# Using GIS Data to Identify Wintering Behavior of White-Tailed Deer (Odocoileous Virginianus) in Pennsylvania

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## Abstract

Understanding the characteristics and behavior of wildlife is vital to conservation efforts, particularly regarding keystone species. White-tailed deer (Odocoileous Virginianus) are vital to the ecosystems that they belong to, along with being the most widely hunted animal in the United States, and as such have been widely studied. Previous studies have recognized the deadly effects of winter on white-tailed deer; how deer in colder regions of North America mitigate the dangers of winter by using wintering areas; and how deer in Pennsylvania behave differently during winter than in other northern areas. This study analyzes habitat use of white-tailed deer in northern Pennsylvania during winter using locations of deer collected using satellite GPS radio collars and GIS data. White-tailed deer movements during winter months are influenced by several factors including food availability, ground cover, home range, and topography. Spatial and statistical analyses were used to compare locational data of deer with slope, aspect, elevation, and vegetation layers to determine what types of areas deer favor for food and protection during the winter. The results could help confirm previous studies (and assumptions), and reinforce the efforts of wildlife, hunting, and land management organizations.

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# i. Introduction

## I. Background

### The Toll of Winter on White-Tailed Deer

White-tailed deer have an average life expectancy of about five years. At any point in their lives, they experience risks introduced by predators, disease, and humans (hunters, traffic, development, etc). Fawns have the lowest survival rate of any age group, and as shown in Table 1, their greatest threats are predators and natural causes (malnutrition, starvation, disease, elements, etc). In the case of the study done by Vreeland, Diefenbach, and Wallingford (2010), 70.8% of the fawns died within 9 weeks of being captured for the study. Fawns are born in spring to early summer, so this means that most do not survive to their first winter.

**Table 1.**

*Fawn Mortality Rates*

| | PV | | QWA | |
|---|---|---|---|---|
| Mortality cause | % | 95% CI | % | 95% CI |
| Predation | 17.0 | 9.2–31.5 | 69.5 | 58.7–82.3 |
| Natural causes[a] | 38.3 | 26.7–54.9 | 18.6 | 11.0–31.4 |
| Vehicles | 14.9 | 7.7–28.9 | 3.4 | 1.0–11.6 |
| Hunting | 10.6 | 4.8–23.5 | 3.4 | 1.0–11.6 |
| Farm machinery | 6.4 | 2.3–17.8 | | |
| Poaching | 2.1 | 0.4–10.7 | 3.4 | 1.0–11.6 |
| Bizarre accidents[b] | 4.3 | 1.3–14.6 | | |
| Deer depredation[c] | 4.3 | 1.3–14.6 | | |
| Unknown[d] | 2.1 | 0.4–10.7 | 1.7 | 0.3–8.6 |
| Censored[e] | 12.7 | 7.8–20.6 | 6.5 | 3.2–13.0 |

*Note:* Causes of mortality in a two-year study of 106 newly released collared fawns, in Penns Valley (PV) and Quehanna Wild Area (QWA) Pennsylvania (Vreeland, Diefenbach, Wallingford, 2010). From Vreeland, J., Diefenbach, D., & Wallingford, B. (2010). Survival rates, mortality causes, and habitats of Pennsylvania white-tailed deer fawns, *Wildlife Society Bulletin*, 32: 542-553. DOI: 10.2193/0091-7648(2004)32[542:SRMCAH]2.0.CO;2

During winter months fawns are still at the greatest risk for mortality, followed by bucks and then does. Fawns do not yet have the body mass to provide them with insulation and energy reserve and are at much greater risk of malnutrition or starvation. Harsher winter elements, such as deeper snow, reduce their ability to forage and require greater energy expenditure to travel in search of food. Late winters can also mean late breeding seasons, which means fawns encounter winter elements at an earlier age and more vulnerable life stage. If a herd experiences consecutive severe winters, the result of fawn loss over multiple breading cycles can potentially results in a 90% reduction in the recruitment (Wiley and Hulsey, n.d.).

## Seeking Refuge in Deer Wintering Areas

Deer wintering areas, or deer yards, are areas where deer normally go to avoid severe winter weather conditions, including deep snow, and have plentiful food (Wiley and Hulsey, n.d.). According to Beauchemin (2019), year after year, deer return to the same places where the climate is more conducive to winter survival (less snow on the ground, favorable sunshine, etc), and may travel dozens of miles to shelter there for winter. Deer observed in Vermont were thought to decrease activity and increase group size as well as prefer densely forested areas for protection during severe winter temperatures (Cole, 2016).

Deer usually travel to slightly lower elevations and utilize south-facing slopes during those winter months. There is more direct sunlight in these types of locations, and therefore less snow and an abundance of easily accessible food sources. Concurrently, white-tailed have been observed in Eastern Michigan during extreme winters congregating near stands of eastern hemlock and white cedar to provide themselves with thermal cover, reduced snow depth, and forage (Parikh, 2019). Those stands of trees are likely to at least reduce winds during extreme temperature scenarios.

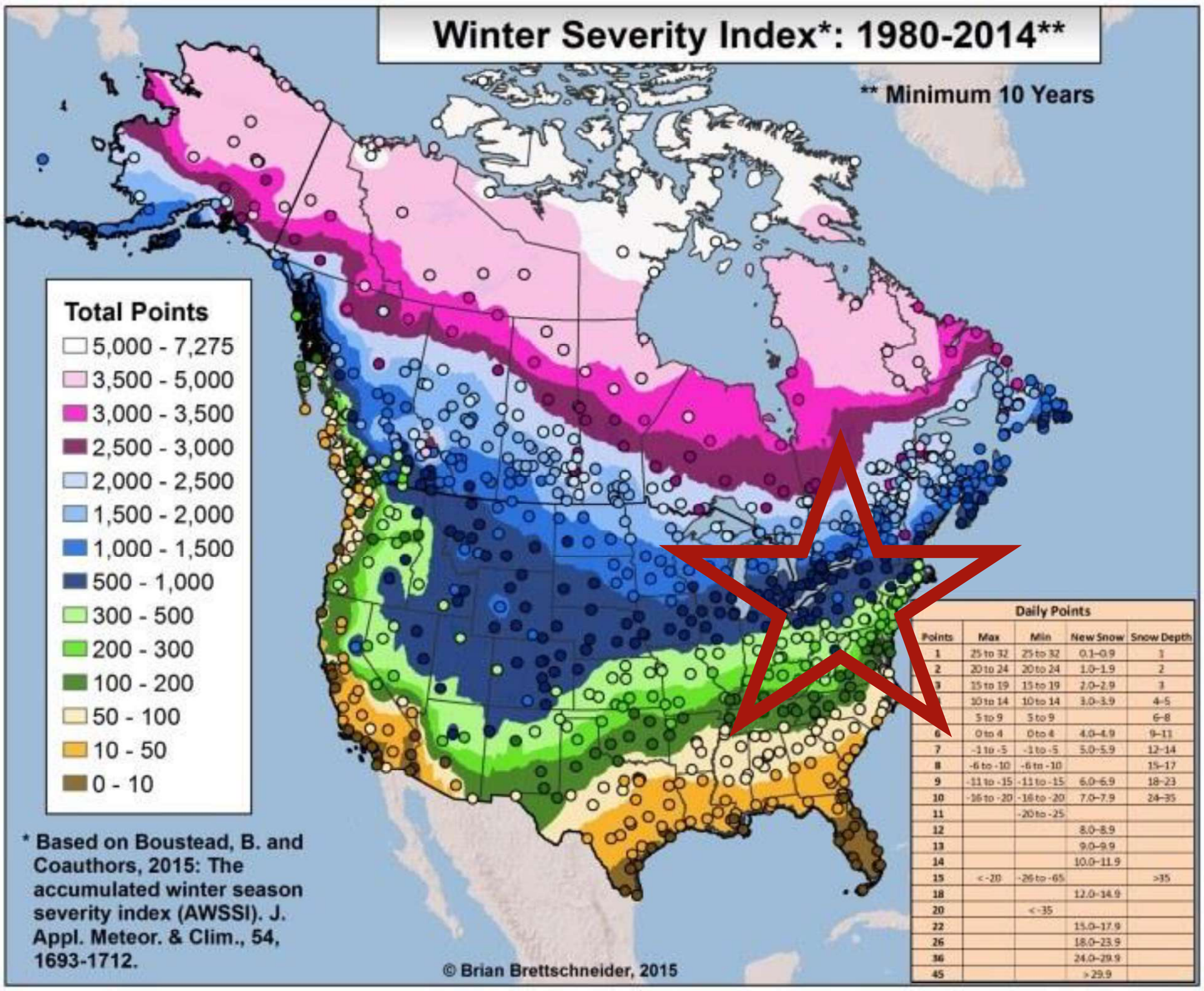
White-tailed deer diets throughout the United States consist of readily available food sources. During spring and summer, herbaceous plants and new growth on woody plant species provide plentiful food resources. However, in winter months, woody browse is the primary source of food (Beauchemin, 2019).

## Winter Behavior of Pennsylvania White-Tailed Deer

In parts of North America that do not experience severe winters, deer home ranges seem to stay relatively similar year-round (Nielsen and Stroud-Settles, 2018). The winters are not as severe in Pennsylvania as in more northern ranges, as shown in Figure 1, and Pennsylvania white-tailed deer tend to have smaller home ranges than that of deer in more northern regions of the United States. During winters, deer studied in Pennsylvania did not necessarily shift their home ranges but did move to different areas within their annual home range (Diefenbach and Fleegle, 2015). Pennsylvania deer have not been observed to yard, but during deep snows will congregate in the hollows and hillsides with dense conifer, mountain laurel, and rhododendron cover (Pennsylvania Game Commission, 2021).

**Figure 1**

Winter Severity Index




*Note.* Average Pennsylvania winters compared to all North America (Boustead, 2015). From Boustead, B., Hillberg, S., Shulski, M., & Hubbard, K. (2015). The Accumulated Winter Season Severity Index (AWSSI), *Journal of Applied Meteorology and Clomatology, 54*(8), 1693-1712.

White-Tailed deer studied as far north as Quebec, Canada, experienced their highest rates or mortality during winter months. Those deer adapt to harsh winters by building-up fat reserves and use coniferous forest habitats where the microclimate is less harsh relative to locations they use in summer (Beauchemin, 2019). White-tailed deer in Pennsylvania have likely adapted to harsh winter temperatures and snow fall through herd adaptation and learning from elder deer in the herd, which are passed down to the new fawns in the Spring and stay with their mothers through their first winter.  If the deer experienced consistently severe winters, they would likely yard, but they are presumably still using areas that would protect them from deep snow and improve their opportunities to forage, such as coniferous habitats used by deer in Quebec.

## II. Project Objectives

The data reviewed in previous studies has shown that the white-tailed deer in Pennsylvania did not use a deer wintering area, unlike deer in more northern ranges. The objective of this study is to identify landscape and habitat features that are more likely to be used by deer in winter. Data gathered with the use of GPS tracking collars has given us the ability to study deer location data and compare it to characteristics of the landscape and foliage that the deer favor during winter months. In this study, GIS data was used to evaluate if deer in Pennsylvania are more likely to use certain habitat types during winter.

GIS data was expected to support previous studies, which suggested that white-tailed deer in Pennsylvania would follow certain trends during winter months. It was hypothesized that the data would indicate that deer favor south-facing slopes, higher elevations, clear cuts, and areas with hemlock and pine coverage, since these conditions offer less snow cover, more sun exposure, and more available food.

## ii. Methodology

### I. Study Area

The Susquehannock State Forest of northern Pennsylvania was used for analysis, where locational data for 31 white-tailed deer was available. This was a favorable area for this project because there is little human impact, such as traffic or infrastructure present.

*Study Periods*

The study focused on the analysis of data during months with the harshest winter conditions in Susquehannock State Forest, over a period of two winters. In the study area, January through February is the period with lowest average temperatures (10-35 degrees Fahrenheit), and the greatest average snowfall (>10 inches). The month of December was excluded since rut activity often runs through the middle of the month and can cause altered travel behaviors.

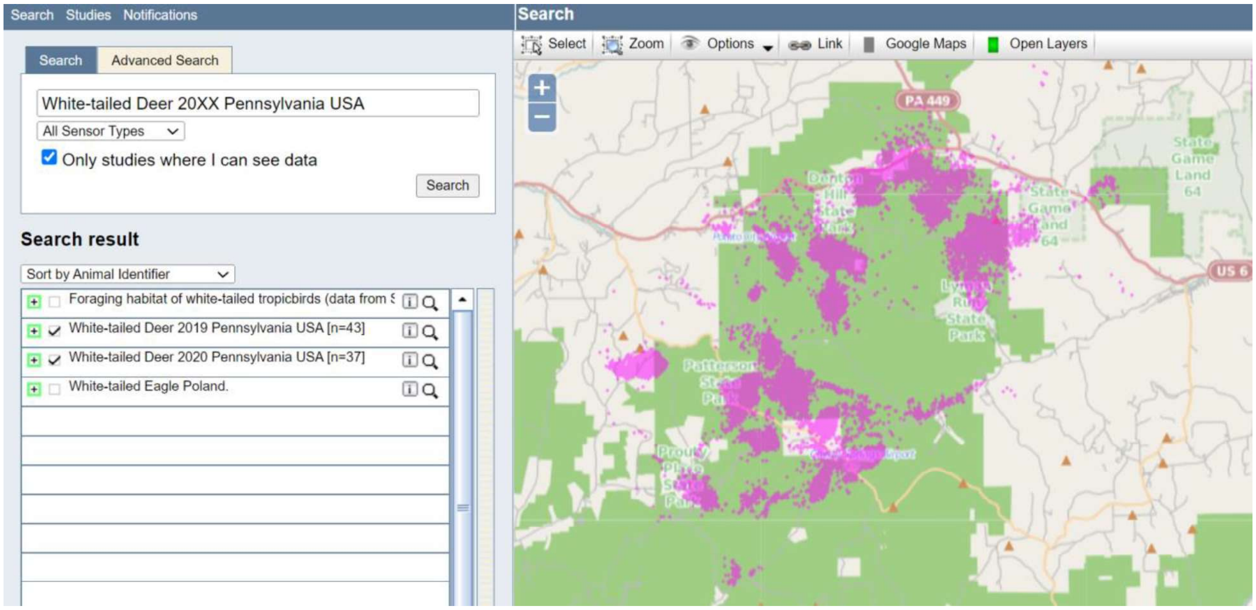
- January 2019 through February 2019
- January 2020 through February 2020

### II. Data

White-tailed deer location data was obtained from Movebank, an animal tracking database. Collar data from studies conducted by Penn State University (Figure 2-1) was made available for the use of this study by Dr Deifenbach. Digital elevation model (DEM) data was obtained from Pennsylvania Spatial Data Access (PASDA), which is an open geospatial data portal developed by Penn State. A habitat and forest stand type GIS layer and vegetation manual was obtained through Pennsylvania Department of Conservation and Natural Resources Bureau of Forestry.

**Figure 2-1**

Movebank Animal Tracking Display




*Note.* Locations of collared deer, visualized in Movebank (2022). Retrieved from https://www.movebank.org/cms/webapp?gwt_fragment=page=search_map

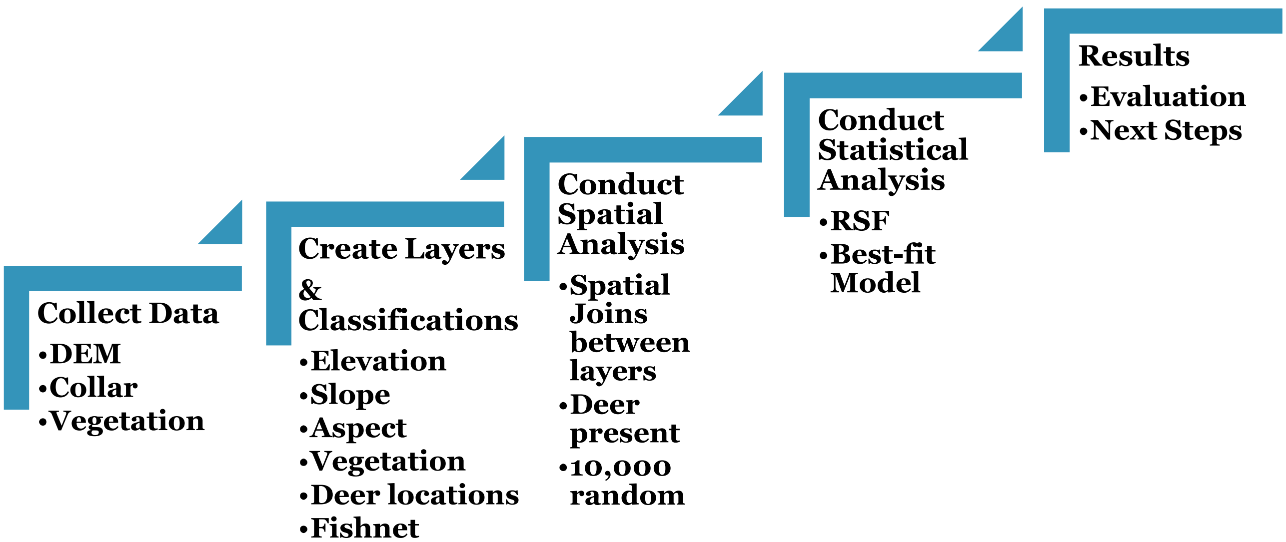
*Software*

Esri's ArcGIS Desktop (ArcMap) 10.7.1 was used for processing, spatial analysis, and statistical representation of the obtained data.

## III. Analysis and Methods

**Figure 2-2**

A Step-by-Step Process



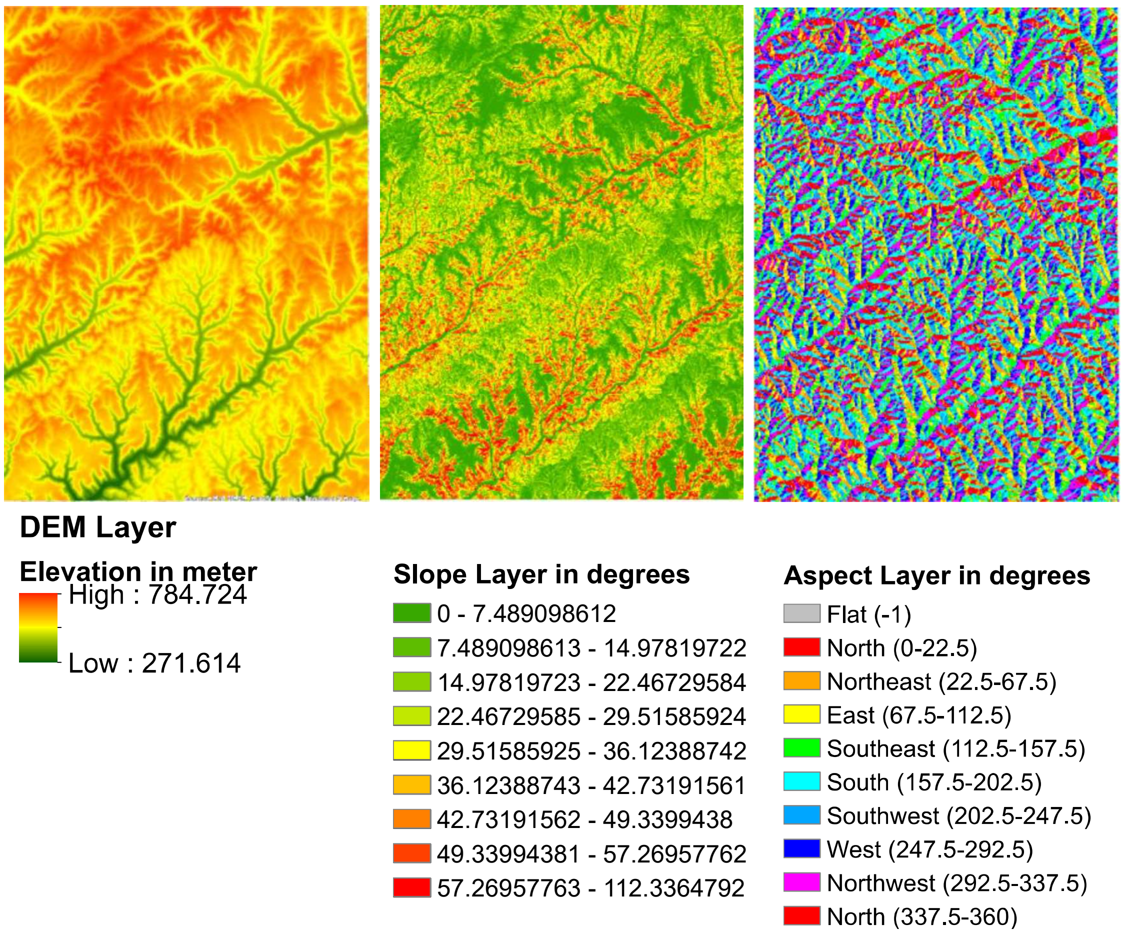

*Note*. A brief breakdown of the data collection and analysis that was required to obtain results.

<u>**Data processing**</u>

A DEM layer was acquired and used to represent elevation levels. Slope and Aspect functions in ArcMap were used to create slope and aspect raster outputs (Figure 2-3). The cell ranges were converted to true values using the Integer function, and then each elevation, slope, and aspect raster was converted to a polygon.

**Figure 2-3**

Raster layers created from the obtained DEM data




The vegetation layer and manual were acquired and analyzed to consider what material within would be the most suitable to include in the study. It was determined that the type and size stock attributes would be most appropriate to apply. The 27 vegetation types available in the Type field of the dataset were generalized into four categories, based on confer coverage or lowland type. The Size Stock field contained 8 values, indicating the diameter at breast heigh (dbh) for the majority of trees in at location, and whether they are more or less than 50% stocked. These values were generalized into two categories, designating them at mature stock or clear-cut.

**Type Categories**

| >25% of the over-story cover | ≤ 25% of the over-story cover | Wetlands | Lowlands |
|---|---|---|---|
| Hemlock (White Pine) Forest | Mixed Oak – Mixed Hardwood Forest | Hemlock Palustrine Forest | Pine Plantation |
| Hemlock (White Pine) – Northern Hardwood Forest | Dry Oak – Heath Forest | Hemlock – Mixed Hardwood Palustrine Forest | Spruce Plantation |
| Hemlock (White Pine) – Red Oak – Mixed Hardwood Forest | Red Oak – Mixed Hardwood Forest | Scrub / Shrub | Sweetfern Savannah |
| | Northern Hardwood Forest | Palustrine Woodland | Woodland |
| | Black Cherry – Northern Hardwood Forest (Allegheny Hardwoods) | Emergent Wetland | Orchards |
| | Red Maple Forest | | Scrub / Shrub |
| | Sugar Maple – Basswood Forest | | Natural Herbaceous Area |
| | Aspen / Grey (Paper) Birch | | Cultivated Herbaceous Area O3 |
| | | | Miscellaneous Herbaceous Area |
| | | | Pipeline |
| | | | State Forest Facility, Forest Headquarters, District Office, Fire Tower, etc. |

**Size Stock**

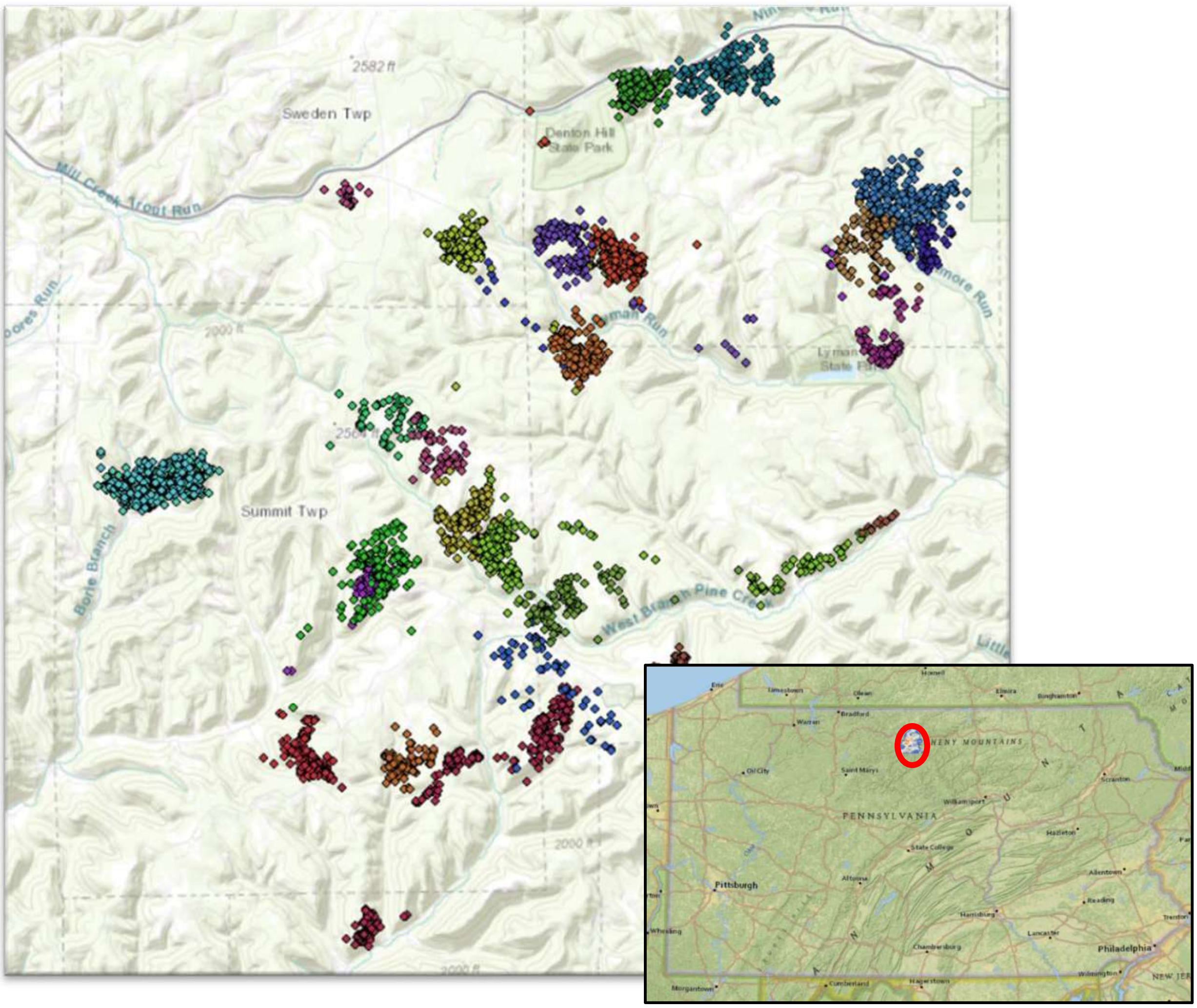
Mature stock- Majority of the dominant and codominant trees are > 6” dbh.

Clear-cuts- Majority of dominant and codominant trees are < 6” dbh.

The 2019 and 2020 white-tailed deer collar data was acquired and merged to one layer in ArcMap. All attributes for January and February were selected and exported as a separate layer, as shown in Figure 2-4. In order to do the spatial and statistical analyses, all layers needed to be present in each cell.

**Figure 2-4**

Individual deer active during winter months symbolized in different colors




The vegetation layer was chosen as the clip feature to define the study area, and the deer, slope, aspect, and elevations feature classes were clipped to fit the area. The Create Fishnet tool was used to create 30m x 30m cells within the study area, so that samples for the statistical analysis would come from evenly sized grids. A layer of 10,000 randomly chosen cells was derived from the original fishnet layer, by applying the Create Random Points tool.

**Spatial Analysis**

A spatial analysis was performed in ArcMap Performed a spatial analysis in ArcMap, by comparing all of the prepared layers. Spatial Joins were run between only fishnet cells in the study area that contained deer locations during winter and the slope, aspect, elevation, and vegetation layers, as in Figure 2-5. Separately, spatial joins were run between the layer containing 10,000 randomly chosen cells and the slope, aspect, elevation, vegetation, and winter deer location layers, as in Figure 2-6. For the random cell layer, cells were included whether or not deer were present. Tables for both spatial comparisons were exported to excel files to use during the statistical analysis.

**Figure 2-5**

Cells where deer are present during winter visually compared to year-round locations

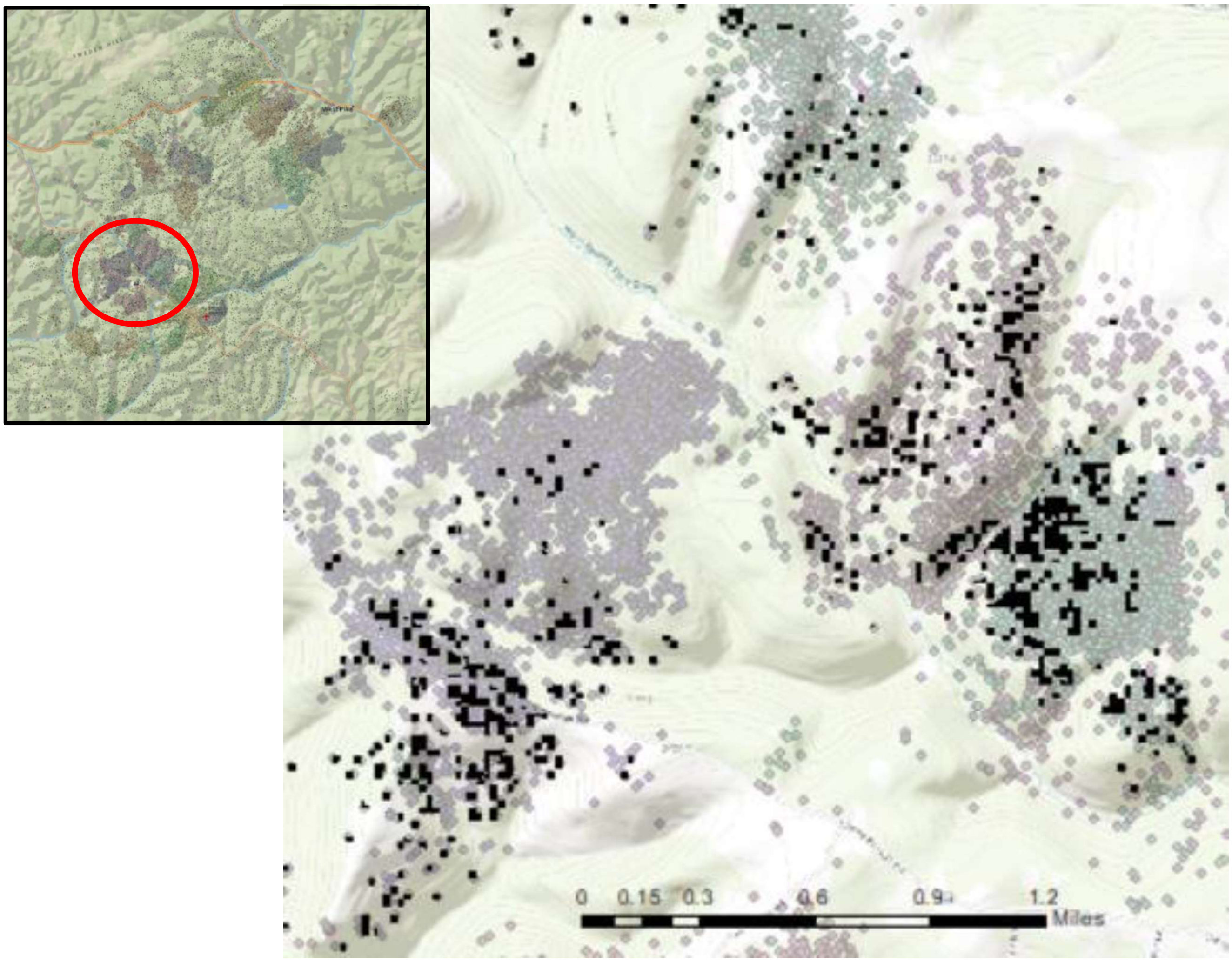
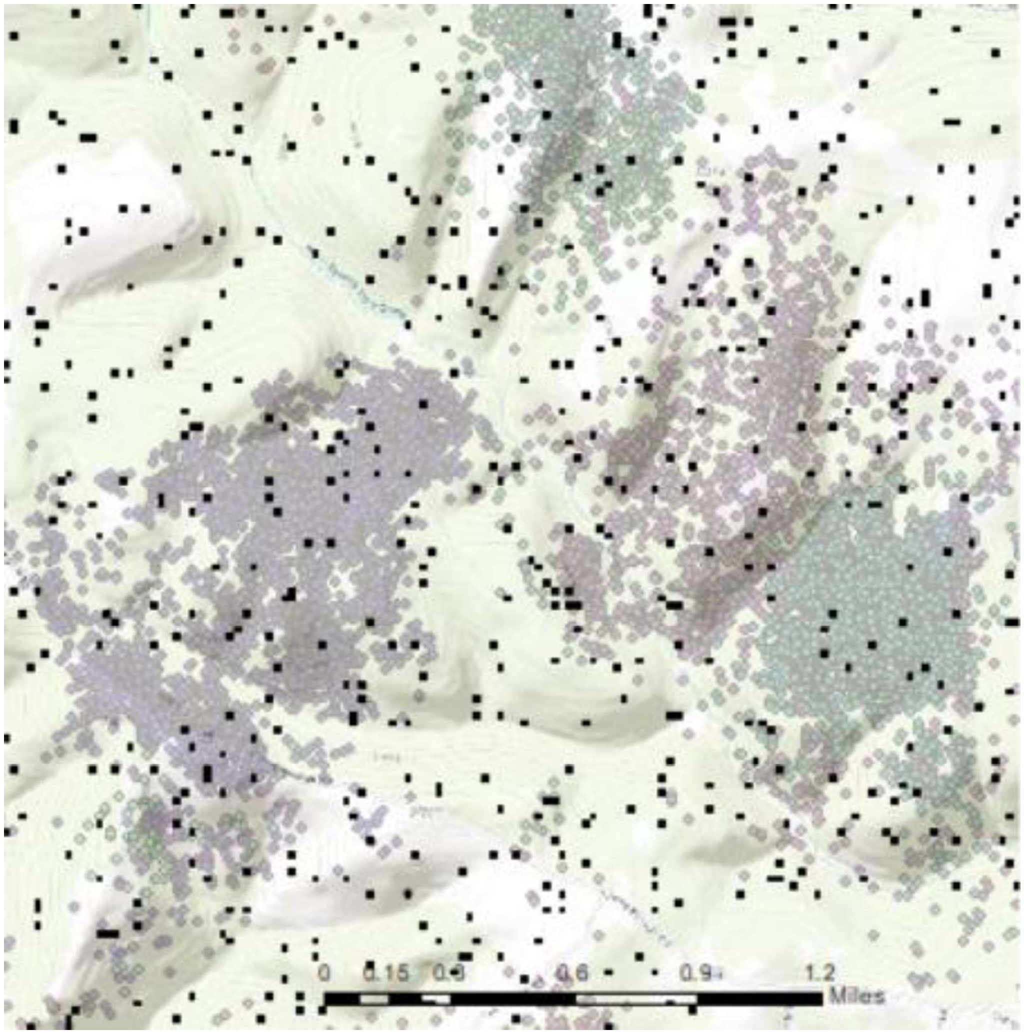


**Figure 2-6**

Randomly selected cells compared to year-round locations




**<u>Statistical Analysis</u>**

A statistical analysis was conducted by developing nine logistic regression models, which used both the used cells (1) and available cells (0) as response variables. Individual deer were treated as a random effect for each of the nine models. Five predictor variables-slope, aspect, elevation, diameter of trees, and type of forest-were considered, as well as interactions between slope and aspect, tree diameter and aspect, and elevation and aspect. The model with the lowest

Akaike's Information Criterion (AIC) value was determined to be the best fit model. The coefficients from the chosen model were used to create a Resource Selection Function (RSF).

RSF values for each cell ($i$) were calculated using $RSF_i = \frac{\exp(\beta_1 \times x_i + \beta_2 \times y_i + \beta_3 \times z_i)}{\exp(\beta_1 \times \bar{x} + \beta_2 \times \bar{y} + \beta_3 \times \bar{z})}$ with $\beta_1, \beta_2, \beta_3$ being coefficients for a given covariat $w, x_i, y_i, z_i$ being the covariate value for cell $i$, and $\bar{x}, \bar{y}, \bar{z}$ being the mean value for covariate $i$. The best fit model showed that the most suitable variables to include were slope, slope to the power of 2, aspect, elevation, tree diameter, and the covariate of aspect and tree diameter. It was also determined that forest type would not be included in the model, since only ~1% of the study area had conifer cover that exceeded 25% of the overstory (pine and hemlock).

The statistical analysis provided the information necessary to create a visualization of the types of habitats deer are most likely to utilize. A spatial join of all cells within the study area against slope, aspect, elevation, and vegetation was conducted. The following attribute fields were added, and the Field Calculator was used to apply the following equations (Table 2):

- **SLOPE**=slope/10
- **SLOPEto 2**=slope**2 *(slope to the power of 2)*
- **ASPECT**= cosine(aspect*3.14159265/180)
- **ELEVATION**=elevation/100
- **SizeStock=**Trees > 6" dbh=0

  Trees < 6" dbh=1
- **ASPECT_SIZE=**aspect*size

- **CELL_RSF=** exp(coefficient*<cell value> + …) *Note: Coefficients for each field was determined during the statistical analysis. For this equation, each field mentioned prior was multiplied by its coefficient and then added to the next field.*

- **SCALED_RSF**=cell RSF/758.0128 *Note: 758.0128 is the mean RSF, which was calculated using exp(coefficient*<mean cell value> + ...).*

> 1 then use is more than average

= 1 then use is average

< 1 then use is less than for average

**Table 2.**

Attribute table displaying field calculation results used to determine the scaled RSF of each field.

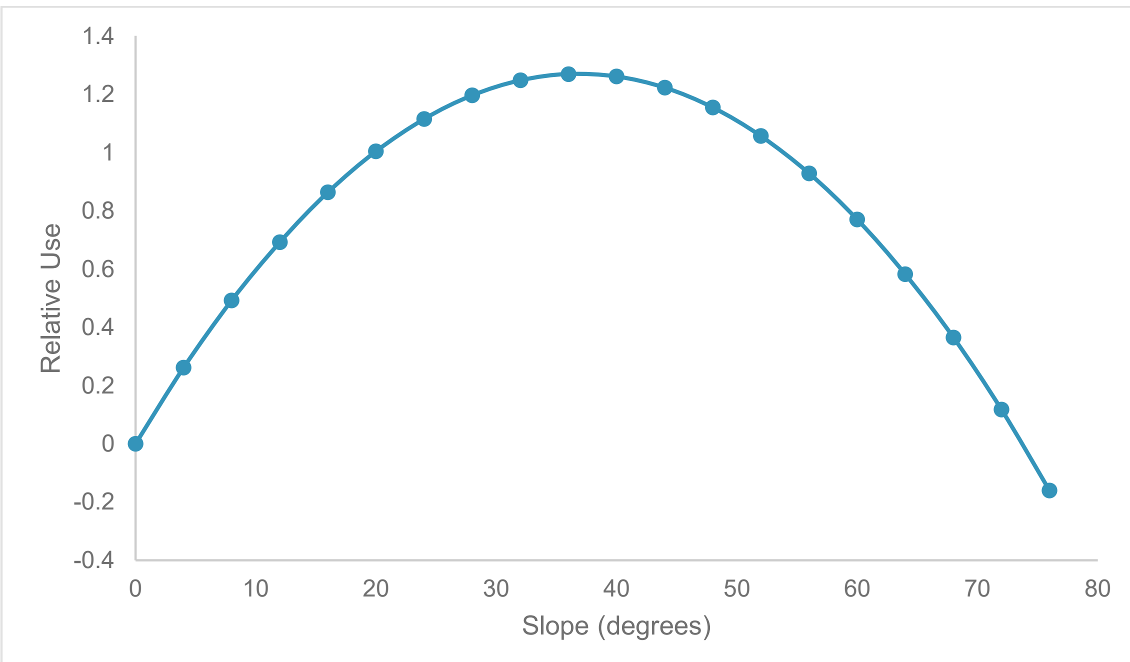
TenK Random Spatial Join

| Slope | slopeto2 | Aspect | Elevation | SizeStock | aspectxsize | Cell RSF | Scaled RSF |
|---|---|---|---|---|---|---|---|
| 1 | 1 | -1 | 7 | 1 | -1 | 1500 | 2 |
| 1 | 1 | -1 | 7 | 1 | -1 | 1500 | 2 |
| 0 | 0 | 0 | 7 | 1 | 0 | 706 | 1 |
| 1 | 1 | 0 | 7 | 1 | 0 | 1281 | 2 |
| 4 | 16 | 1 | 5 | 0 | 0 | 286 | 0 |
| 6 | 36 | 1 | 6 | 0 | 0 | 418 | 1 |
| 3 | 9 | -1 | 7 | 0 | 0 | 1453 | 2 |
| 4 | 16 | 1 | 7 | 0 | 0 | 1630 | 2 |
| 2 | 4 | -1 | 6 | 0 | 0 | 487 | 1 |
| 2 | 4 | -1 | 6 | 0 | 0 | 487 | 1 |
| 2 | 4 | 1 | 5 | 1 | 1 | 288 | 0 |
| 3 | 9 | 1 | 5 | 0 | 0 | 276 | 0 |
| 3 | 9 | 1 | 5 | 0 | 0 | 276 | 0 |

### iii. Results

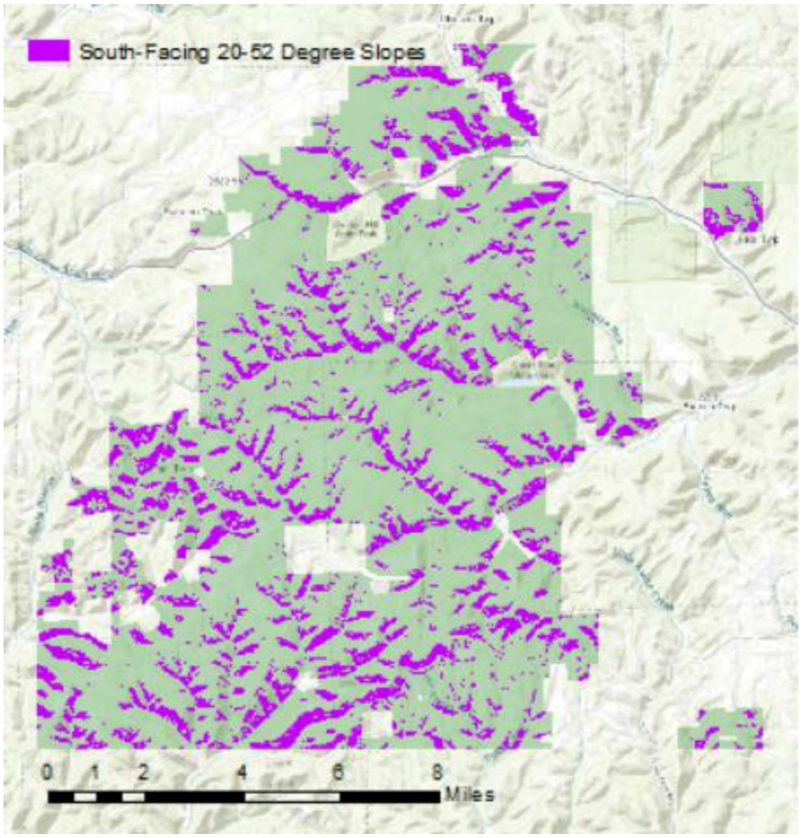
The results from the spatial and statistical analyses showed that the deer in the study preferred higher altitudes and south-facing slopes, regardless of elevation. The deer showed an aversion to slopes that were too flat or steep. Figure 3-1 shows the tendency to use the slopes more often as they went from flat to around 20 degrees, and then increasingly less as the slopes exceeded around 52 degrees and became too steep.

**Figure 3-1**




*Note.* A graph showing the interactions between the steepness of a slope and the likelihood of deer to use or avoid it.

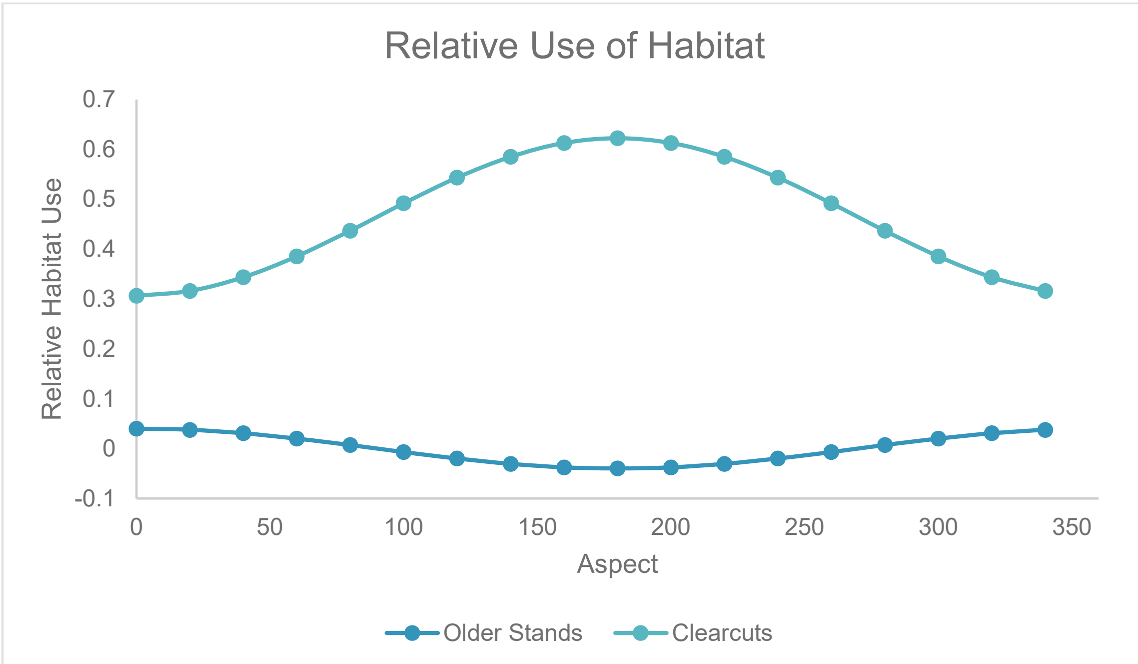
**Figure 3-2**




*Note.* A map showing all cells in the study area that contain only south-facing slopes of 20-52 degrees.

The analysis, shown in Figure 3-3, positive interactions between south-facing slopes and clear cuts. When available, the deer prefer south-facing clear cuts. There were no significant relationships found relating to vegetation type.

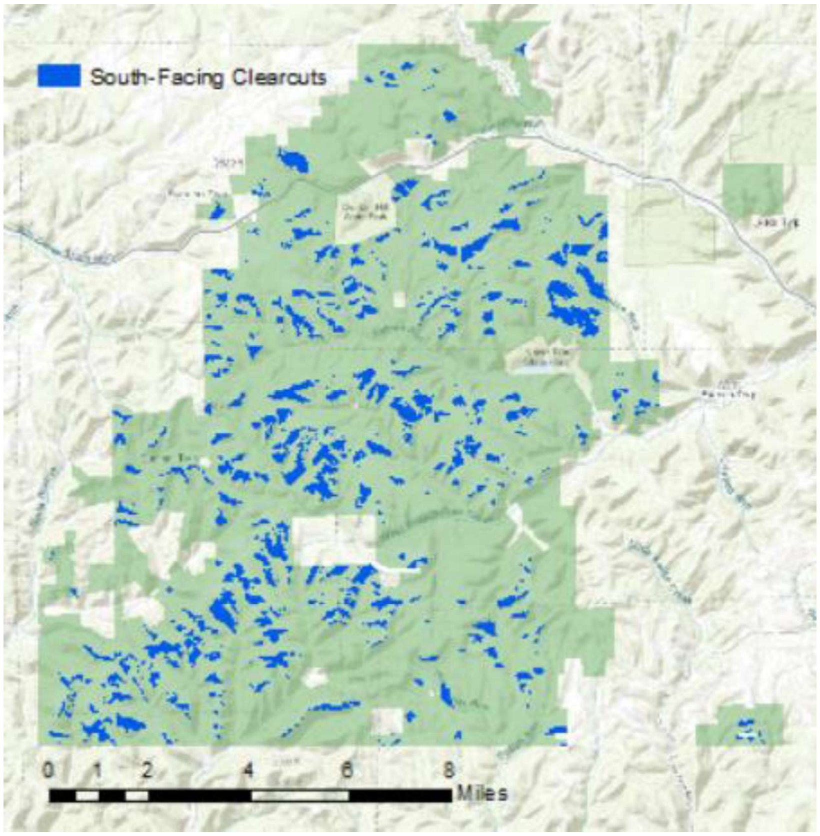
**Figure 3-3**




| | |
|---|---|
| (Flat (-1)) | South (157.5-202.5) |
| Southwest (202.5-247.5) | North (0-22.5) |
| West (247.5-292.5) | Northeast (22.5-67.5) |
| Northwest (292.5-337.5) | East (67.5-112.5) |
| North (337.5-360) | Southeast (112.5- |

*Note.* Aspect influenced clear cuts but had little influence on mature stands.

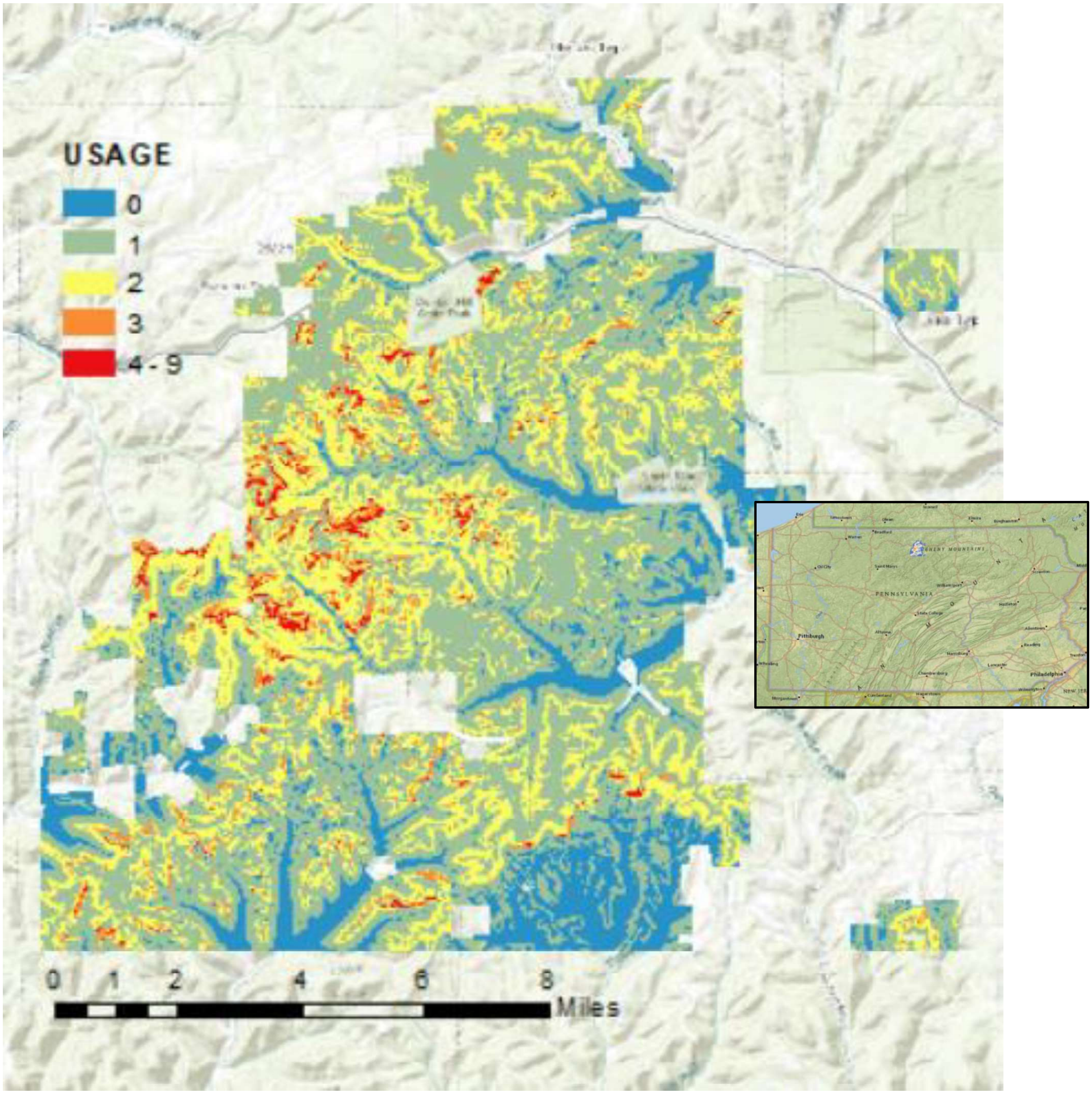
**Figure 3-4**




*Note.* A map showing all cells in the study area that contain only south-facing slopes with clearcuts.

**Figure 3-5**

Habitat use of white-tailed deer during winter months




*Note:* Map of RSF values, with areas greater than one being used more than average.

## iv. Conclusion

The study supports the hypothesis that south-facing slopes are the favored habitat for gaining access to sunlight and food and allowing them to travel and avoid predators more easily during winter months. They also preferred clear-cuts for further opportunities to forage, travel, and bed down when the protection of south-facing slopes is available. The deer in this study did show preference to higher elevations, unlike deer researched in other areas.

The theory that the deer would prefer hemlock and pine vegetation during the winter months was unsubstantiated during this study. Applying different data sets or a different analytic method could provide more meaningful results to show vegetation type preferences of white-tailed deer in winter.

*Future Opportunities*

Wildlife and hunting management organizations could apply the results from this study to provide more meaningful monitoring and population control of white-tailed deer. The information could aid in determining annual regulations and tag limits for zones with differing habitat types; and could help determine boundaries for protected areas each year as necessary for fawn protection and population strengthening. Land Management organizations could apply the visualizations when making decisions for clear cutting and reforestation. Deer browse seedlings on clearcuts on south-facing slopes, so it could be deduced that tree regeneration in those areas will be negatively impacted.

This study’s data and analysis could be applied for additional research on behavioral patterns of white-tailed deer in different areas or during different times of the year, such as rut or hunting seasons. Further data, if available, could be applied to identify impactful interactions between white-tailed deer and predators, biological factors (disease, abnormal breeding cycles, etc), group sizes, and human impacts. The analysis techniques and data types used in this study could also be applied towards other species whose locational data is available.

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