Predicting quality of habitat on a landscape:

sagebrush and juniper in the Indian Creek grazing allotment

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**Abstract**

Although it is currently one of the largest ecosystems in the United States, sagebrush habitat is declining rapidly (Wisdom and Rowland 2007). In the Indian Creek grazing allotment, an area of the Colorado Plateau consisting of Beef Basin and Dark Canyon Plateau, sagebrush mortality ranges from 40% to 100% and juniper encroachment has contributed to this (USDI BLM 2011). In an effort to address this problem MatLab’s fuzzy logic toolbox as well as ArcMap’s Fuzzy Membership and Raster Calculator tools were used to create predicted vegetation utilization models for sagebrush and for juniper. These outputs were compared to current vegetation data to assess the accuracy of these models. The resulting bar graphs from this comparison show that both the sagebrush and the juniper models did not accurately predict landscape quality.

**Key Words:** Colorado Plateau, juniper, sagebrush, vegetation modeling.

# Introduction

Sagebrush ecosystems previously covered approximately 150 million acres (Wisdom and Rowland 2007). Now overgrazing, fire suppression, invasive species, fragmentation, and a variety of other threats degrade this iconic ecosystem and regionally imperil over 350 species of associated plants and animals (Wisdom and Rowland 2007). The Indian Creek grazing allotment on the Colorado Plateau is considered crucial winter and spring habitat for mule deer and elk and is also used to graze livestock (USDI BLM 2011). However, sagebrush in this area has declined and juniper has encroached to such a significant extent that the Bureau of Land Management (BLM) is proposing management action with the primary purpose of restoring native sagebrush ecosystems (USDI BLM 2011). *The goal of this research paper is to predict (accurately or otherwise) areas in the Indian Creek grazing allotment with low, medium, and high quality habitat for both sagebrush and juniper using these five inputs: cattle utilization, soil type, aspect, elevation, and slope.*

To do this fuzzy logic will be used in MathWorks MatLab Fuzzy toolbox and ESRI’s ArcMap Fuzzy Membership tool. But what is fuzzy logic? Go for a moment to a beautiful March day right on the cusp between winter and spring. The weather has finally warmed to a balmy 52°F and you decide to wear shorts and a tank top to celebrate. When you get to the airport to pick up your friend who has just flown in from Florida you see that he is wrapped tightly in his jacket and shivering as though it were the dead of winter. If someone were to ask you and your friend to each give the temperature at which it changes from cold to warm likely your answers would be quite different. So who is right? According to fuzzy logic you both are partially correct. Fuzzy logic uses a scale of membership from 0 to 1 where 0 is no membership (it is definitely not cold), 1 is full membership (it is definitely cold), and any value between 1 and 0 has partial membership (is ‘fuzzy’ whether it would be considered warm or cold) (See Figure 1).

# Study Site

This project focuses on the a modified version of the Indian Creek grazing allotment which is in San Juan County, Utah on the Colorado Plateau (See Figure 2). This grazing allotment consists of Beef Basin and the Dark Canyon Plateau which is the two focus areas of the BLM’s proposed management mentioned above, and is notable for its plethora of Native American ruins. It is located just south of the Needles District of Canyonlands National Park, just north of the Manti-La Sal National Forest, and east of Lake Powell.

# Methods

**2.1 Data and Data Preparation**

Data Downloaded:

From BLM: Grazing allotments

From Landfire: Vegetation Type

From Utah AGRC: Utah Counties, Soil Type, Streams and Lakes, 30m Digital Elevation Model (DEM).

The Indian Creek allotment was selected from the Grazing allotments shapefile and exported it to its own shapefile. The polygon was then edited to remove the SW portion that had no soils data available (See Figure 3). A new polygon rectangle was created around the Indian Creek Allotment and data layers were clipped to a manageable size but large enough so the area of interest would not suffer from edge effects.

## MatLab- Predicted Cattle Utilization

The Predicted Cattle Utilization output is one of the five inputs for the Sagebrush and Juniper Predicted Vegetation Quality Models. It is run using MathWorks MatLab program and Fuzzy toolbox. This program uses the concept of fuzzy logic described in the Introduction above by combining input data and assigning values (0-1) to output data based on rules defined by the user which are created using expert knowledge obtained from the relevant literature. Below are the specific steps taken to produce this model’s output.

The major streams were selected from stream data layer table of contents into new shapefile. The lake polygons were converted to polylines and merged with major streams to create one water shapefile which was used with the 30m DEM to run Euclidean distance to water.

The Landfire Vegetation Type data was classified into Unsuitable, Barely Suitable, Moderately Suitable, Suitable, and Preferred forage types for cattle. The ‘project raster’ tool was used to change this from NAD 83 Albers to NAD 83 UTM Zone 12N.

The 30m DEM values were converted from meters to feet using Raster Calculator. This was done solely for personal interpretability and would work as well in meters. Next, the slope (degrees not %) was calculated from the 30m DEM.

The slope, vegetation, and Euclidean distance were all clipped to the Indian Creek allotment, and the concurrency calculator provided on Joe Wheaton’s Advanced GIS course webpage was used to make rasters orthogonal and concurrent before being converted to ASCII files (Data Preparation Vignette 2009-2013).

The Predicted Cattle Utilization model was written in MatLab using slope, vegetation, and Euclidean distance as inputs based on Joe Wheaton’s Predicted Cattle Utilization Model from Lab 09 (Lab 09 - Habitat Modeling 2009-2013). This produced a Predicted Cattle Utilization output which is used as one of 5 inputs into both the Sagebrush and Juniper predicted habitat models described in the sections below (See Figure 4).

## Sagebrush and Juniper Inputs

The Sagebrush and Juniper models take a different approach to fuzzy logic. Membership functions based on mathematical equations that scale continuous data (again, to values between 0 and 1) are used instead of user defined rules based on expert knowledge. These equations are based off of the curve of different lines (Normal curve, Sigmoidal curve, positive or negative linear lines, etc…) and use midpoint and spread to determine how steep or shallow a particular function should be. The specific steps described below use three different equations:

1. MS Large:

m=mean, s=standard deviation, a=multiplier of the mean, b=multiplier of the standard deviation

1. Large:
2. Small:

These equations come from ESRI’s ArcGIS Desktop Help 10.0 Fuzzy Membership (2011). Figure 5 shows a graphical representation of the Small membership function used to create the Sagebrush Slope and Juniper Slope Inputs.

The soil data was clipped to the allotment, converted to raster and the fields ‘Sage’ and ‘Juniper’ fields to attribute table to be used as classification fields. These fields were assigned values between 1 and 3 as unsuitable, suitable, and preferred soil types based on NRCS soil series descriptions, NRCS plant guide habitat descriptions, and USU’s extension service ‘Range Plants of Utah (Range Plants of Utah 2013, Soil Series Name Search 2013, USDA NRCS 2013).’ The soils raster was then reclassified into two new rasters based on the ‘Sage’ and then the ‘Juniper’ field. The Fuzzy Membership tool was run on reclassified sage soil where Type = MS Large with default settings which resulted in the Sage Soil Input. The Fuzzy Membership tool was run on reclassified juniper soil where Type = Large with default settings which resulted in the Juniper Soil Input.

Next, the Fuzzy Membership tool was run on the degree slope used in the Predicted Cattle Utilization model where Type = Small, midpoint = 35, and default spread which resulted in the Sage Slope Input. The Fuzzy Membership tool was run on slope where Type = Small, midpoint = 53, and default spread which resulted in the Juniper Slope Input.

Aspect was calculated from 30m DEM and reclassified so that flat and southern aspects had low values and northern aspects had higher values. The Fuzzy Membership tool was run on this reclassified aspect where Type = Small with default midpoint and spread which resulted in the Input for both Sagebrush and Juniper models.

The Fuzzy Membership tool was run on the 30m DEM where Type = Large, midpoint = 7000, and a default spread which resulted in the Sage Elevation Input. The Fuzzy Membership tool was run on the 30m DEM where Type = Small, midpoint = 7000, and a default spread which resulted in the Juniper Elevation Input.

# Results & Interpretation

## Sagebrush and Juniper Outputs

The Raster Calculator tool in ArcMap was used to average the Cattle Utilization, Soil, Slope, Aspect, and Elevation inputs for the sagebrush model and then for the juniper model. This resulted in the Predicted Sagebrush Landscape Quality and the Predicted Juniper Landscape Quality rasters (with values in both ranging from 0 to 1). This was then reclassified into low (values from 0 - 0.33), medium (values from 0.33 - 0.66), and high habitat quality classes (values from 0.66 - 1) which is shown in Figure 6.

The original Landfire vegetation data was reclassified so that only sagebrush, and then only juniper, vegetation types were present. These vegetation layers were used to extract all Predicted Sagebrush Landscape Quality raster cells, and then all Predicted Juniper Landscape Quality raster cells, that were within the vegetation type masks. The area in square kilometers was calculated based on the number of cells in each class and a 30 X 30 meter cell size. Two bar graphs were created from this data which graphically displayed the area (Km2) of sagebrush (Figure 7) and juniper (Figure 8) that was in each of the three Landscape Quality classes listed above.

If the models described above were able to accurately determine which areas on the landscape were high, medium, and low quality habitat for sagebrush and for juniper, the expected results would be a large portion of the area in the ‘high quality’ section of the graph, and little to no area in the ‘low quality’ section with intermediate results in the ‘medium quality’ category. These results show that the Sagebrush Landscape Quality Model did a very good job of capturing current sagebrush vegetation in the high quality class, but that the Juniper Landscape Quality Model failed to accurately predict what areas of the landscape is high quality habitat for juniper.

# Discussion

When looking at the Sagebrush output in Figure 6 we see that much of the area in the allotment is covered by a prediction of high quality habitat. This is a red flag indicating that the Sagebrush model is too inclusive, so its results cannot be trusted. The Juniper model also failed to produce accurate predictions of Landscape quality. There are several factors inherent in the methods described above which likely contributed to these results.

First, the Soil Type and Aspect rasters were categorical not continuous and should not have been used in the Fuzzy Membership tool in ArcMap. Also, the Soil Type classification system was hastily classified and not well researched. Finally, the mathematical equation expected to be used in the elevation input did not yield the predicted results. An equation that did not make as much sense was used instead because it visually produced seemingly the most appropriate results.

Another area of concern is how the accuracy of the vegetation models’ output was determined. For this study Landfire vegetation type was used to match what the models’ predicted and what is “known” to occur on the landscape. However, different vegetation layers from different sources do not all agree with each other. This method of comparing model results to vegetation layers should only be used as a ballpark estimate, and further ground truthing would need to be done from there.

# Conclusion

To make these vegetation models more accurate all of the considerations mentioned above need to be addressed. The Predicted Landscape Quality models for both sagebrush and juniper should be analyzed using MatLab’s Fuzzy Logic tool using a written code based on expert knowledge rather than forcing the categorical soil and aspect data into the Fuzzy Membership tool of ArcMap. More time and deliberation should be spent classifying the soil types as well as in determining why the mathematical equation expected to be used in the elevation input did not yield the predicted results. Thought needs to be given to what needs to be done differently with data and the original equation so that the output makes sense, or determining if the equation used above is actually the one that should have been used in the first place.

Furthermore, a third vegetation type to consider modeling is grassland. It seems that in the Indian Creek grazing allotment while juniper in encroaching downward, grassland is invading sagebrush habitat from the opposite front (USDI BLM 2011). When the models are corrected to successfully predict the quality of areas across the landscape for each dominant vegetation type of concern, this can become a very useful tool for land managers.

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