

# Performing a Habitat Suitability Analysis for the Mexican Gray Wolf Using GIS Software

GEO 327G: GIS and GPS Applications in Earth Science, Fall 2015

By Cole Speed

## Introduction and Problem Formulation

The Mexican gray wolf, also known as “El Lobo”, is the southernmost dwelling and smallest subspecies of gray wolf on the North American continent (Nowak, 1995). The onset of the livestock industry in the southern United States during the late 1800s and early 1900s resulted in near eradication of the species by concerned ranchers and eager hunters and trappers. After a dramatic decline in population during the early 20<sup>th</sup> century, the Mexican gray wolf was finally listed on the Endangered Species Act in 1976 (Brown, 1983). Around this time, many of the remaining Mexican wolves in the southwestern United States and Mexico were captured by US and Mexican wildlife restoration agencies. These wolves were allowed to breed in captivity until 1998, when 11 captive-bred Mexican gray wolves from 3 independent packs were successfully released in the southeastern portion of Arizona (Nie, 2003). Although the population recovery efforts appear to be successful thus far, it is important that we continue to protect wolf habitats for future generations. For this project, I am performing a suitability analysis using ArcGIS software to identify the most ideal Mexican gray wolf habitats in Arizona in the event that future population restoration becomes necessary. The most important factors to consider in determining habitat suitability are: Availability of primary food source, human population density, road and highway density, and availability of natural vegetation. I hypothesize that the large majority of Mexican wolf packs will be located in mountainous (high elevation), wooded areas containing abundant food, a low human population density, with very little to no major roads crosscutting. To do this I will obtain relevant vector and/or raster data including DEMs of the study area, datasets of known food source locations and human population/road density. I will convert vector data sets to raster format, reclassify them to create a ranking scheme needed to identify the most prominent areas in region for a particular attribute, and use the Raster Calculator to generate a map layer depicting the area that I predict will be most suitable for wolves. I will then compare the final result to the known Mexican wolf pack locations to examine the validity of my model.

## Data Collection

I begin the data collection process by acquiring zipped files containing raster and vector data that will be used for the project from a variety of online sources. This project requires the use of a digital elevation model (DEM) for the study area and numerous shapefiles including: Arizona state boundary, Arizona surface vegetation data, mule deer population distribution data, major cities in the state of Arizona, and major highways. Some of the zipped files contain all the relevant metadata, but for the others I am able to acquire the metadata from the online source which will be included in ArcCatalog. After collecting the zipped files, I extract the data from each to a project folder for use in ArcMap (**Figure 1**). Also, provided in **Figure 2** is a screenshot of the metadata contained in the “Description” tab in ArcCatalog for the Major\_Roads file.

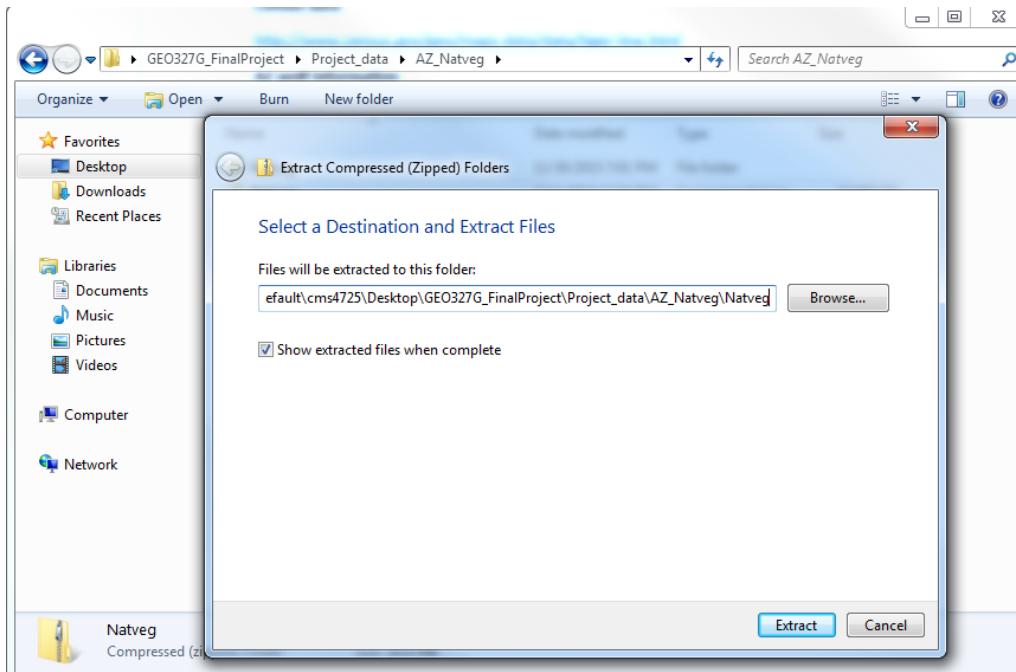


Figure 1. Extracting data from zipped file

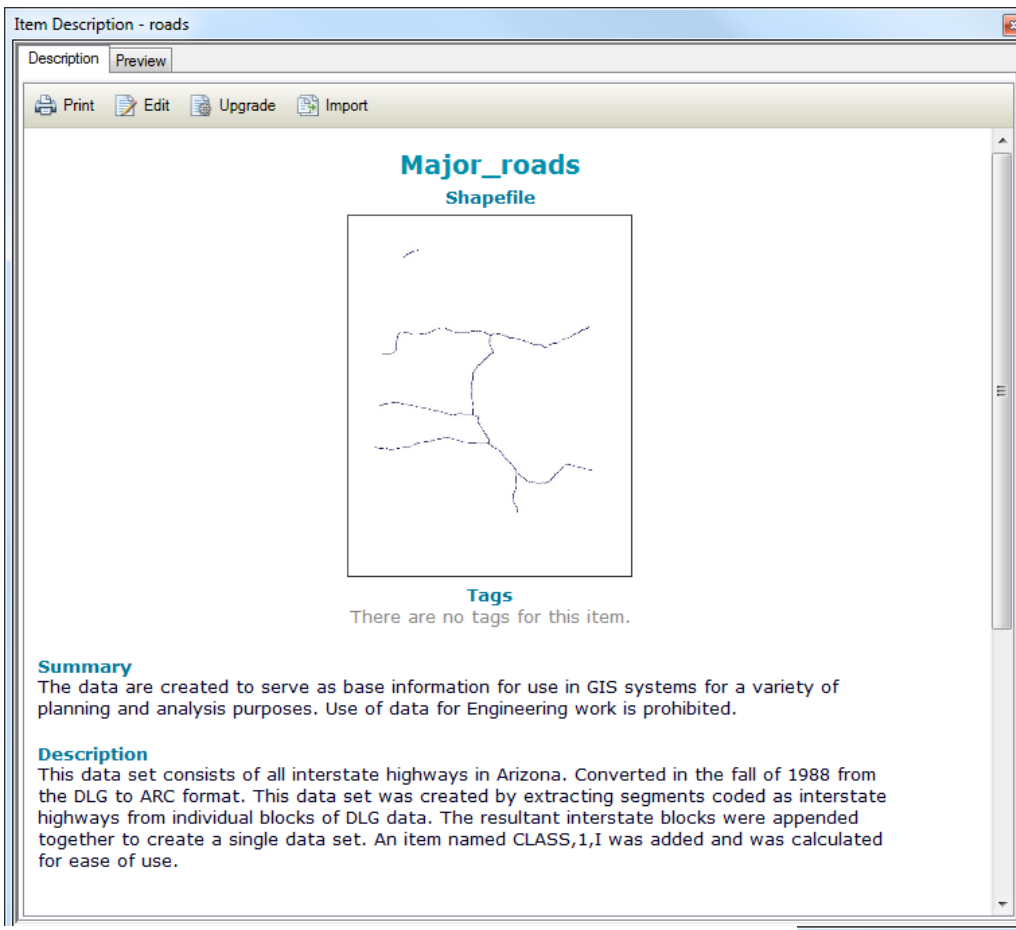


Figure 2. Relevant metadata within ArcCatalog

The table below contains the file names, file type, online source where the data was acquired, spatial reference information, and a brief description of the data (obtained via metadata) and how it will be implemented.

Layer name	Data Type/File Type	Source	Spatial Reference	Description
GTOPO30_DEM	Raster Dataset (DEM)	<a href="http://earthexplorer.usgs.gov">http://earthexplorer.usgs.gov</a>	GCS WGS 1984	USGS Global 30-Arc Second DEM for the study area.
State_boundary	Vector Shapefile - Polygon	<a href="http://www.census.gov/geo/maps-data/data/tiger-line.html">http://www.census.gov/geo/maps-data/data/tiger-line.html</a>	GCS WGS 1984	Tiger/Line shapefile of state boundary. TIGER/Line and Census TIGER are registered trademarks of the U.S. Census Bureau. This population distribution data will be used to identify areas of low human inhabitation.
Natveg	Vector Shapefile - Polygon	<a href="http://uair.library.arizona.edu/item/292543/browse-data/Vegetation%20%2526%20Animals">http://uair.library.arizona.edu/item/292543/browse-data/Vegetation%20%2526%20Animals</a>	NAD 1983 UTM Zone 12N	Shapefile containing all vegetation information. We will use wilderness locations for ideal wolf habit.
muledeer	.E00 Interchange format	<a href="http://www.gis.usu.edu/current_proj/muledeer.html">http://www.gis.usu.edu/current_proj/muledeer.html</a>	NAD 1983 UTM Zone 12N	Data set containing population distribution of mule deer across N. America. We will mule deer as the food source and clip the distribution to the state boundary.
Population	Feature class within a geodatabase	<a href="http://www.census.gov/geo/maps-data/data/tiger-line.html">http://www.census.gov/geo/maps-data/data/tiger-line.html</a>	Unknown	Shapefile showing major cities. These will be buffered, because wolves will not reside near cities.
Major_roads	Vector Shapefile - Line	<a href="http://uair.library.arizona.edu/item/292543/browse-data/Transportation">http://uair.library.arizona.edu/item/292543/browse-data/Transportation</a>	NAD 1983 UTM Zone 12N	Shapefile showing major roads. These will be used in the spatial analysis.

## Data Preprocessing

### Assigning a spatial reference

Initially, as seen in the table above, the acquired data files possess inconsistent spatial references. In fact, a few contain no spatial reference at all. This must be corrected for, so that all of the data shows up in its true geographic position. I create a new personal geodatabase and feature dataset, assigning NAD 1983 UTM Zone 12N as the spatial reference. I have done so because the majority of the state of Arizona lies within UTM Zone 12N. I then use “Import → Feature class (multiple)” to import roads, natural vegetation, and state boundary feature classes into my new feature dataset within my project geodatabase (**Figure 3**).

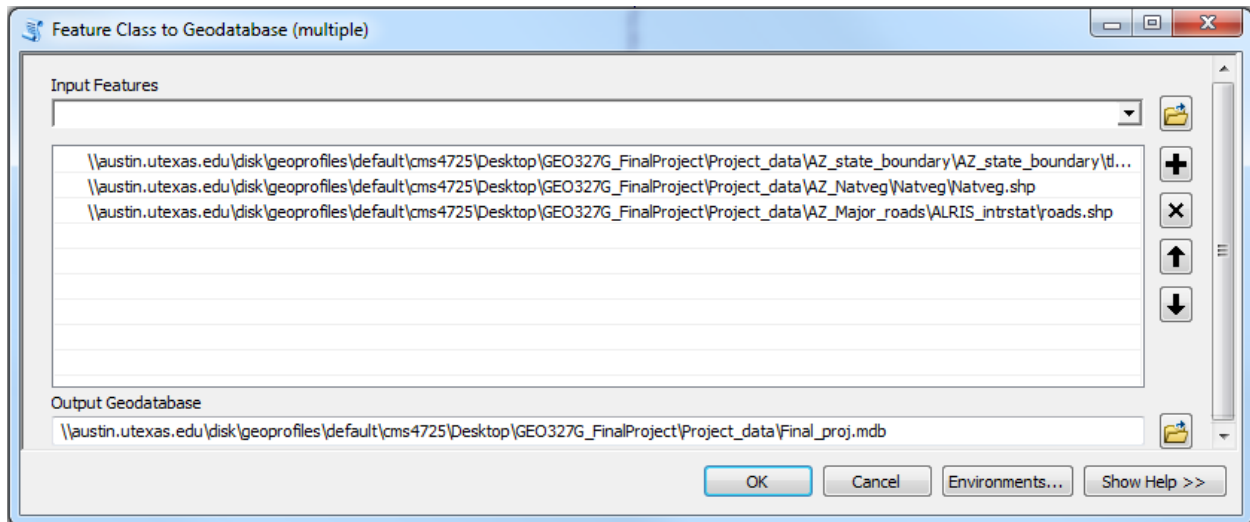


Figure 3. Assigning a spatial reference.

I have obtained population distribution data for mule deer in a coverage. This coverage contains a series of feature classes (A-F), which are used to represent distribution of mule deer throughout the state of Arizona at different times of the year. A description of the different classes is provided in text format within the file, and is shown in **Figure 4**, below. I choose to use “Class F” because it is the year-round distribution throughout the study area and import the feature class into my geodatabase. As an aside, I have chosen to use mule deer population because extensive research has concluded that they are a major staple of the Mexican gray wolf diet (Reed, et al., 2008).

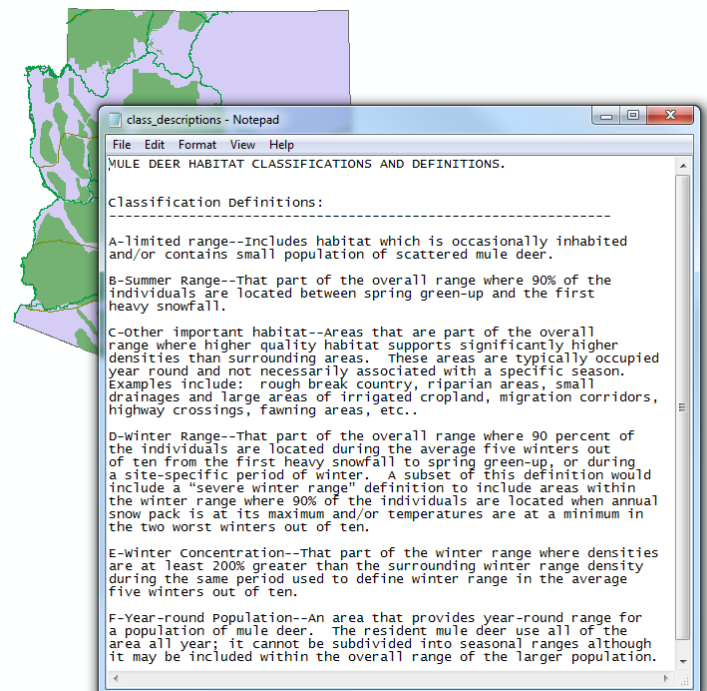


Figure 4. Description of data.

I then use the “Define Projection” tool in the Data Management toolbox to create a new feature class for the Census data. This new feature class now shares the same spatial reference as the remaining data. This step is shown in **Figure 5**, below.

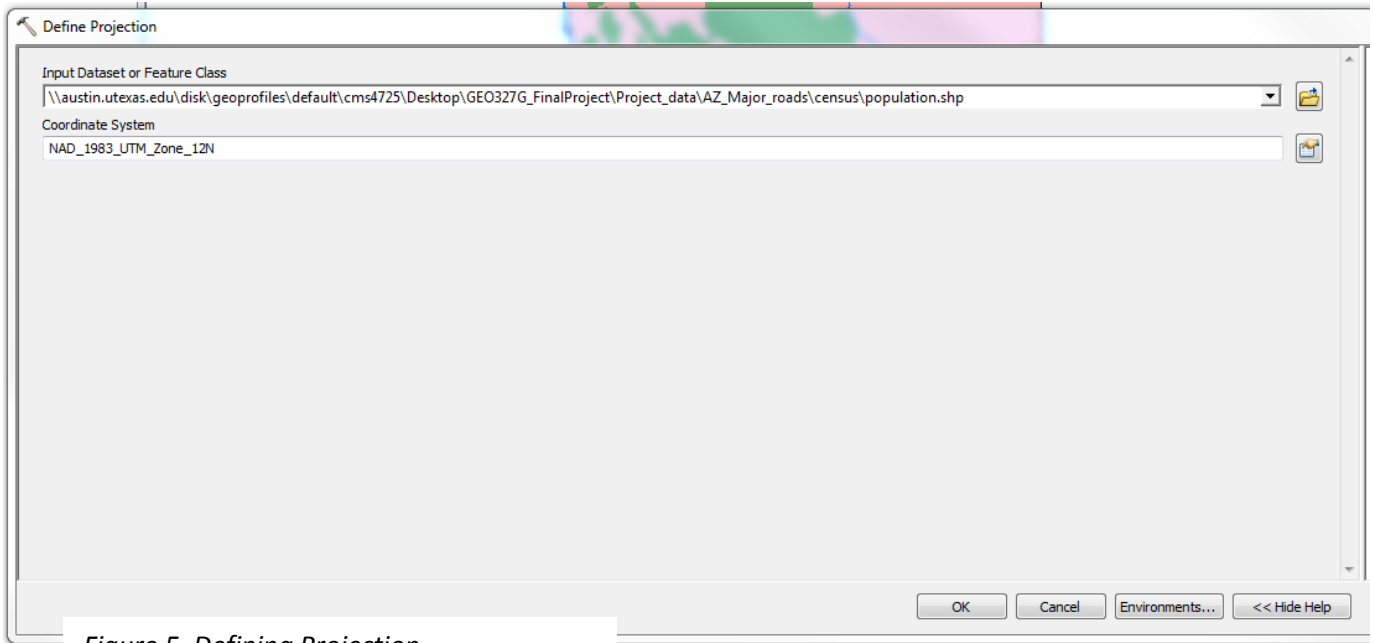


Figure 5. Defining Projection

To access actual elevation values from the previously acquired GTOPO30 DEM needed for this analysis, it is necessary to convert the DEM to ESRI grid format. This is desirable because it will produce elevation in meters. The process to do so involves converting the original cell values from signed 16-bit binary format to ASCII format values. I start by replacing the .dem extension with .bil and exporting the raster to GRID format within ArcCatalog (**Figure 6**).

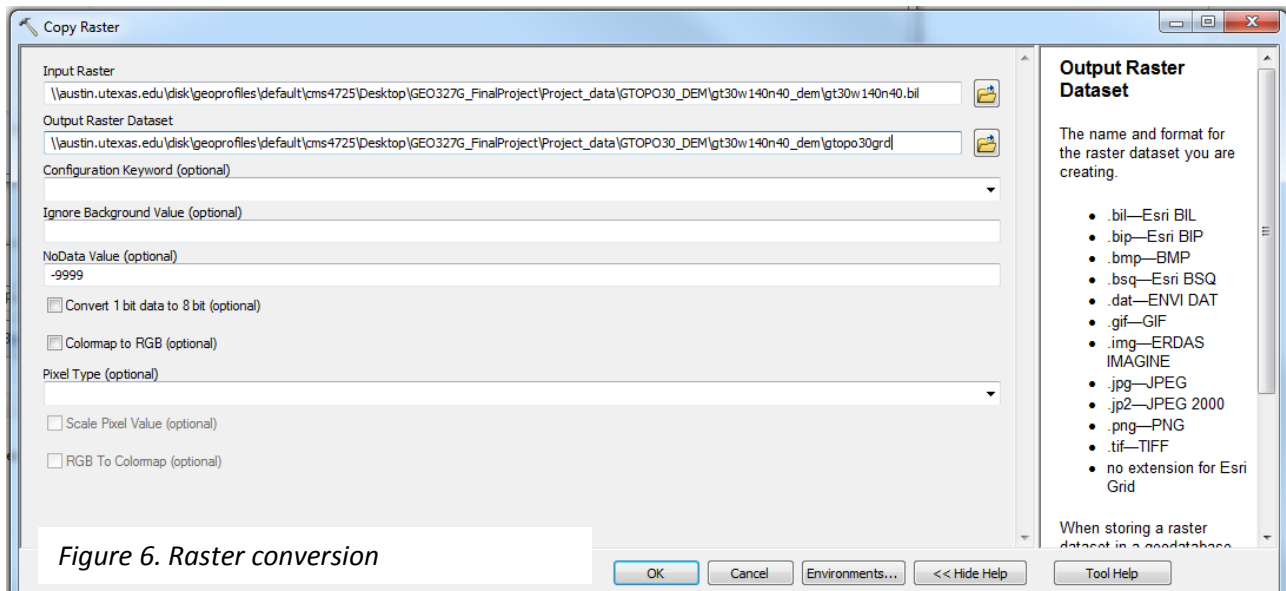
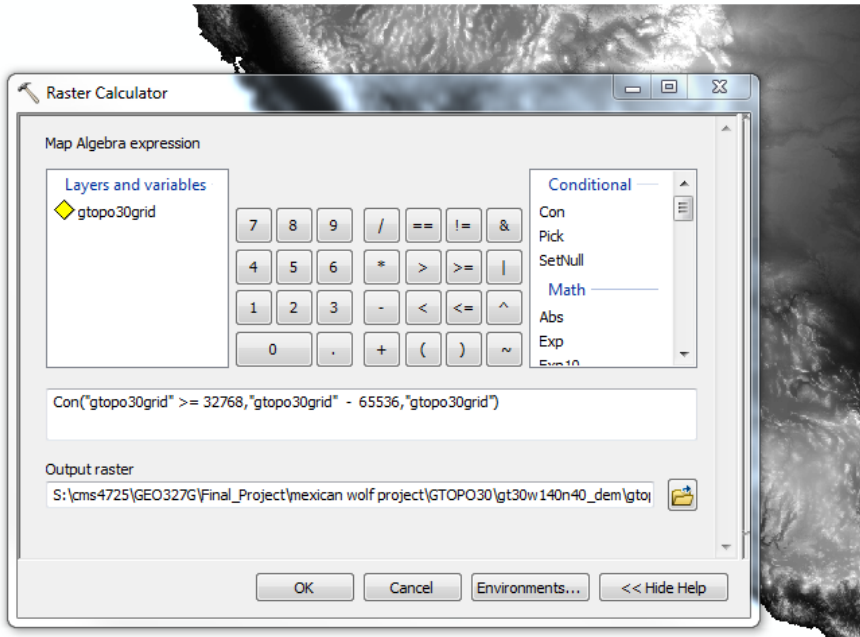


Figure 6. Raster conversion

Then, in ArcMap, using the Spatial Analyst Raster Calculator, I derive a new grid. This process ensures that the negative values will be properly represented. The syntax used is shown in **Figure 7**

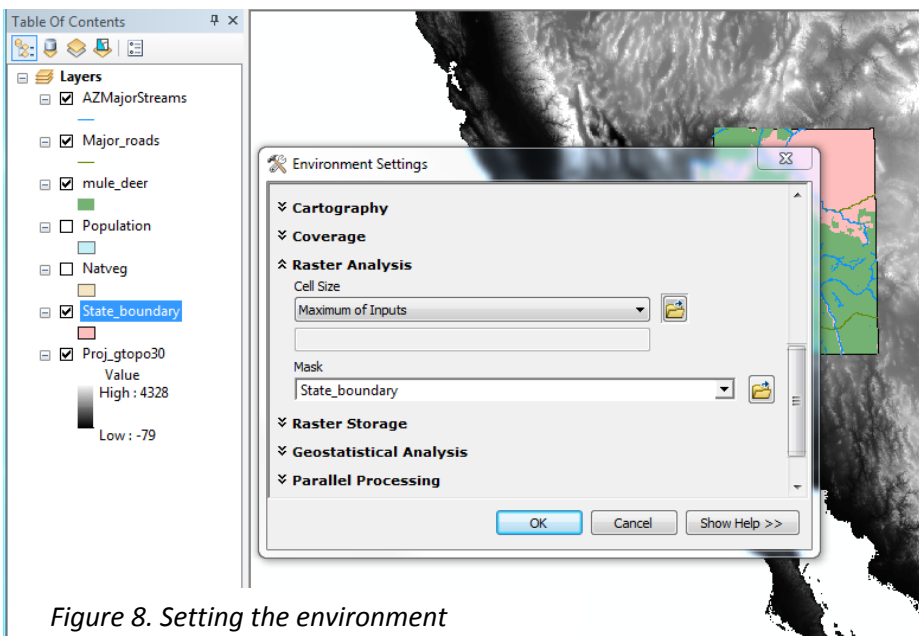


Now that the negative values are properly depicted, the final step is to project the DEM into UTM Zone 12N using the “Raster Projection” tool within the Data Management toolbox. This will result in a raster possessing units of meters in the x, y, and z directions.

Figure 7. Correcting raster

**Preparing data for rasterization and reclassification**

Now that all the data is projected into the same coordinate system, I need to prepare the data for rasterization. I start by creating a folder called “new\_grids” and using the “Environments” tab, set this folder as my working directory. I need to define the grid properties using the same



tab because, ultimately, all the rasters used in the suitability analysis must have the same spatial extent and resolution. To achieve this, I create and set a mask, using the state boundary polygon as the masking element. These steps are depicted in **Figure 8**. Even though it is not necessarily required, I choose to clip my vector data to the state boundary as well using the Clip tool in the Analysis toolbox. The only data that requires clipping are a few overhanging roads.

Figure 8. Setting the environment

The vegetation (land cover) file's "description" field contains a wide variety of different types of natural vegetation located in the state of Arizona. Some entries are very similar (e.g. "Great Basin Conifer Woodland" and "Madrean Evergreen Woodland"). I would like to, instead, have general descriptors such as "Grasslands", "Forests", "Woodlands", et cetera. To do this, I add a field to the vegetation attribute table, and populate the new field with a number, 0-5, depending on the overall type of vegetation. I then use the Dissolve tool in the Data Management toolbox to aggregate all the polygons for the corresponding surface vegetation. The process and the result are shown in **Figures 9a-9b**.

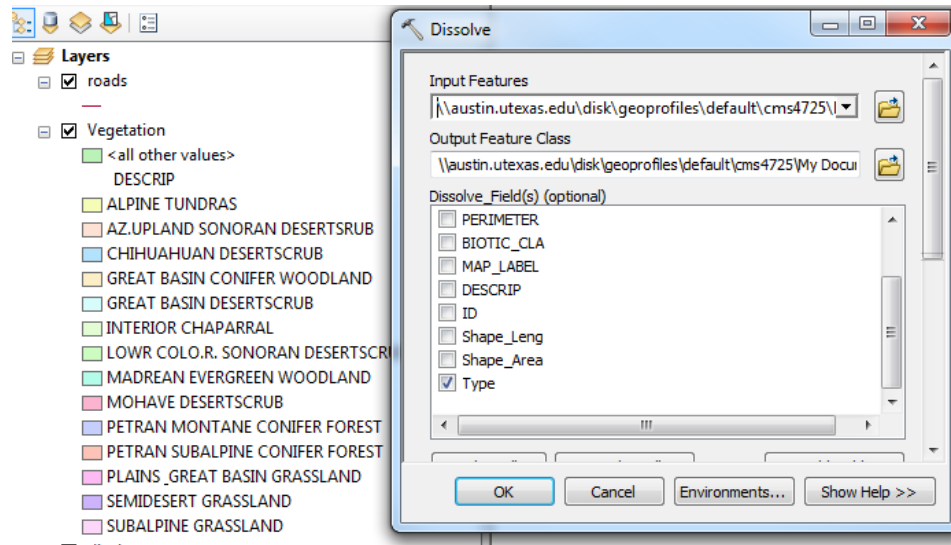


Figure 9a. Dissolving the land cover data

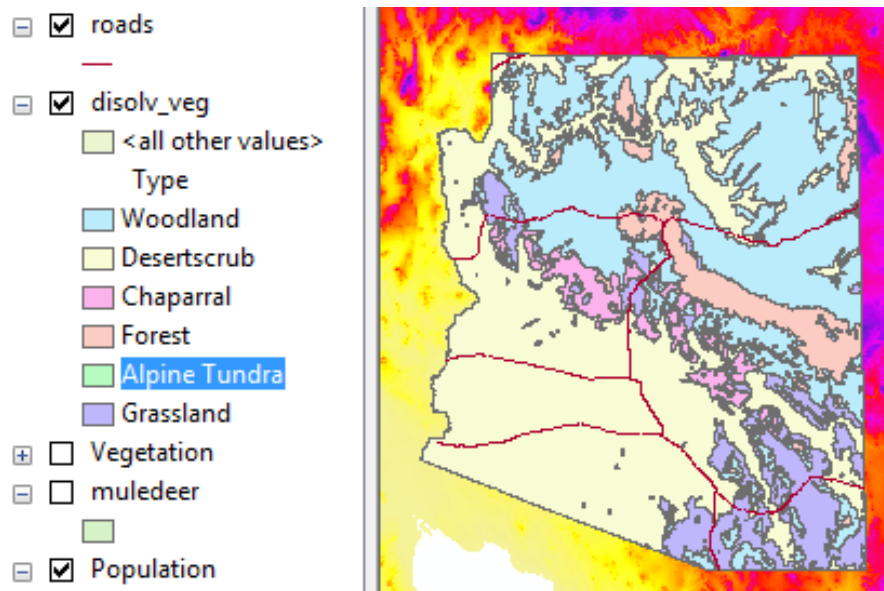


Figure 9b. Dissolved data



The final step in the data preprocessing section of the project is generating population density information from population data and census tract area. Originally, the areas for the census tracts in the census layer file are in square meters. I add a new field for area of each tract in square kilometers and use the Field calculator to generate the areas. I then add another field and use the field calculator to calculate the population density according to the syntax shown in **Figure 11**. I now have a file containing population density which will be converted to raster form in the next section for the spatial analysis.

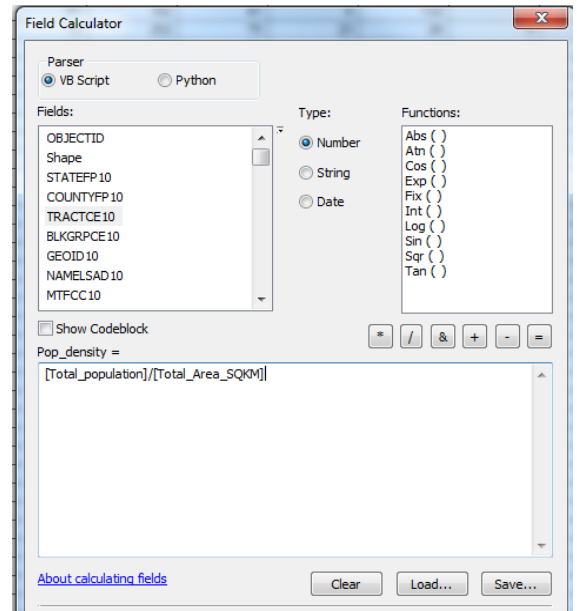


Figure 11. Calculating Population density

## Data Processing: Rasterizing and Reclassifying Generating raster datasets

As I explain in more detail in the next section, wolves historically live at or above an elevation of 1370 m. I wish to create a binary raster from the GTOPO30 DEM in which cells below this elevation are attributed NoData. To do this, I use a Conditional Statement in the Raster Calculator provided in **Figure 12**. Now cells with values above 1370 m take on a value of 1 and all other cells take on a value of NoData. Conveniently, all raster data outside of my study area has been masked to produce a binary raster depicting elevations above 1370 m *only* within the state of Arizona.

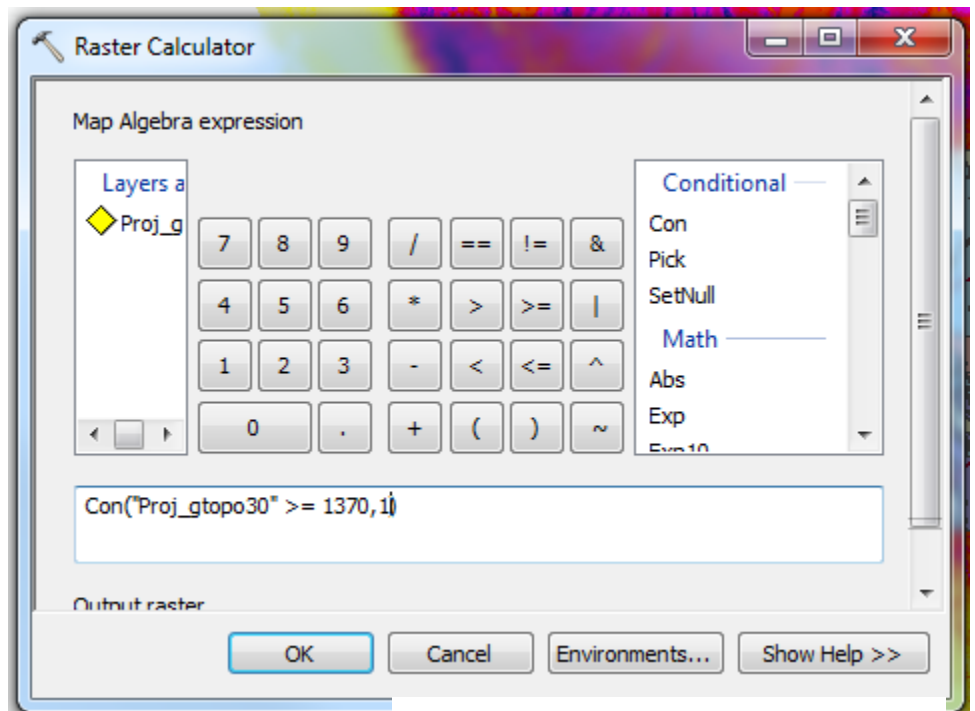


Figure 12. Creating a binary raster

Next, using the Convert > Features to Raster tool within the Conversion toolbox, I convert the dissolved vegetation layer to a raster layer. I then repeat this process for mule deer distribution (using the Class F field), human population density (using the population density field), and the state boundary layer files, making sure that the output cell size is equal to that of the DEM raster file. We leave these layers with the default symbology for now. The process used is shown in **Figure 13**, with the result in **Figure 14**.

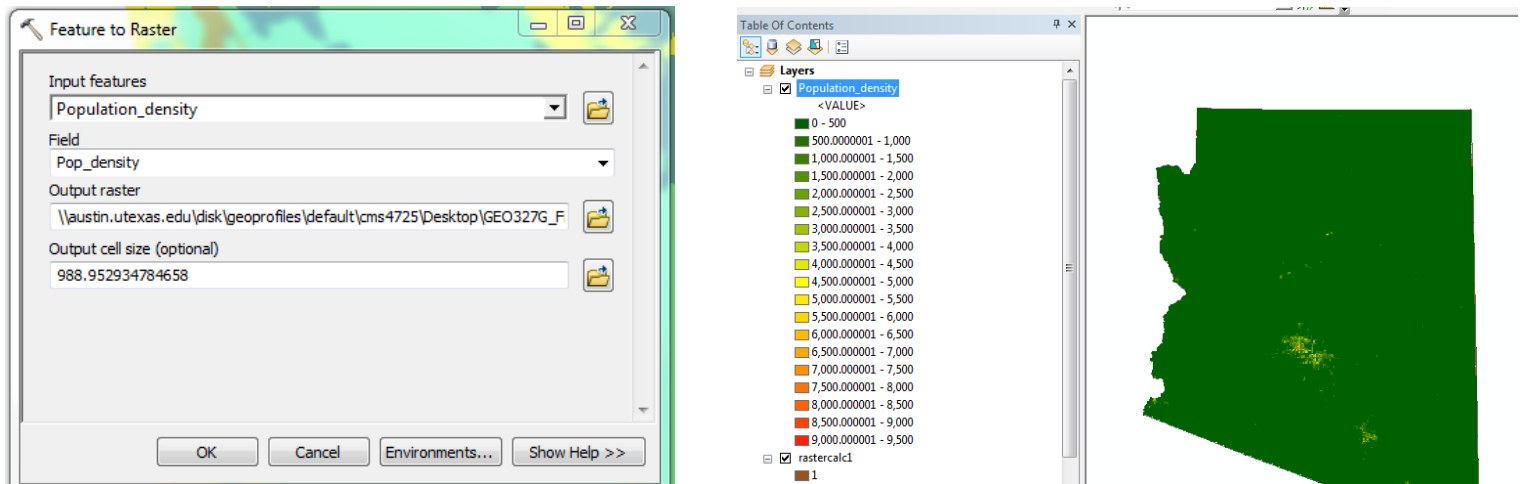


Figure 13 and 14. Raster conversion process and result

### ***Defining a ordinal ranking scheme for Mexican Wolf habitat suitability***

I now need to establish the factors that make a specific locality the ideal habitat for Mexican wolf populations. Using information obtained from publications, I can apply a ranking scheme for each of the new rasters via reclassification. I will use a differing scale for each raster, with the highest value corresponding to the most habitable attribute for wolves for each particular raster dataset.

### ***Elevation***

Almost all historical records of the Mexican gray wolf occur above an elevation of 4,500 feet or 1370 meters (AZGFD, 2002). For this reason I have assigned all values less than this elevation NoData via the creation of a binary raster in the previous section.

### ***Landuse/land cover***

Mexican wolves are adaptable creatures, but prefer woodlands and forests, over desert scrub and grasslands, while chaparral is not a preferred habitat for wolves (Brown, 1983). However, whether these wolves prefer woodlands over forest or vice versa is not well known. Therefore, some ambiguity arises when assigning ordinal values to these two land cover types. I've chosen to assign the highest value (5) to forests, while assigning woodlands a value of (4). The remaining values are given in the table in the next section.

### ***Primary food source***

As stated previously, a main staple in the Mexican wolf diet is the mule deer, so I expect that the wolves will likely follow the food source. The only mule deer distribution data I was able to obtain does not provide population density, so I assign cells containing mule deer (1) and those not a value of (0).

### ***Human Population Density***

I expect wolf packs to settle in a location with very low human population density. In addition, it is unlikely that wolf packs will settle within a few kilometers of a major road.

Proximity to roads

I expect, generally, for wolf packs to avoid major roads and highways if at all possible. Therefore, I expect that an ideal wolf habitat will not have major roads crosscutting or within a close proximity. Here, I have utilized the Euclidean Distance tool within the Spatial Analyst toolbox to generate a classified raster based on proximity to roads.

**Reclassifying raster data based upon the ordinal ranking scheme**

The table below shows the ranking schema which will be used to determine habitat suitability.

Rank	Elevation	Land cover	Mule Deer Present?	Human Population Density (ppl/km <sup>2</sup> )	Proximity to Roads (km)
0	Below 1370m	Chaparral	No	9001-10000	0-20
1	Above 1370m	Desertscrub	Yes	8001-9000	21-40
2	-	Grassland	-	7001-8000	41-60
3	-	Alpine Tundra	-	6001-7000	61-80
4	-	Woodland	-	5001-6000	81-100
5	-	Forest	-	4001-5000	101-120
6	-	-	-	3001-4000	121-140
7	-	-	-	2001-3000	141-160
8	-	-	-	1001-2000	161-180
9	-	-	-	0-1000	181-200
10	-	-	-	-	201-220

Now, I reclassify the raster datasets using the parameters in the table above for each attribute. This is performed using the Reclassify tool within the Spatial Analyst toolbar. An example of this process is provided in **Figure 15**. In addition, the reclassified rasters are provided in **Figures 16a-e** with an explanation of symbology. From these, we can begin to identify which locations may be the most suited for Mexican wolves based on our criteria.

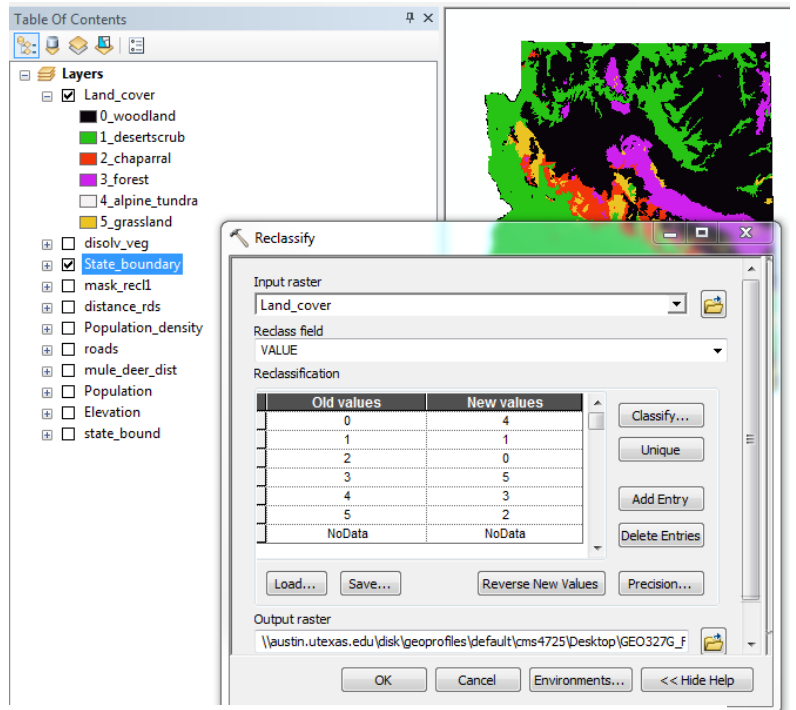


Figure 15. Reclassifying the rasters to match the ranking scheme

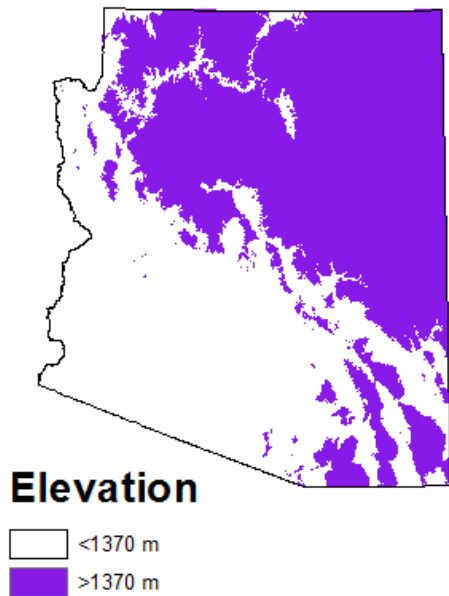


Figure 16a. Reclassified Elevation raster

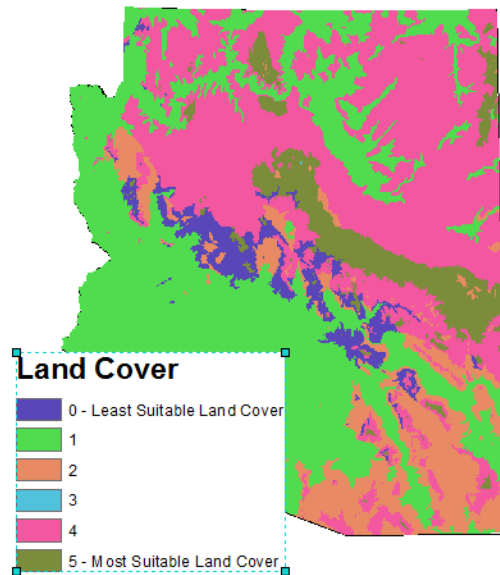


Figure 16b. Reclassified Land cover raster

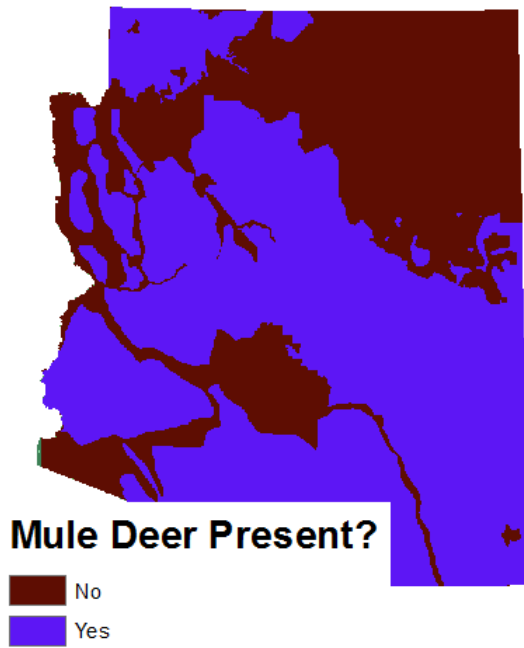


Figure 16c. Mule deer raster

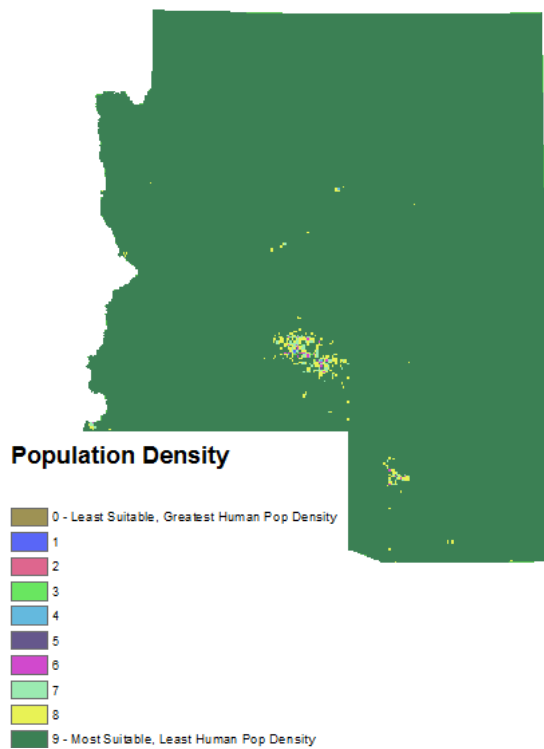


Figure 16d. Reclassified Population density raster

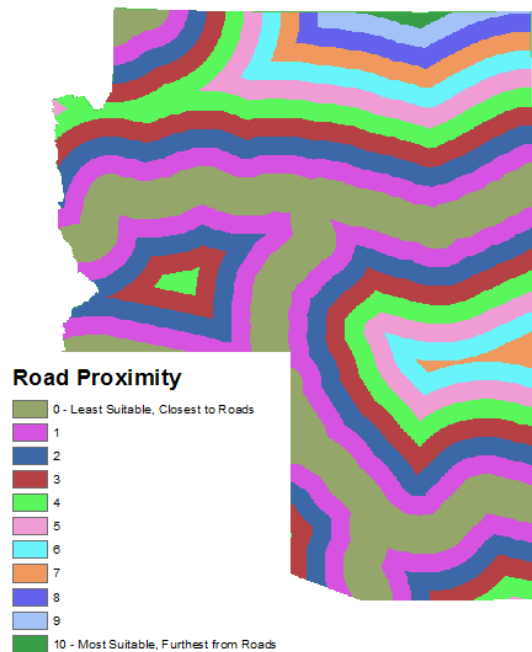


Figure 16e. Reclassified Road Proximity raster

### Combining the Raster datasets to identify most suitable habitats

I have chosen to assign equal weighting to each of the 5 factors considered. I have done so because I believe weighting the data would cause the end result to be somewhat subjective, due to my lack of expertise in wolf ecology. I now need to combine the data from each of the above raster datasets into a composite raster. To do this I use the Raster Calculator within the Spatial Analyst toolbar as shown in **Figure 17**. A map depicting the end result is provided on the next page.

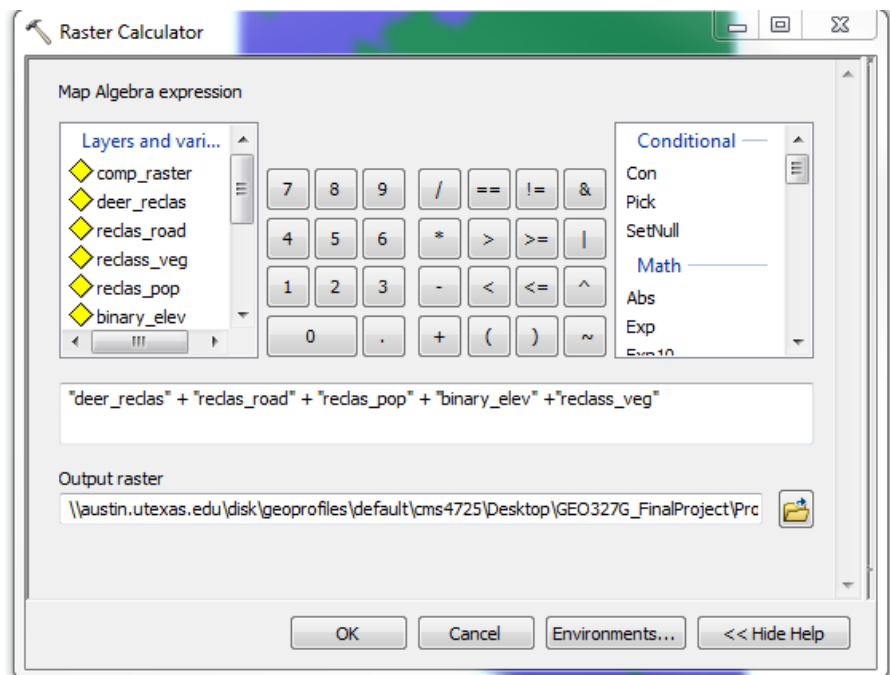
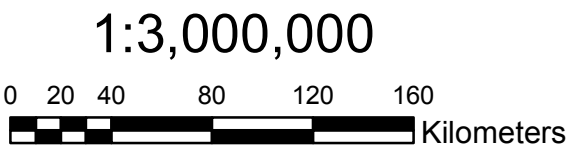
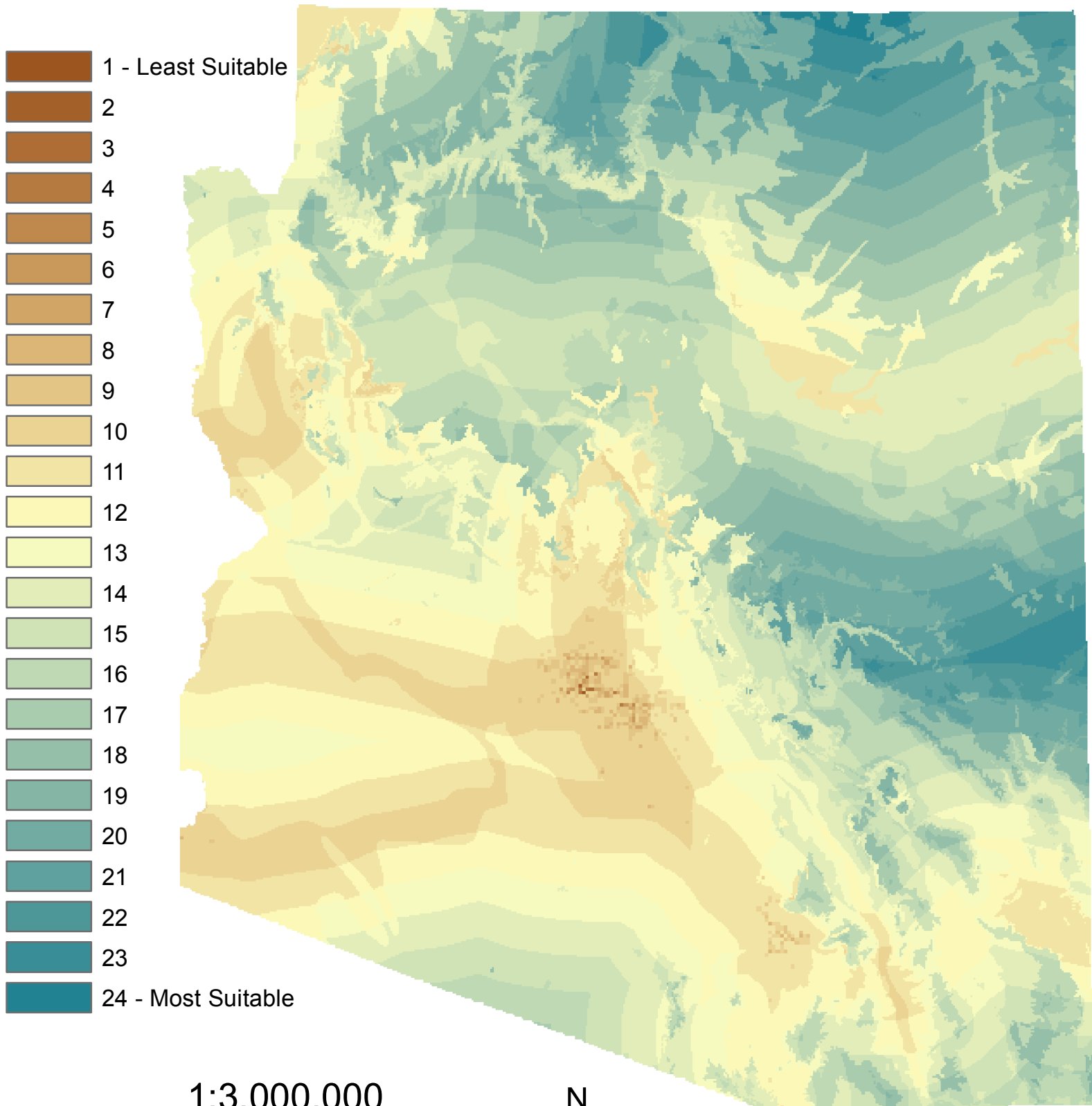


Figure 17. Compiling all the rasters into a single composite raster

# A Mexican Gray Wolf Habitat Suitability Analysis, Arizona

by Cole Speed  
December 3, 2015



NAD 1983  
UTM Zone 12N

## Results and Discussion

I performed this suitability analysis using GIS software for a few reasons. First, I wished to determine somewhat quantitatively whether the assumptions that we make regarding habitat preference for Mexican Gray wolves is actually what is observed in the wild. Secondly, because Mexican Gray wolf populations are still at risk, it is worthwhile to identify these areas so that we can take the appropriate measures to protect them. Upon visual inspection of the map above, we see that the areas deemed most suitable for these wolf populations are located in the eastern and northern parts of the state. These locations are above elevations of 1370 m, contain ample prey, and experience very little human interaction. We can now compare the

habitat suitability model with real Mexican wolf distribution data obtained from the U.S. Fish and Wildlife Service (**Figure 18**). We can see a clear correlation between the model and real observations. The population distribution for Mexican wolves in Arizona is exclusively in the eastern portion from north to south. However, the real distribution of wolves differs from the suitability model that I created with respect to the population density and major roads assumptions.

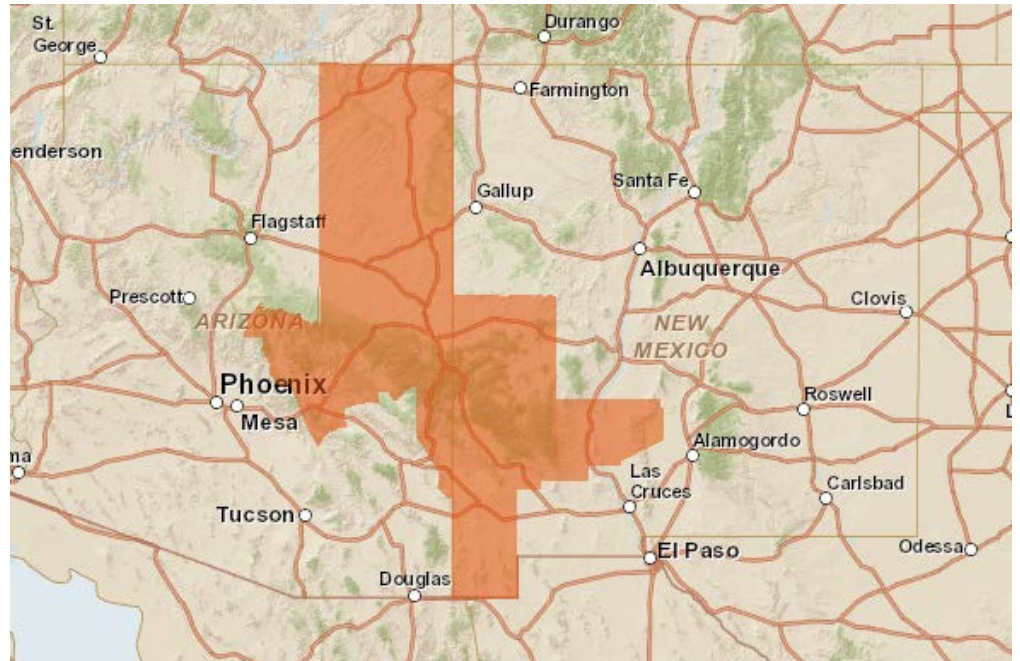


Figure 18. Known Mexican wolf locations

It appears that the wolves habitat is essentially unobstructed by the major roads cross-cutting, and that the distribution extends more closely to densely populated areas than the model predicts. Therefore, to further improve the model, weighting of individual raster datasets should also be performed in addition to assigning ordinal ranking values.

## References

AZGFD. (2002). *Mexican Gray Wolf*.

Brown, D. (1983). *The Wolf in the Southwest: The Making of an Endangered Species*. Tucson: University of Arizona Press.

Nie, M. A. (2003). *Beyond Wolves: The Politics of Wolf Recovery and Management*. University of Minnesota Press.

Nowak, R. M. (1995). *Another look at wolf taxonomy. Ecology and conservation of wolves in a changing world*. Edmonton: Canadian Circumpolar Institute.

Reed, J., Ballard, W., Gipson, P., Kelly, B., Krausman, P., Wallace, M., & Webster, D. (2008). Diets of free-ranging Mexican gray wolves in Arizona and New Mexico. *34*, 1127-1133.