

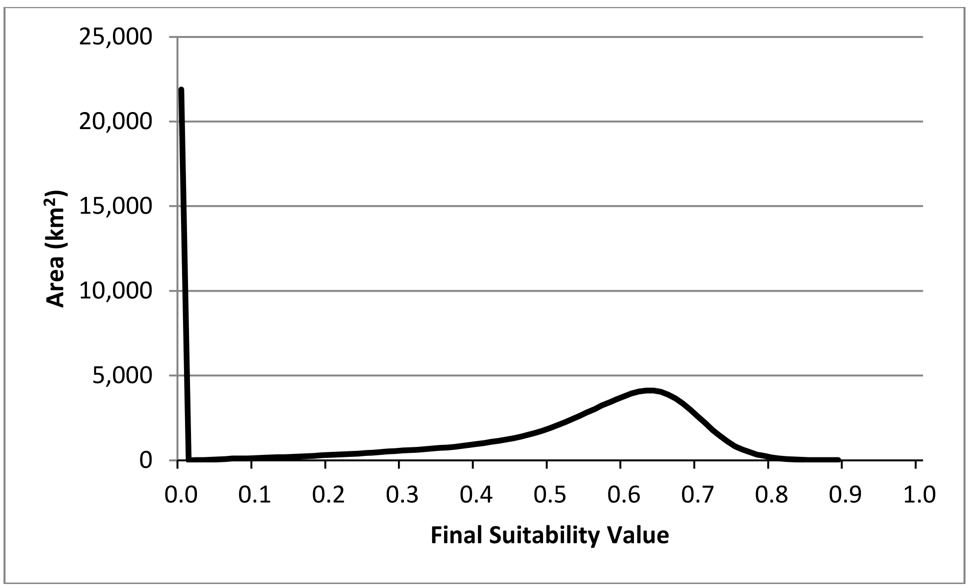

Figure 27.  Distribution of final suitability value with no sociological constraints.

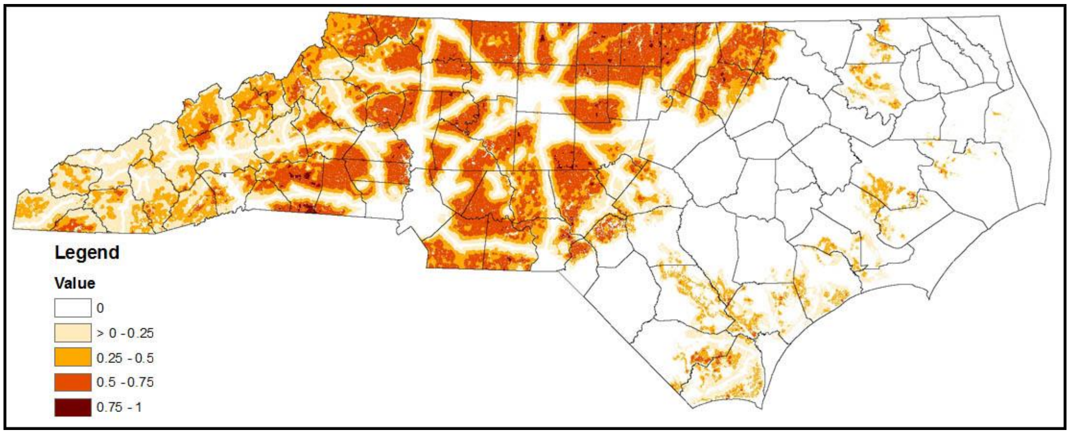


Figure 28.  Final suitability value with sociological constraints.

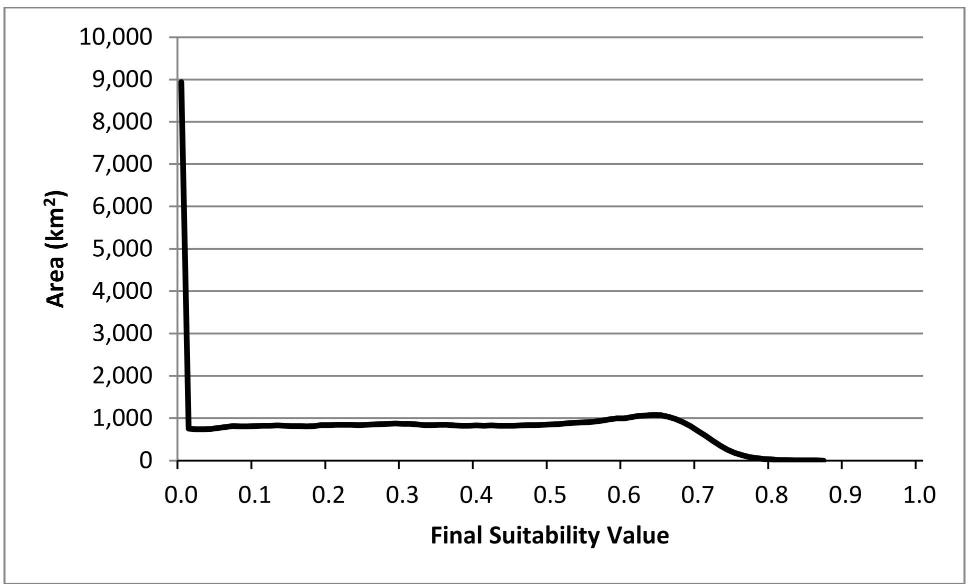


Figure 29.  Distribution of final suitability value.

DISCUSSION

We used a combination of fine scale data sets to delineate sociological constraints as well as state-wide analyses of biological requirements for elk.  The end result was a more precise and complete assessment of potential elk habitat in North Carolina.  For example, using the fine scale data sets to delineate sociological constraints allowed the inclusion of almost 3 times as much land area as the coarse scale data approach in earlier studies.  Over 55% of the land area had some suppression of suitability due to proximity to 4-lane highways and/or substantial row crops.  Because we based the suppression of suitability values on functional relationships, instead of county based categorical data, results are deemed a more precise representation of potential conflicts.

Suitability values of 1.0 were prevalent for the biological parameters used in this assessment. This is indicative of the spatial heterogeneity of habitat within North Carolina. There were relatively few large blocks (> 500 $km^2$) of contiguous habitat types (i.e., forest, open, successional scrub/shrub) with the exception of forest habitat in the mountainous Blue Ridge region. The only outlier to this pattern was successional scrub/shrub habitat ($SV_{sh}$), where more than 83% of the total land area had a suitability value < 0.3 and only 4% > 0.5. As such, successional scrub/shrub became the primary biological constraint in the model and the highest suitability values were clearly associated with the presence of successional scrub/shrub habitat. Because this plant community association is such a critical component to categorize the suitability of elk habitat, future studies should pay particular attention to the source and accuracy of thematic classification of use/land cover data.

Habitat throughout the coastal plain and piedmont offered the best suitability throughout the state. The coastal plain, however, was largely eliminated from the suitable habitat pool due to extensive agricultural activities. The pervasiveness of secondary roads throughout the coastal plain and piedmont also served to diminish final suitability values fairly consistently in this region of the State.

Habitat was relatively poor within the Great Smoky Mountain National Park due to the contiguous nature of mature forests with few grazing opportunities. Elk habitat is contingent on open valleys where the potential for conflicts with human activities exists. The current elk population will most likely continue a slow expansion along the valleys.

This work provides an important building block to develop a reintroduction strategy for elk in North Carolina. Specifically, it provides a basis to evaluate some of the consequences and the trade-offs associated with alternative actions (e.g., site selection, reintroduction strategy). Our assessment underscores that any proposed reintroduction site, be it in the mountains or piedmont, will quickly lead to elk-human interactions. As such, a reintroduction strategy should be coupled with a well-coordinated outreach and education campaign.

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