Determining Suitable Habitat and Home Range of Feral Horses on the Nevada National Security Site Using Geographic Information Systems

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Capstone Project

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Contents

Abstract

Feral horses (*Equus caballus*) are free-roaming descendants of domesticated horses and legally protected by the Wild and Free-Roaming Horses and Burros Act of 1971, which mandates how feral horses and burros should be managed and protected on federal lands. Using a geographic information system to determine the home range and suitable habitat of feral horses on the federally managed Nevada National Security Site can enable wildlife biologists in making best management practice recommendations. Home range was estimated at 88.1 square kilometers. Site suitability was calculated for elevation, forage, slope, water presence and horse observations. These variables were combined in successive iterations into one polygon. Suitability rankings established that 85 square kilometers are most suitable habitat, with 2,052 square kilometers of good habitat 1,252 square kilometers of fair habitat and 122 square kilometers of least suitable habitat.

Introduction

Feral horses (*Equus caballus*) are free-roaming descendants of domesticated horses that can be found in many wilderness areas throughout western United States (Figure 1). This project will indicate the ways vegetation, slope, elevation and water resources can be used to determine feral horse home range in an isolated geographic region using a geographic information system (GIS). Feral horses are legally protected by the Wild and Free-Roaming Horses and Burros Act of 1971 (Ninety-Second Congress of the United States 1971), which mandates how feral horses and burros should be managed and protected on federal lands. Using a GIS to determine the feral horse home range could improve horse management practices.

Figure 1. Two wild horses in southwest Wyoming (Anderson 2008)

Problem Statement

The Nevada National Security Site (NNSS) is a federally managed land located in a remote portion of the Great Basin and Mojave Deserts in south-central Nevada. Biologists conduct periodic horse-census surveys on the

NNSS. The feral horse home range is then deduced to determine whether on-site activities are impacting the resident horses. Can feral horse home range for the NNSS be computed using GIS to determine the preferred habitat based on horse observations, vegetation type, slope, elevation and water accessibility? This research will assist wildlife biologists in making best management practice recommendations by helping target feral horse habitat that is most utilized.

Literature Review

Feral horse monitoring has occurred on the NNSS since 1989 and has continued through the present (Greger and Romney 1999; Hansen, et al. 2010). Biologists have collected information on the resident horse population annually, including the geospatial location of individual horses and bands found on the NNSS. Road surveys are conducted to assess horse distribution by interpreting the observed signs found along roadways, including horse droppings and hoof prints. Water resources, both natural and man-made, were also assessed for horse usage by determining the condition of the area around the water source and through observation. The horse range is then manually estimated by melding the biologist's innate knowledge of the historic horse utilization with the observed sign during a particular calendar year.

Hooge et al. stated in 2001 that GIS is the perfect environment to analyze movement patterns using multiple layers of habitat data, further declaring that there are "obvious advantages" of combining GIS with the spatial aspect of animal movement behavior. Because no commercial off-the-shelf application then existed, Hooge developed an application with numerous analysis functions. These functions include, but are not limited to, home range analyses, random walk models, and habitat analyses (Hooge, Eichenlaub and Solomon 2001).

Selkirk and Bishop evaluated in 2002 whether home range and habitat analysis could be extended and improved by using the tools integrated in geographic information software rather than using external home range software. They used the minimum convex polygon, fixed kernel technique and Schoener index independence test, which are integrated as functions in ArcView and various extensions for evaluating home range (Selkirk and Bishop 2002).

Koehler and Pierce evaluated in 2003 the size of home ranges to determine if the size of the home range was dependent upon sex, study site or objectives of forest management. They evaluated three study sites in Washington State. Forest-cover was evaluated at each study site for individual bears and between study sites within composite home ranges to measure "use, interspersion and juxtaposition of cover types" (Koehler and Pierce 2003). Using fixed-kernel estimates of home range, Koehler and Pierce determined that males and females occupied different home-range sizes in different forest-cover types, which may be explained by differences in annual precipitation and behavioral differences between males and females (Koehler and Pierce 2003).

Owen et al. examined in 2003 home range size and habitat use of nine bats in West Virginia, United States of America. The mean home range was calculated using the 95% adaptive kernel method and evaluated for preference between pristine areas verses disturbed areas (Owen, et al. 2003).

Litzgus and Mousseau evaluated habitat use, movement patterns and seasonal activity of spotted turtles in 2004 using a combination of radio telemetry, global positional systems and GIS software. Habitat use during a 3-year period was different between males and females, and varied seasonally. Annual fidelity was observed between individual animals with concentrated overlap during breeding. Because the study differentiated between the role of natural and anthropogenic disturbances, management recommendations for habitat preservation of this declining species were made (Litzgus and Mousseau 2004).

Wong et al. evaluated in 2004 data collected over a 2-year period of time from six radio-collared sun bears in the rainforest of Borneo. Home range sizes were calculated using the 95% adaptive kernel method. Daily movement distances were calculated and were impacted by food availability. Diurnal activity patterns were analyzed. Logging management practice recommendations were made based on the study (Wong, Servheen and Ambu 2004).

Katajisto and Moilanen declared in 2006 that studies of habitat selection can be inherently biased because the radio-tracking data used to calculate the utilization density distribution is temporally irregular. Radio-tracking data consists of "frequent autocorrelated observations interspersed with temporally more independent observations" (Katajisto and Moilanen 2006). This results in some areas being heavily oversampled, skewing the data. The common solution is to resample for a more appropriate time interval which may introduce data loss through over-reducing the sample size. Katajisto and Moilanen propose a time-kernel method to "account for temporal aggregation of observations" while reducing the potential data bias introduced by temporally autocorrelated observations.

Grueter et al. evaluated in 2009 the choice of analytical methodology used to estimate home ranges, stating that the size can vary tremendously. Specifically addressing the grid cell and the minimum convex polygon methods, Grueter et al. proposes an adjusted polygon method where only those areas suitable for habitation are analyzed, stating that the adjusted minimum convex polygon method is much more reliable when group movement is limited. The minimum convex polygon was preferred for monthly and seasonal home range calculation while the grid cell method was more precise for annual home range estimates (Grueter, Li and Ren 2009).

Kie et al. evaluated in 2010 how recent advances in animal telemetry technology have propagated large datasets where data-intensive techniques are used to determine animal home ranges. Kie et al. compared methodologies such as kriging and non-linear generalized regression models with more traditional methods, such as kernel density estimators, to determine if traditional methods are still relevant (Kie, et al. 2010).

Scull et al. concluded in 2012 that more meaningful home range modeling can be calculated from field data using GIS while evaluating mountain gorilla data from Uganda. Scull et al. compared the modeling methods of local convex hull and minimum convex polygon by looking at sensitivity to outliers, comparison among groups with different ranging behavior, and proportion of home range found outside a predefined geographic area. The local convex hull ranges were found to be smaller than minimum convex polygon ranges and more sensitive to outliers (Scull, et al. 2012).

Girard et al. addressed in 2013 how habitat selection can vary throughout the season in free-ranging feral horse herds in Alberta, Canada. By tracking global positioning system collared horses for 2 years, Girard et al. evaluated home ranges and vegetation preferences of four harems to establish critical horse habitats within a portion of the Rocky Mountain Forest Reserve. Home ranges were created using the Home Range Tool suite for ArcMap 9.3.1 (Girard, et al. 2013).

Design and Implementation

The study area included all of the NNSS, which is located in Nye County in south-central Nevada (Figure 2). The southeast corner of the NNSS is about 90 kilometers northwest of the center of Las Vegas in Clark County. The NNSS encompasses about 1,360 square miles and is surrounded on all sides by federal lands (National Security Technologies, LLC. 2011). There is currently a Cooperative Agreement directing the Management and Operations Contractor for the NNSS to maintain favorable habitat for the existing feral horse population. Biologists conduct periodic horse census surveys on the NNSS by driving selected roads to observe both animals and animal signs and by using cameras to record individual animals. The direct population count for calendar year 2010 was 35 individuals, not including foals, occupying a home range of approximately 271 square kilometers (Hansen, et al. 2010). A total of 422 records, collected from September 1, 2008, through December 4, 2011, were used in this analysis.

Figure 2 Map of study area showing relative location of NNSS to Las Vegas, Nevada.

Ecological data used in these analyses were provided by National Security Technologies, LLC. Ecological Service wildlife biologists that observed and documented the data from 1950 through present (National Security Technologies, LLC., Ecological Services 2014). Horse observations, roads surveyed for horses, water resources, and vegetation data were provided to the author in an Esri file geodatabase. Horse observations from conducted surveys and opportunistic sightings are available from 2000-present; however, only data collected from September 1, 2008, through December 4, 2011, were analyzed for this project. These datasets include information on the number of animals observed in each band or the type of sign observed, their geospatial location and general condition comments for observations occurring on a specific date, including the number of horses observed. "Horse survey roads" are those road routes that are driven by biologists while conducting horse surveys on the NNSS during 2010. The "water resources" data include the spatial locations of 30 naturally occurring and man-made watering holes on the NNSS that include seeps, springs, ponds and tanks. Data provided include the geospatial coordinates, names and type of water resource. The methodology used while conducting these surveys is available in the Annual Environmental Monitoring and Compliance Report (Hansen, et al. 2010).

Additional ecological data include vegetation polygons for the whole NNSS. These geospatial polygons delineate similar vegetative species, grouped together as ecological landform units (ELU). Samples collected along transects within the ELU provide information on species of plants and their frequency of occurrence within the ELU. The ELU attribute data also contains information on slope, elevation and average vegetation cover (Ostler, et al. 2000). Biologists also noted during transect surveys if signs of animal use, including horse signs, were detected. All data were provided to the author in Esri file geodatabase format.

Additional local geographic data used were provided by the National Security Technologies, LLC. Geographic Information Systems Group. Data provided include the NNSS Operational Boundary, Road Centerlines, and shaded-relief (National Security Technologies, LLC., Geographic Information Systems Group 2014). The NNSS Operational Boundary is the administrative extent of the NNSS as defined by various Public Land Orders and Memoranda of Understandings with the United States Air Force. Road Centerlines were digitized from orthophotography collected in 1997-1998 at a scale of 1:2000 feet. The shaded-relief was created from the DEM generated in 1997-1998. These datasets will be used to provide geographic context to the biologic data used in the analyses and were provided in an Esri file geodatabase.

Background images provided in maps for context are accessed via Esri's ArcGIS Online and include the National Geographic World Map Service (National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC 2011), USA Counties Map Service (Esri, TomTom, Department of Commerce, Census Bureau, U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), United States Central Intelligence Agency 2012) and World Topographic Map Service (USGS, FAO, NPS, EPA, NRCAN, GeoBase, ESRI, DeLorme, TANA, AND, other suppliers, and the GIS community 2010). Maps and spatial geostatistical analyses used throughout this document were created using ArcGIS® version 10.1 software by Esri (Esri 2012). Jake Wall's Movement Ecology Tools for ArcGIS® (ArcMET) were used to calculate an Adaptive Local Convex Hull (a-LoCoH) range (Wall 2014). All maps were designed with a Universal Transverse Mercator (meters) projection, using the North American Datum of 1983, which is the same projection and datum assigned to the data that were analyzed.

Geostatistical analyses were used to ascertain whether there were correlations between horse observations and vegetation, slope and elevation. Vegetation data were spatially joined to the horse observation data to determine in which vegetation association polygon horses can be most frequently seen or scat observed. The Chi-square Test, Correlation Coefficient and Frequency and Percentage Distributions were calculated in Microsoft Excel® (Microsoft 2007). To test whether correlations exist between horse observations and slope and elevation, vegetation data were spatially joined to the horse observation data to determine vegetation associations and extract slope and elevation values. Records with missing slope and elevation data were excluded. The Multiple Regression and Correlation data were calculated in Student MicroCase® (Wadsworth/Thomson Learning 2001). To test whether there was a correlation between horse observations, average vegetation cover and elevation, vegetation data were spatially joined to the horse observation data to extract their average vegetation cover and elevations from the vegetation association polygon. Records with missing vegetation cover and elevation data were excluded. The Multiple Regression and Correlation data were calculated in Student MicroCase®. To test whether there is a link between horse observations and average vegetation cover, slope and elevation, vegetation data were spatially joined to the horse observation data to determine their related vegetation association polygon and extract their average vegetation cover, slope and elevations. Records with missing vegetation cover, slope and/or elevation data were excluded. The Multiple Regression and Correlation data were calculated in Student MicroCase®. Results for all analyses are reported in tables and maps.

Horse observation data were manipulated to modify the time and date format of the observations into the correct format for the ArcMET a-LoCoH Range Tool to calculate an estimated home range (Wall 2014). Records without a time stamp were given a default value of 12:00:00, since the tool assumes all geospatial locations have been provided through Global

Positioning System tracking systems. Polygons were generated at the 50%, 90%, 95% and 100% level, where the percentage indicates how many points are closest to the average center of all the points located within the polygon.

Site Suitability was calculated in ArcGIS® using the Identify Tool from the Analysis Toolbox (Andris 2008). This Tool calculates the geometric intersection of two input vector features, which creates a feature class combining the attributes found within the spatial overlap, rather than the traditional method using raster datasets. The Identify Tool requires that all features must have the same geometry type, so point values were spatially joined to polygons for analysis. Since the Identify Tool copies attribute values from the input feature classes into the output feature class, part of the preparation involved deleting fields unnecessary to the final analysis.

Point data were prepared for analysis by performing spatial joins on the vegetation association polygons to determine presence or absence within the polygon extent. Water resources, both man-made and naturally occurring, were calculated with a value of 10. All other polygons without documented water resources were assigned a value of 0. Horse observations documented by biologists during annual surveys were calculated with a value of 20. Horse sign documented during vegetation surveys were calculated with a value of 5. All other polygons without horse observations were assigned a value of 0.

Slope and elevation data were spatially joined to horse observation data to determine horse preference. Polygons containing NULL values for Slope or Elevation were not evaluated. The slope spatial join indicated that any value less than 20 was used most frequently by horses observed on the NNSS; these were calculated with a value of 10. Slope values between 21 and 30 were calculated with a value of 5 and all other polygons were calculated with a 0. The elevation spatial join indicated that any elevation between 1300 and 2000 meters were used most frequently by horses observed on the NNSS; these were calculated with a value of 10. Elevations between 2001 and 3000 meters and elevations between 1000 and 1299 meters were used less frequently, but horses were still observed to utilize locations; these were calculated with a value of 5. All remaining polygons were assigned a value of 0.

The values for forage were derived from the vegetation association data by determining if specific species of plants were more desirable as forage. The Bureau of Land Management states that forage species important to feral horses include sagebrush, spiny hopsage, winterfat and various grasses and forbs (U.S. Department of the Interior, Bureau of Land Management 2013). The U.S. Forest Service maintains an online database of plants and their importance for management considerations (U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory 2014). One management consideration is whether the plant is valuable as forage. Crosschecking the vegetation association dominant plants against the U.S. Forest Service database yielded that *Krascheninnikovia lanata* (winterfat), *grayia spinosa* (spiny hopsage) and various species of *Artemisia* (sagebrush) and *Ephedra* (jointfir) are documented as good forage sources (U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory 2014). These species were assigned a value of 10. Additionally, if biologists indicated during the vegetation transects that there were forbs and grasses present, the polygons were assigned a value of 5. All remaining polygons were assigned a value of 0.

Results

To test the null hypothesis that vegetation associations cannot be used to predict horse observations, vegetation data polygons were spatially joined to the horse observation data points to determine in which vegetation association horses were most frequently seen or scat were observed. The Chi-square Test and Regression Correlation Coefficient were calculated in Excel (Table 1). The chi-square value was 20.1, with 10 degrees of freedom and the regression coefficient was 0.7. The p-value was less than 0.02, indicating that vegetation associations and horse observations are not related strictly by chance; the null hypothesis was rejected. Figure 3 shows the relationship between the vegetation association and total documented occurrences of all horse observations and sign.

Vegetation Association	Frequency Distribution: Sign	Horse	Percentage Distribution: Sign	Horse
A. nova-A. tridentata	3	10	2.19%	3.51%
A. nova-C. viscidiflorus	34	46	24.82%	16.14%
A. tridentata-C. viscidiflorus	23	37	16.79%	12.98%
C. viscidiflorus-E. nevadensis	2	19	1.46%	6.67%
C. ramosissima-E. nevadensis	2	13	1.46%	4.56%
E. nevadensis-G. spinosa	14	17	10.22%	5.96%
E. nauseosa-E. nevadensis	12	34	8.76%	11.93%
H. salsola-E. nevadensis	0	6	0.00%	2.11%
P. monophylla-A. nova	11	49	8.03%	17.19%
P. monophylla-A. tridentata	9	25	6.57%	8.77%
Disturbed	27	29	19.71%	10.18%
Total (N)	137	285	100.00%	100.00%

$\chi 2 = 20.976$; df = 10; $p < 0.02$; $r = 0.710$

Table 1 Frequency and Percentage Distributions with Chi-square Test and Regression Correlation Coefficient for Vegetation Association by Horse Observation

To test the null hypothesis that slope and elevation cannot be used to predict horse observations, vegetation data polygons were spatially joined to the horse observation data points to determine their related vegetation association and extract their slope and elevation from the vegetation association attribute table. Records with missing slope and elevation data were excluded. A Multiple Regression and Correlation test was calculated in Student MicroCase®, with results shown in Figure 4. R-squared was determined to be 0.061 and the Y-intercept was calculated to be 8.270. The F ratio generated indicated that R^2 was significant when $p<0.052$. This significance test rules out that random observations are the cause of the relationship between slope and elevation. Based on the regression coefficient

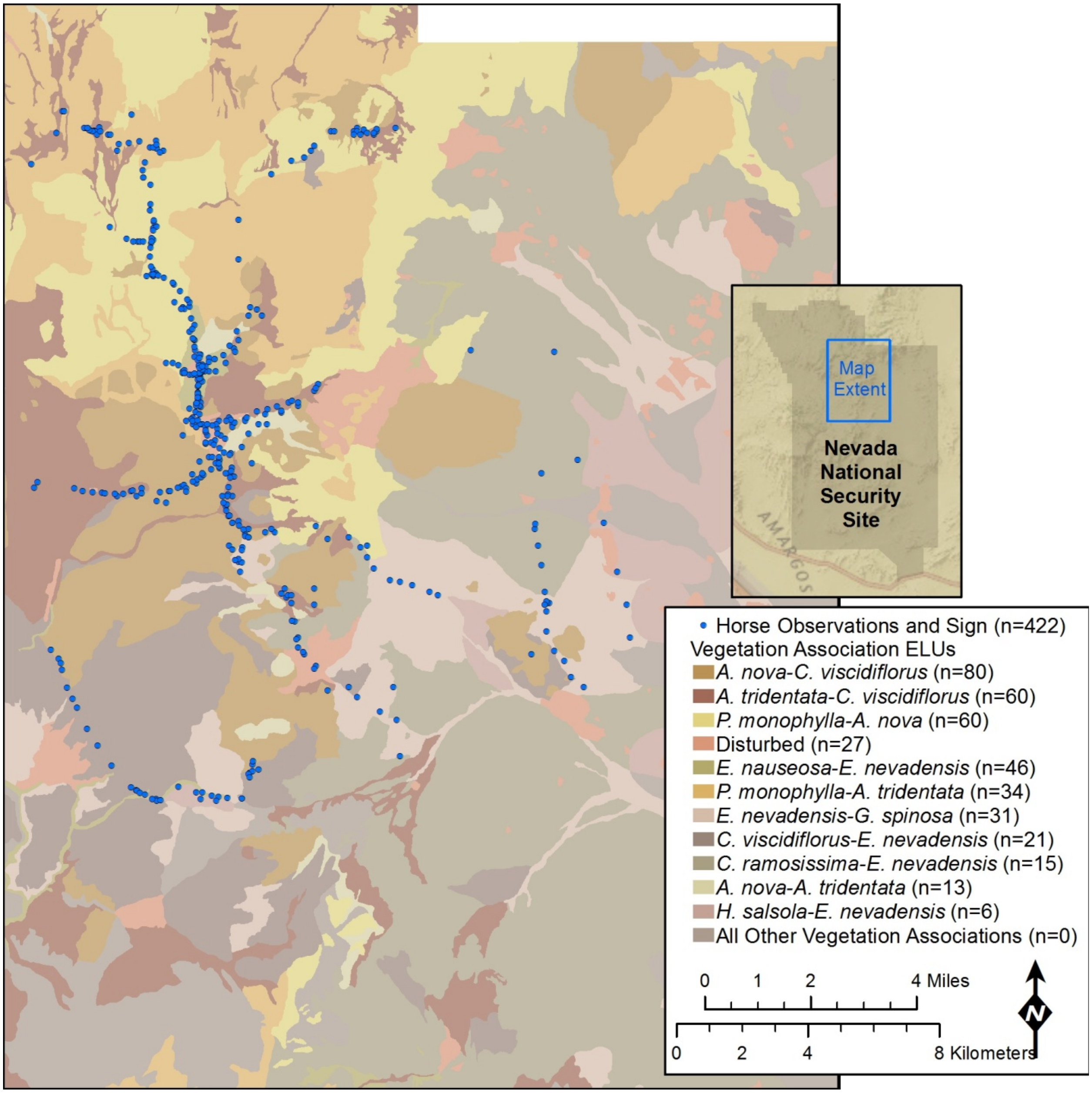

Figure 3 All Horse Observations within Vegetation Associations

and with slope held constant, there is a correlation towards a decrease in elevation when the horse observations increase by one standard deviation. The multiple correlation coefficient of 0.061 indicates that approximately 6% of the variation in horse observations is explained by the combined effects of slope and elevation. Slope, elevation and horse observations are not related strictly by chance, which can be visualized in Figure 4; the null hypothesis was rejected.

Analysis of Variance
Dependent Variable: horse
N: 97 Missing: 3
Multiple R-Square = 0.061 Y-Intercept = 8.270
Standard error of the estimate = 1.976
LISTWISE deletion (1-tailed test) Significance Levels: **=.01, *=.05

Source	Sum of Squares	DF	Mean Square	F	Prob.
REGRESSION	23.864	2	11.932	3.056	0.052
RESIDUAL	367.023	94	3.904		
TOTAL	390.887	96			

	Unstand.b	Stand.Beta	Std.Err.b	t
slope	-0.009	-0.043	0.023	-0.406
elevation	-0.003	-0.229	0.001	-2.163 *

Figure 4 Analysis of Variance Statistic from Student MicroCase® for Horse Observations by Slope and Elevation

To test the null hypothesis that average vegetation cover and elevation cannot be used to predict horse observations, vegetation data polygons were spatially joined to the horse observation data points to determine their associated vegetation association and extract their average vegetation cover and elevations from the vegetation association attribute table. Records with missing vegetation cover and elevation data were excluded. A Multiple Regression and Correlation test was calculated in Student MicroCase®, with results shown in Figure 6. R-squared was determined to be 0.059 and the Y-intercept was calculated to be 8.446. The F ratio generated indicated that R^2 was significant when $p<0.056$. This

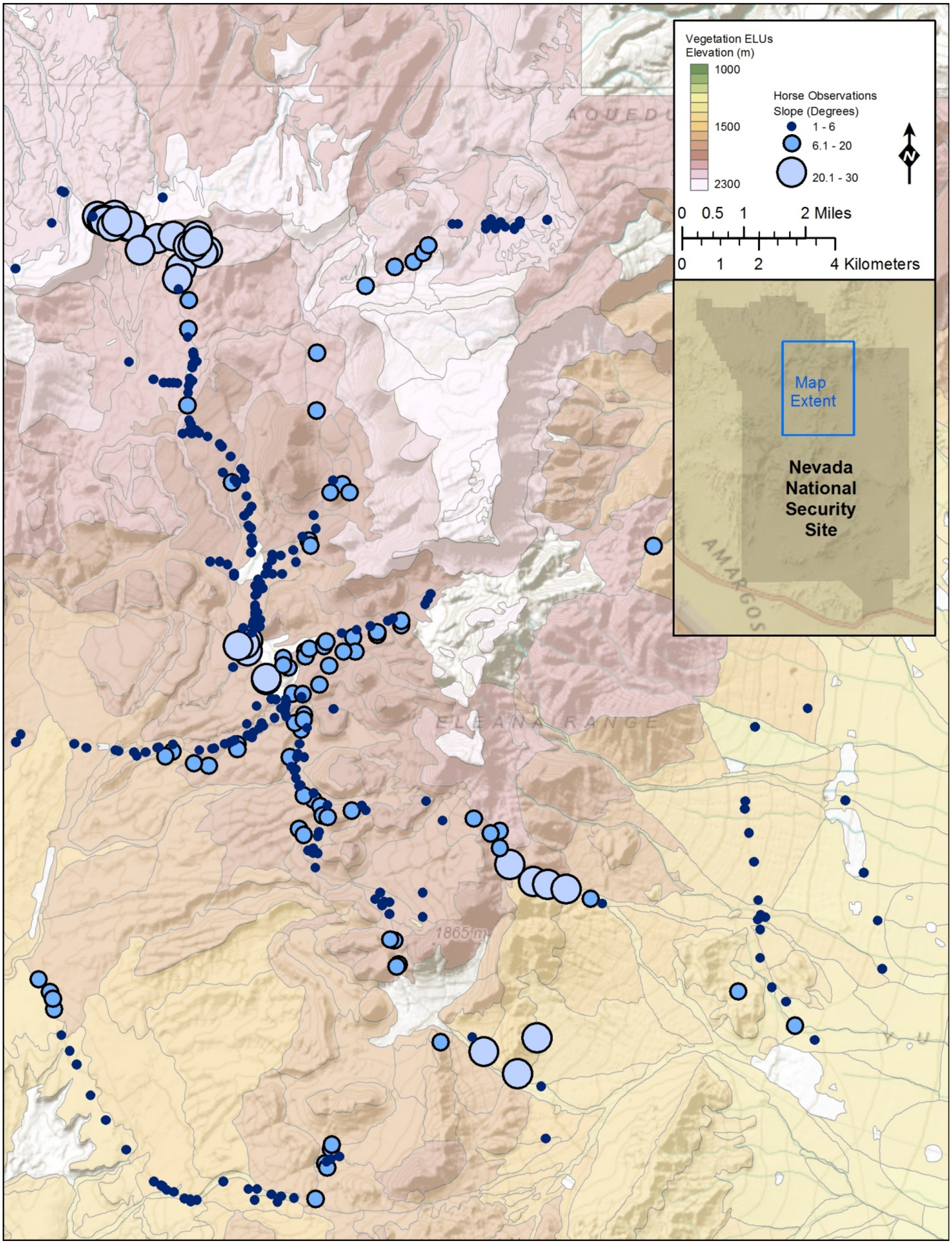

Figure 5 Horse Observations Correlated by Slope with Vegetation Association and Elevation

significance test rules out that random observations are the cause of the relationship between elevation and average vegetation cover. Based on the regression coefficient and with average vegetation cover held constant, there is a correlation towards a decrease in elevation when the horse observations increase by one standard deviation. The multiple correlation coefficient of 0.059 indicates that approximately 6% of the variation in horse observations is explained by the combined effects of elevation and average vegetation cover. Average vegetation cover, elevation and horse observations are not related strictly by chance, which can be visualized in Figure 7; the null hypothesis is rejected.

Analysis of Variance
Dependent Variable: horse
N: 97 Missing: 5
Multiple R-Square = 0.059 Y-Intercept = 8.446
Standard error of the estimate = 1.978
LISTWISE deletion (1-tailed test) Significance Levels: **=.01, *=.05

Source	Sum of Squares	DF	Mean Square	F	Prob.
REGRESSION	23.226	2	11.613	2.969	0.056
RESIDUAL	367.661	94	3.911		
TOTAL	390.887	96			

	Unstand.b	Stand.Beta	Std.Err.b	t
elevation	-0.003	-0.243	0.001	-2.398 *
avgvegcove	0.001	0.004	0.020	0.038

Figure 6 Analysis of Variance Statistic from Student MicroCase® for Horse Observations by Average Vegetation Cover and Elevation

To test the null hypothesis that average vegetation cover, slope and elevation cannot be used to predict horse observations, vegetation data polygons were spatially joined to the horse observation data points to determine their related vegetation association and extract their average

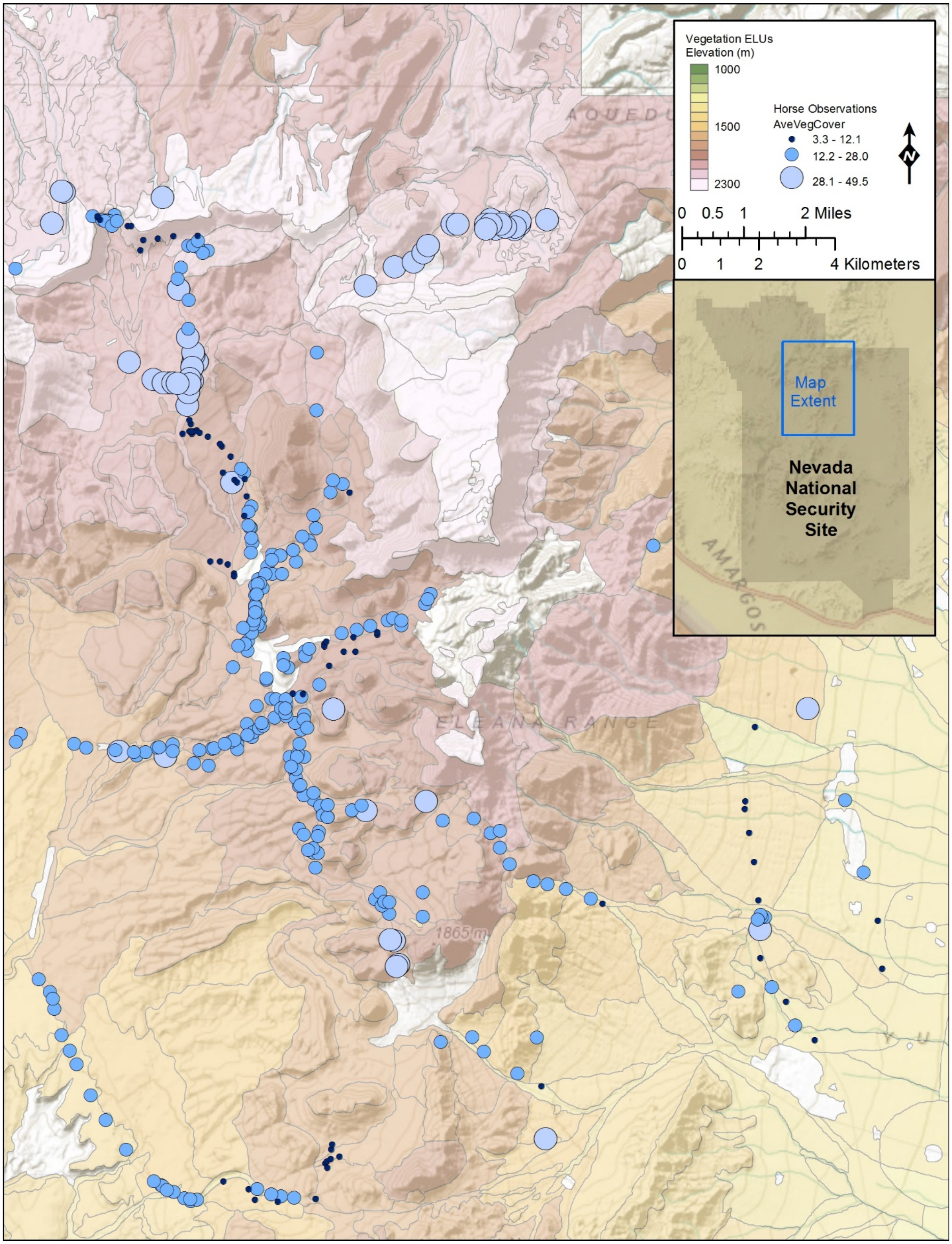

Figure 7 Horse Observations Correlated by Average Vegetation Cover with Vegetation Association and Elevation

vegetation cover, slope and elevation from the vegetation association attribute table. Records with missing vegetation cover, slope and/or elevation data were excluded. A Multiple Regression and Correlation test was calculated in Student MicroCase®, with results shown in Figure 8. R-squared was determined to be 0.061 and the Y-intercept was calculated to be 8.249. The F ratio generated indicated that R^2 was significant when $p<0.117$. This significance test rules out that random observations are the cause of the relationship between elevation, slope and average vegetation cover. The multiple correlation coefficient of 0.061 indicates that approximately 6% of the variation in horse observations is explained by the combined effects of elevation, slope and average vegetation cover. Average vegetation cover, slope, elevation and horse observations are not related strictly by chance and the null hypothesis is rejected.

Analysis of Variance
Dependent Variable: horse
N: 97 Missing: 5
Multiple R-Square = 0.061 Y-Intercept = 8.249
Standard error of the estimate = 1.987
LISTWISE deletion (1-tailed test) Significance Levels: **=.01, *=.05

Source	Sum of Squares	DF	Mean Square	F	Prob.
REGRESSION	23.867	3	7.956	2.016	0.117
RESIDUAL	367.019	93	3.946		
TOTAL	390.887	96			

	Unstand.b	Stand.Beta	Std.Err.b	t
elevation	-0.003	-0.229	0.001	-2.124 *
avgvegcove	0.001	0.003	0.020	0.029
slope	-0.009	-0.043	0.023	-0.403

Figure 8 Analysis of Variance Statistic from Student MicroCase® for Horse Observations by Average Vegetation Cover, Slope and Elevation

ArcMET was used to calculate the a-LoCoH as the estimated home range of feral horses. The 422 feral horse observations gathered between September 2008 and December 2011 were used as the input movement dataset for the ArcMET a-LoCoH tool, and the modified time field containing both date and time were used for the time field. Data were output to a file geodatabase at the 50%, 90%, 95% and 100% levels. A total area of 88.1 square kilometers was derived at the 100% level; 57.6 square kilometers for the 95% level; 48.2 square kilometers for the 90% level; and 13.0 square kilometers for the 50% level (Figure 9).

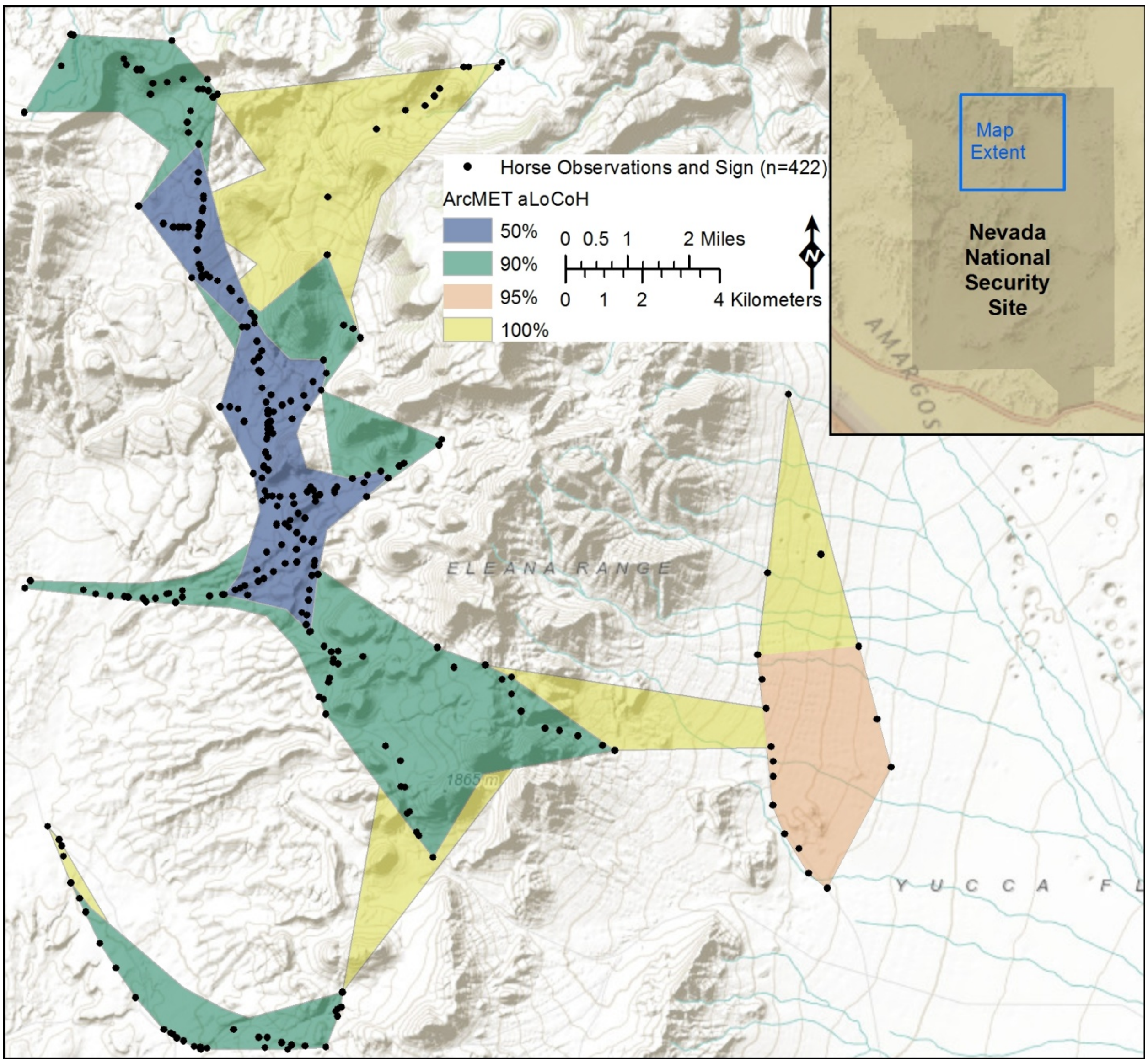

Figure 9 ArcMET Adaptive Local Convex Hull Estimated Home Range with All Horse Observations

Suitability ranking values were derived from the prepared polygons for elevation, forage, slope, water presence and horse observations by combining the output of four successive iterations of Esri's Identity Tool into one feature class polygon (Figure 10). A new field was created named "Suitability" to house the final calculation. Then, the values for each variable were added together using the Field Calculator in ArcMap® in the Suitability field.

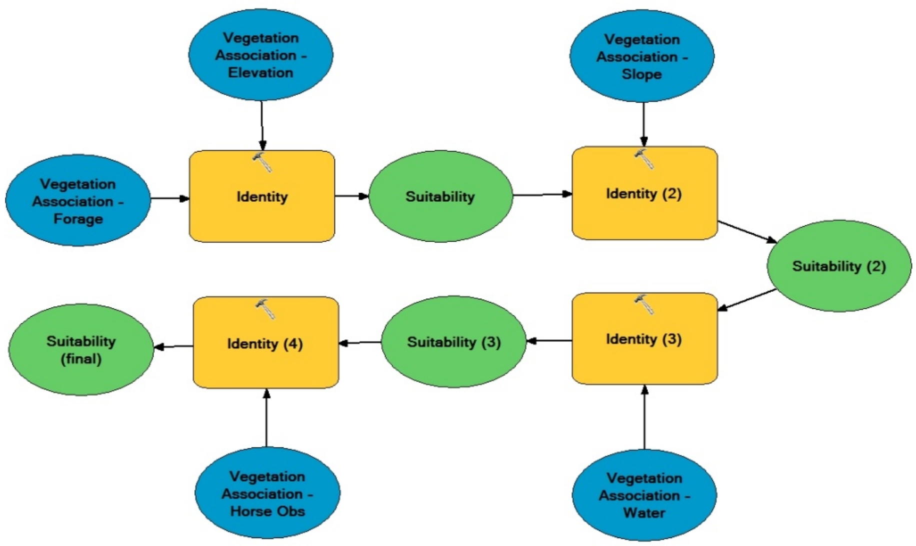

Figure 10 ArcMap Suitability Model

Derived data values ranged from 0 through 55 and are displayed in Figure 11 using Natural Breaks (Jenks) with 4 classes. Suitability rankings established that 85 square kilometers are most suitable habitat (ranking of 41-55) for feral horses on the NNSS, with 2,052 square kilometers of good habitat (ranking of 26-40), 1,252 square kilometers of fair habitat (ranking of 11-25) and 122 square kilometers of least suitable habitat (ranking of less than 10).

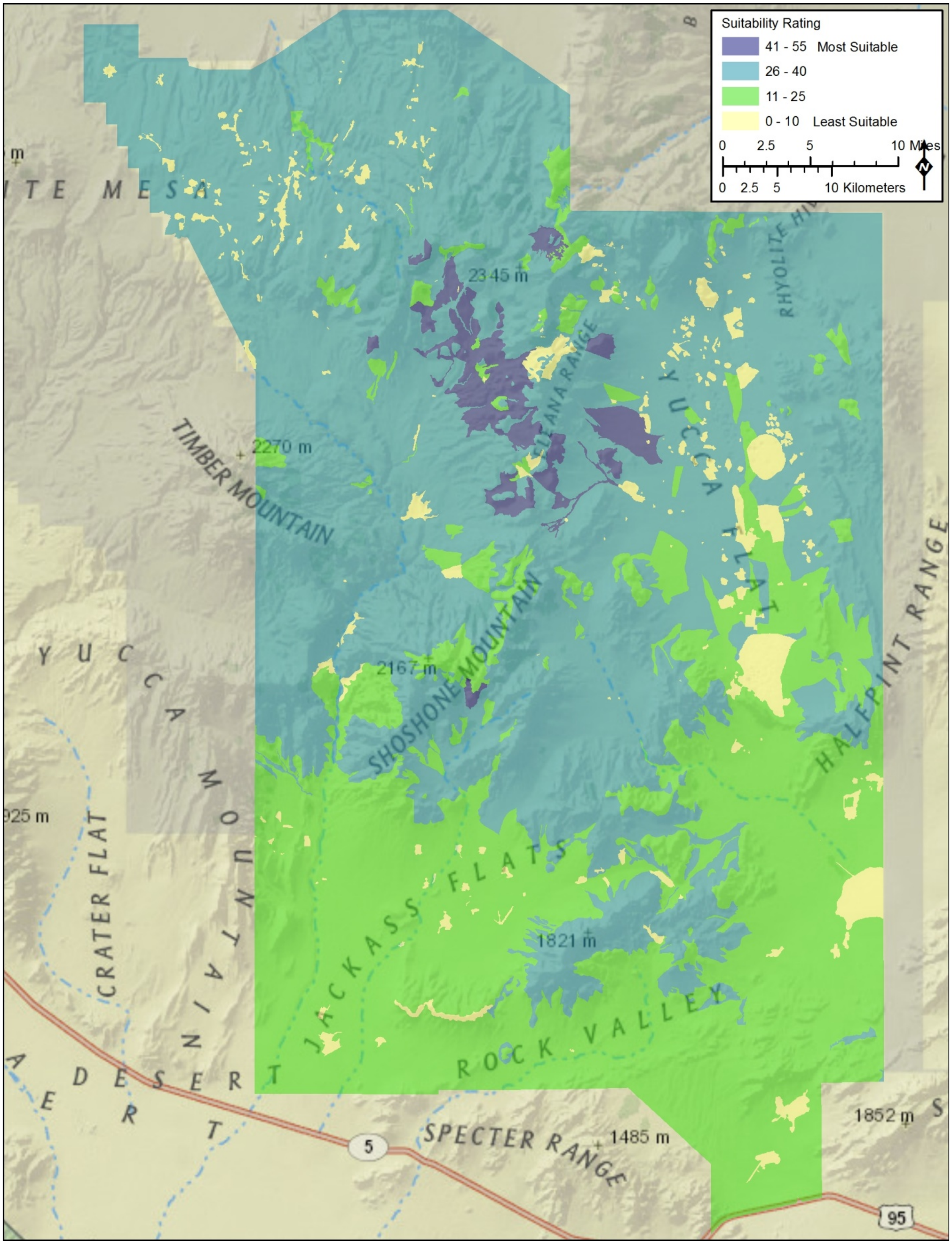

Figure 11 Site Suitability Index Rating

Discussion

Water resources are available as both seasonally and perennially available springs, seeps, ponds and tanks. Water availability had a strong correlation to where feral horses are geospatially located. The community of feral horses living on the NNSS is similar to other communities living in desert ecosystems in that they are exposed to temperature extremes and are limited by access to sufficient water resources. Precipitation in the desert is generally no more than a few inches in a typical year, mostly occurring during the winter months as snowfall. This climate compels wildlife to locate persisting water sources during the summer months as an essential for survival.

Vegetation type, which is an indicator of preferred food resources, also had a strong correlation to the geospatial distribution of horses. Elevation and slope are related to vegetation type, since both are tied to presence or absence of specific plant species. Food and water together comprise the basic elements for survival of any animal species. It is not surprising that these variables can contribute to a meaningful geospatial model predicting preferred feral horse habitat.

Horse observations and documentation of horse sign are biased towards occurring on man-made roads and trails. Because of the size of the study area and remote location, biological surveys conducted along these routes are more effective than conducting random transect surveys or other sampling methodology. Road surveys and casual encounters are documented throughout each calendar year and methodology is consistently utilized to minimize the effects of roads on demography.

This analysis can be extended to utilize the entire range of feral horse observation data available, from 2000 to present, which could be used to further refine feral horse habitat on the site. Likewise, this model could be applied to other feral horse habitats in a different geospatial location. Additionally, observations of other animals could be distilled from the historic records to identify other potentially important habitats. For example, if a new animal species is identified as being potentially listed as threatened or endangered, this tool could help biologists target specific habitats for further study.

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