Raster Analysis

Fuzzy Overlays

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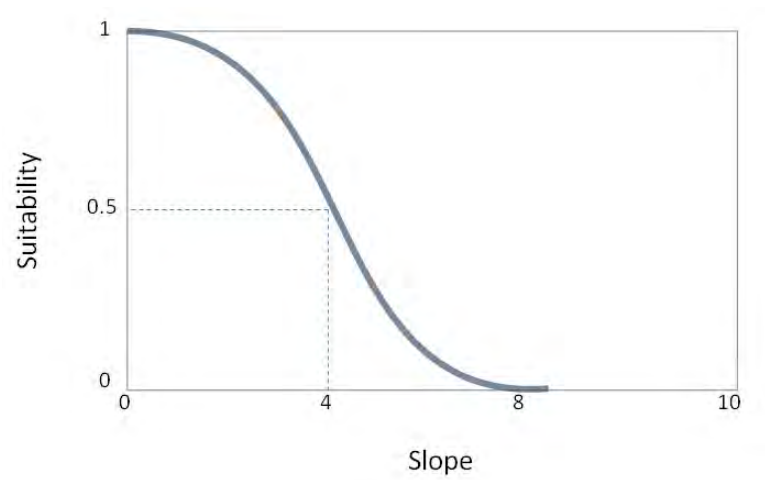
I. Basics of Raster Weighted Overlays

Fuzzy overlays are all about uncertainty. The distances that being specified in criteria for any project could be defined as "plus or minus", or "fuzzy", so when a site requirement to be within 200 feet of a major road is set the 201st fee won't be suitable, this is not realistic. In reality what we mean to say is that the site should be within 200 feet, more or less, from a major road. A "fuzzy" boundary is then defined that the closer to the 200 feet distance the more suitable the site would be, where "zero" distance is totally acceptable, while the further the distance the less suitable it is, until it reaches a distance that it would be totally unacceptable. The overlay method honors this "fuzziness" in the process and weights each layer based on its fuzziness value instead a mere percentage of influence (weighted overlay).

In fuzzy overlays, each of the inputs is nothing but a representation of this "fuzziness" of the criteria for the subject under consideration. For example, if a slope criteria is defined, and less than 10% slope is the limit, then the fuzzy representation of the slopes should consider flat surfaces as the most suitable (value = 1) while slopes greater than 10% is totally unsuitable (value = 0) while all other values in between would be a fraction of 1. So a slope of 2% would tend to be leaning towards a more suitable value, while a slope of 8% would lean towards a much less suitable value. The following graph depicts this example.



This graph shows the suitability level based on the assumption that any slopes that are 8% or more are not suitable. All other values below 8% have a fuzzy suitability level where 4% would be 50% suitable than a totally flat slope (0%).

This remapping of the suitability levels is called "fuzzy membership". A fuzzy membership layer is a re-classified suitability layer that remaps the suitability values to a floating (decimals) scale from 0 to 1.

Therefore, as a pre-requisite to any fuzzy overlay operation, the creation of those "fuzzy membership" layers is necessary. For example, in the case of slopes, a re-classified floating

raster should be created to represent the membership of each cell to a suitability value between 0 and 1. This process can be done manually with a series of steps using tools such as:

1- Reclassify, to remap the range of values to definite class breaks (1-10 for example – reclass will produce integer raster dataset only);
2- Float, to convert the actual reclassified layer into floating numbers instead of simple integers when necessary (for land cover classes for example); then,
3- Divide, in order to convert the classes to values between 0 and 1 (divide by 10, for example, for a reclassified layer of values 1-10, or by 5 for a reclassified layer of values 1-5).

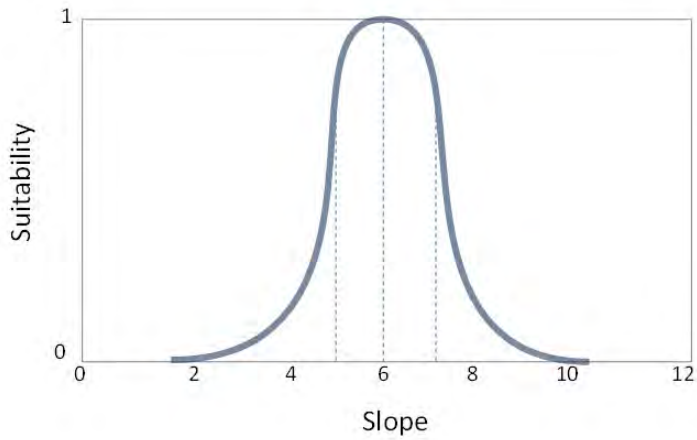
Alternatively, an existing tool, Fuzzy Membership, works with data that are originally in float form can simplify the process and would give more control on how fine or coarse we would like our cells to be reclassified as more or less suitable than a specified average value.

A. Creating Fuzzy Membership Layers

In the Fuzzy Membership tool you'll find different ways of reclassifying the input rasters based on different methods and variables. Here, I included a quick reference to the most commonly used methods.

Fuzzy Gaussian

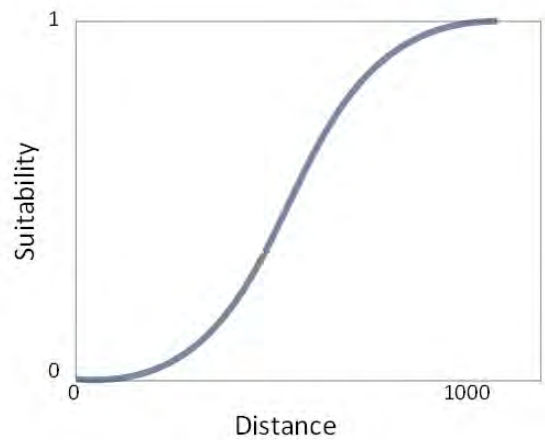
Fuzzy Gaussian follows the bell-curve to calculate the membership of a cell either to most or to the least suitable values (1-0) and calculates the intermediate values accordingly. Basically, we'd use the Gaussian method if the suitable values can be above or below a certain mean, while increasing or decreasing from this mean indicates less suitability membership. For example, considering step farming, assuming that the suitable slope can be defined as a range around 6% where the more it decreases or increases it would be non-suitable, values that are within the 6% range, more or less, are going to be more suitable and therefore would be given higher membership values, while the more the slope deviates from 6% the more their membership values would lean towards lower values instead. The following graph is an example of this situation. The Fuzzy Gaussian is very similar to the Fuzzy Near method.



This graph shows the suitability level (i.e. Fuzzy Membership value) based on the assumption that any slopes that are within the 6%, more or less, are suitable. All other values deviating (increase or decrease) from 6% would be assigned smaller values. The property of the bell curve (stretched or condensed) can be controlled by the definition of the "mean" and the "spread" values.

Fuzzy Large

Use the fuzzy large membership method if the higher values in the input would mean better suitability, while the lower values would reflect the less suitable conditions. For example, if a site is best when it is located far from streams, a distance raster would work as input, while the more the distance from the streams the better the site. Or when there is a direct relationship between the actual distance and the membership values. The Fuzzy Large is very similar to the MS Fuzzy Large (Mean/Standard Deviation Fuzzy Large) method.



Here, the suitability level, or fuzzy membership (Fuzzy Large), is directly related to distances. The further the distance the best suited and a higher membership value the cell is assigned, the closer the distance the lower the membership value. The property of the curve (stretched or condensed) can be controlled by the definition of the "mean" and the "spread" values.

Fuzzy Small

The Fuzzy Small membership method is the opposite to the Fuzzy Large. It is applied when the lower values in the input would mean better suitability, while the higher values would reflect the less suitable conditions. For example, if a site is best when it is located closer to roads, a distance raster would work as input, the closer the distance from the roads the better the site and the further the distance the less suitable the site would be. In other words, the fuzzy small method is applied when there is an indirect relationship between the actual distance and the membership values. The Fuzzy Small is very similar to the MS Fuzzy Small (Mean/Standard Deviation Fuzzy Small) method.

Custom Fuzzy Membership

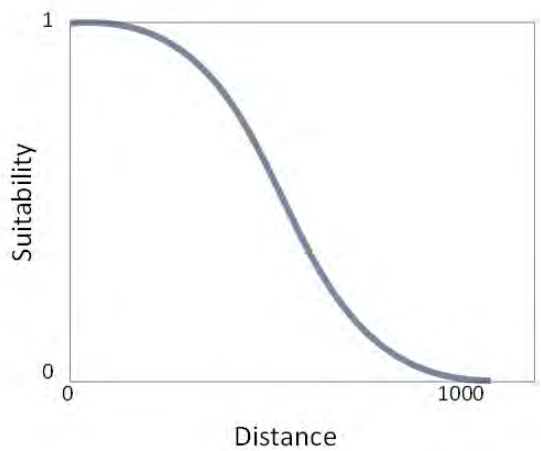
As mentioned earlier, fuzzy membership rasters can be manually created using several tools: Reclassify, Float and Divide. Those tools would be used if the original data does not have a continuous numeric measurement as its main values. Land cover, land use, soil types …etc. are all examples of nominal data that some of the code values in their attribute tables might be suitable for the current application while others are not. In those cases, the different codes need to be reclassified to a specific scale where most suitable, suitable, somewhat suitable, and non-suitable classes are each assigned an incremental value according to their suitability level. Those reclassified values are then converted to a float data type then divided by their maximum number of classes in order to cap the highest number to 1 while keeping all other values above 0. The output of this operation would represent the layer's fuzzy membership.

B. Applying the Fuzzy Overlay

Once all the inputs are prepared as Fuzzy Memberships, they'll be ready to be used in the Fuzzy Overlay tool. The tool has multiple overlay type options, the most important and relevant to our course are the **AND** and the **OR**.

The **AND** overlay option is exclusive and would classify the output cells based on their input's membership values, all inputs have to have higher membership values in order to be classified as suitable in the output.

On the other hand, the **OR** overlay option is inclusive. In other words, a cell is classified as mostly suitable in the output if it has a high membership value in any of the inputs. More cells in the output would be considered suitable than the **AND** option.



Here, the suitability level, or fuzzy membership (Fuzzy Small), is indirectly related to distances. The further the distance the least suited and a lower membership value the cell is assigned, the closer the distance the higher the membership value. The property of the curve (stretched or condensed) can be controlled by the definition of the "mean" and the "spread" values.

Which operator to use?

In general, you may use any of the available overlay operators either alone or in conjunction with the others. The method would depend on the requirements of the analysis as well as with the nature of the data being used. If all criteria have to be true for a site to be considered suitable then use "AND", if any of the criteria being true would make a site suitable then you may use "OR". Some criteria could be combined together for the use of OR and the result can be combined using the AND operator with the remaining criteria or vice versa. Mitchell, A. (2012) summarizes the answer to this question in the following paragraph:

> *"If two or more of your source layes are correlated, avoid using the mathematical operators to combine layers. Since SUM, PRODUCT and GAMMA combine the values on the various input layers, if the layers are correlated, the site characteristic they represent may have too much influence on the result. For example, elevation and slope steepness are often correlated, with steep slopes occurring at higher elevations. Similarly, vegetation types and elevation are also often correlated, with one type of forest occurring at high elevations and another type at lower elevations. If your model includes elevation, slope, and vegetation source layers, the effect of eleva3tion is likely to be magnified in the overall fuzzy membership layer when using one of the mathematical operators. This is not the case with the logical operators AND and OR, where for any given cell, the values from only one layer are retained. (The values for the other layers are essentially discarded, for a given cell, so the result reflects the influence of only one of the input layers for that cell.) This decreases the possibility that correlated layers will result in a particular site characteristic having undue influence."*

Raster Analysis

Fuzzy Overlay Method

SUMMARY

Similar to the Weighted Overlay method presented in the previously, this assignment will repeat the process but with a more realistic vision of the nature of natural wildlife habitats. Those habitats cannot be defined strictly based on given distances, or land covers, but rather a set of levels where areas would be more or less suitable than others based on proximity or land cover types. For example, the closer to an urban area the less likely natural wildlife habitat would prevail or the more rugged the landscape (to a certain extents) the better the habitat for many species, but a little bit of slope would not seriously affect the habitat.

II. Introduction

Download the exercise data from the corresponding link.

Most of the raster data handling and analysis will rely on the use of a software extension (i.e. plug in) called Spatial Analyst. It comes bundled with ArcGIS Pro, but the proper licensing should be acquired/assigned.

III. Problem

To review the problem of the previous exercise, in this assignment we would like to investigate the areas in Clarion County that could be considered as best suited for a general natural wildlife habitat. It is assumed that those areas would be at a close vicinity of water bodies while maintaining a distance from major roads and human environment. Natural forest or open land cover with a relatively rugged slope would be the best, avoid flat landscapes.

The suitable sites would generally match the following criteria:

1. It should be located within 800 meters from water bodies;
2. Generally, it would be about 2000 meters away from major roads;
3. Also should be about 1600 meters away from Urban/Built-up areas;
4. The land should be covered by open land or forested; and,
5. The landscape should be relatively rugged with the variation of topography favored (around 4% slopes more or less).

IV. Source Data

The data required to accomplish the given analysis are listed in the following table:

Dataset	Notes
Water_Distance	Continuous distances from water bodies (calculated in an earlier exercise)
Roads_Distance	Continuous distances from major roads (calculated in an earlier exercise)
Urban_Distance	Continuous distances from urban areas (calculated in an earlier exercise)
LandCover_Reclass	Reclassified land cover data (1-5) based on level of suitability as a natural wildlife habitat (calculated in an earlier exercise)
Slopes	Continuous % slope data (calculated in an earlier exercise)

You may re-create those datasets from the given geodatabase if you did not save the previous assignment data. Follow the previous assignment guidelines on how to prepare those datasets.

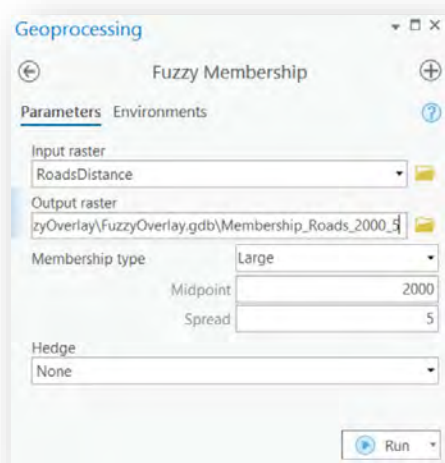
V. Preparing the Fuzzy Membership layers

Before starting, make sure that you have the Analysis Environment set to use the ClarionCounty_Mask raster as the Mask for the geoprocessing. This will ensure that the outputs of all calculations would be limited to the County boundaries.

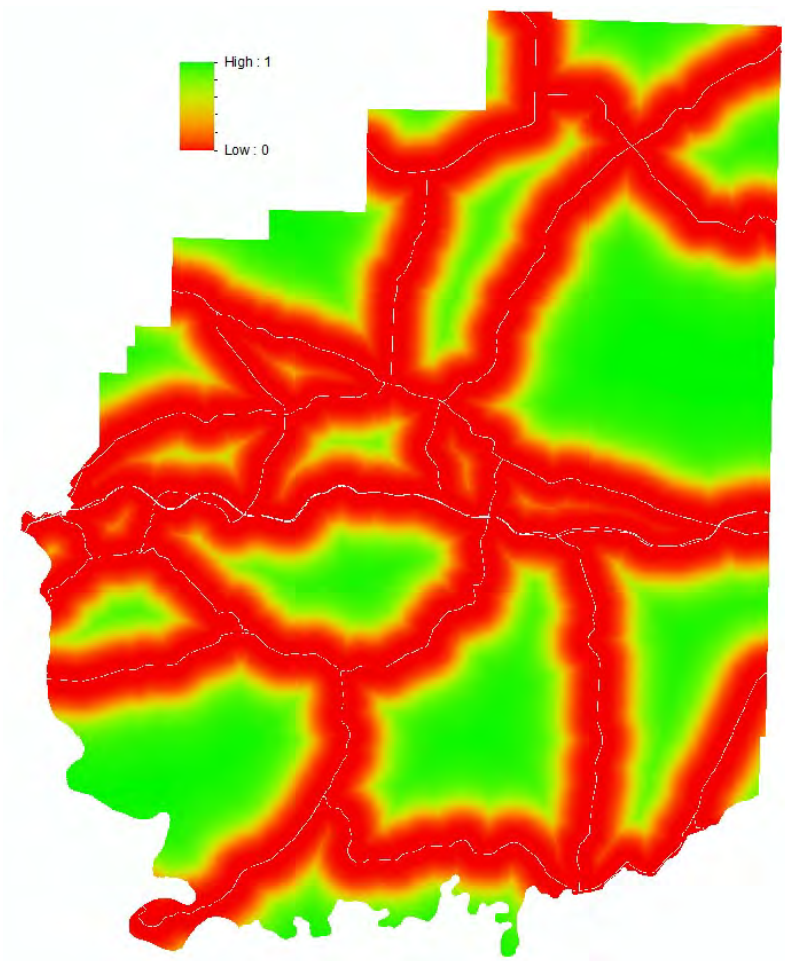
Open the Fuzzy Membership tool from Analysis tab >> Geoprocessing >> Tools >> Toolboxes >> Spatial Analyst Tools >> Overlay >> Fuzzy Membership.

Two inputs, namely the distance from roads and the distance from the urban areas (create those distance rasters using the Euclidean Distance tool or use those created in earlier exercises), are going to use the **Fuzzy Large** membership method since in both of them; the larger the distance the better suited the location. Since the distance from either is a relative factor, an S-shaped curve with small steeper general slope would be more realistic; a spread value of 5 is suggested for both of them. The midpoint, on the other hand would be 2000 for the roads and 1600 for the urban distance. Name the outputs as **Membership_Roads_2000_5** and **Membership_Urban_1600_5** respectively.

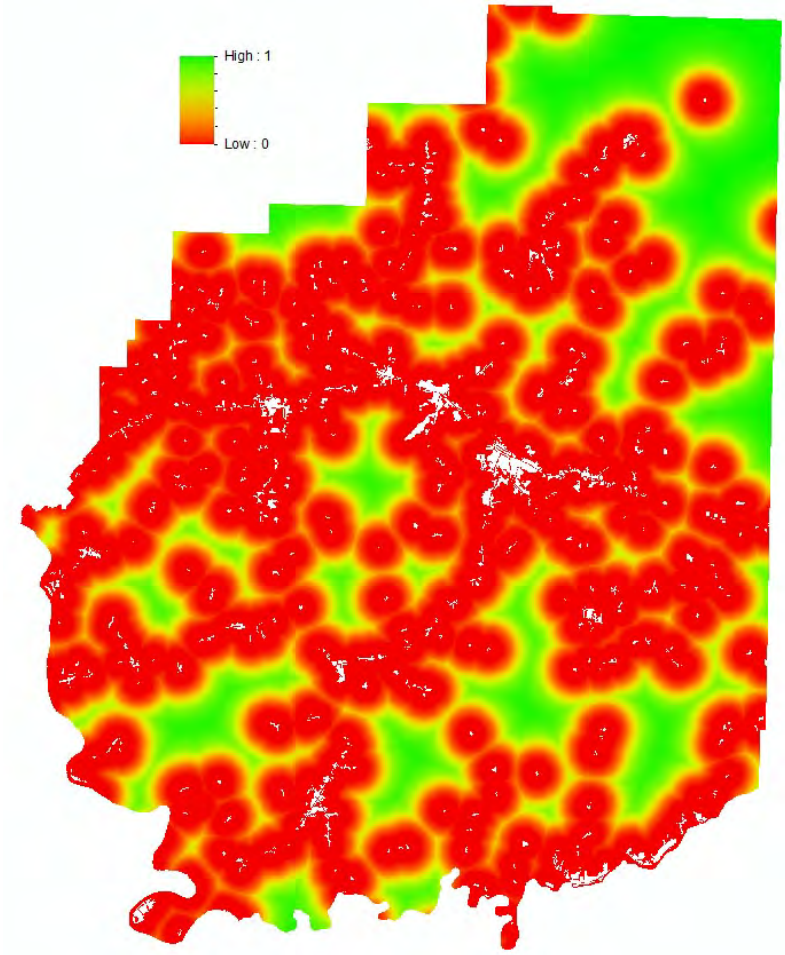
A sample dialogue from the Fuzzy Membership calculation is presented in the following figure:



The resulting Fuzzy Large membership layers are presented in the following figures.



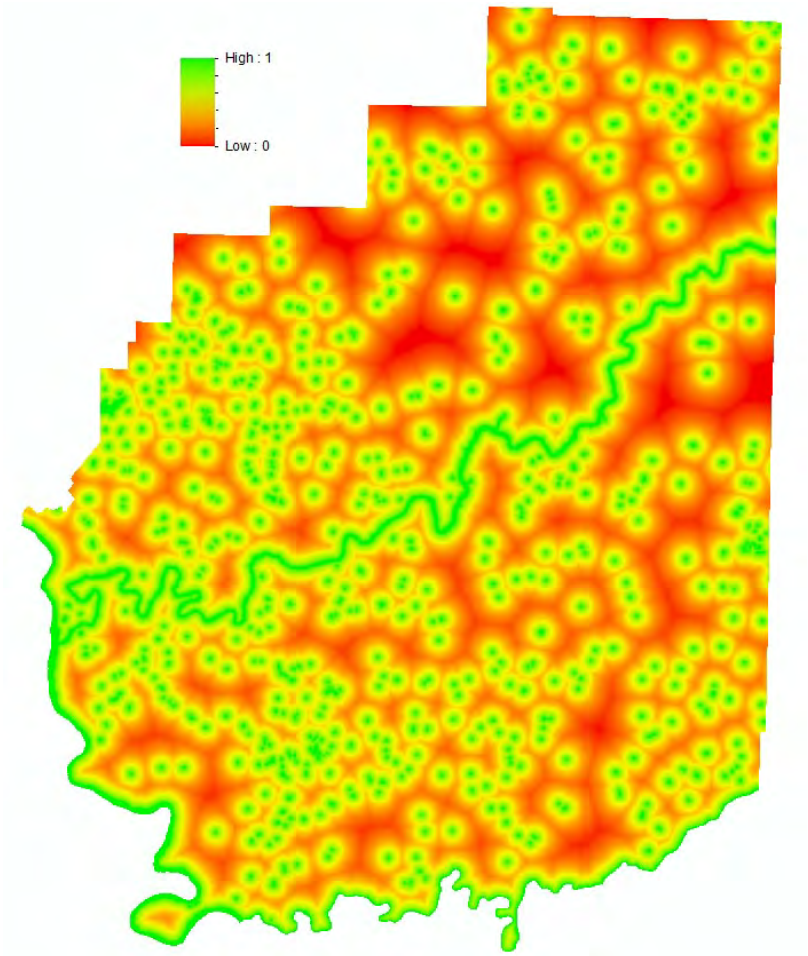
Fuzzy large applied to road distance is revealing a stricter distribution of the fuzzy boundaries to be closer to the defined 2000 meters distance. Areas that are classified as roads are totally excluded from the calculations (NoData-hollow).



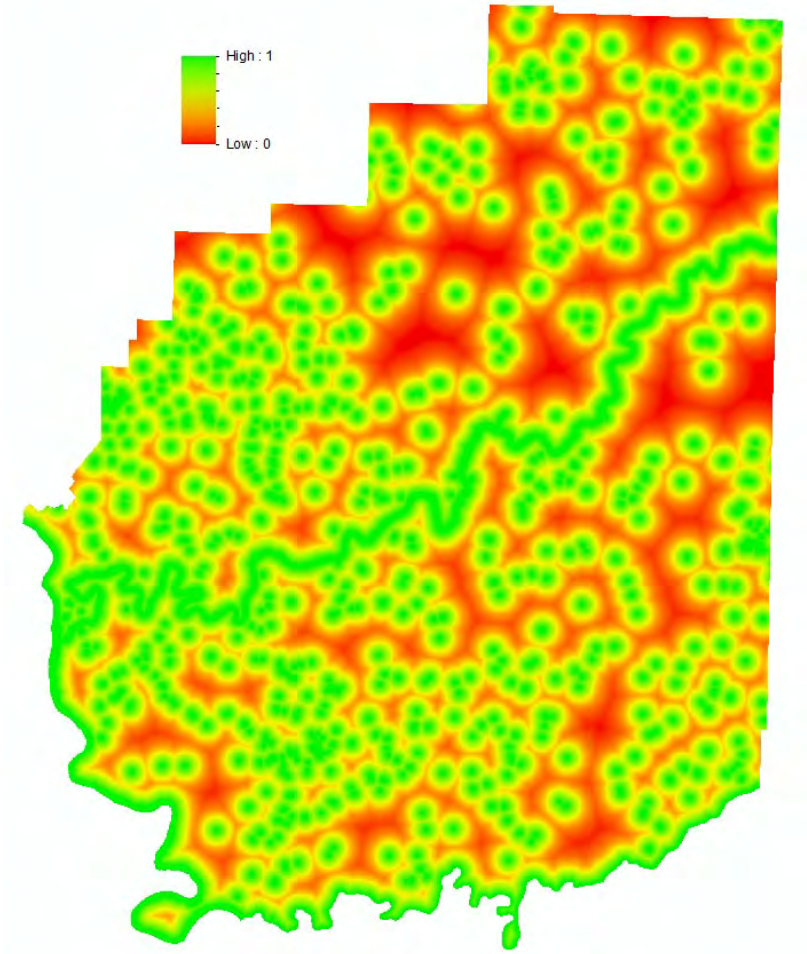
Fuzzy large applied to the distance from urban areas reveals a stricter distribution of the fuzzy boundaries to be closer to the defined 1600 meters distance. Areas that fall inside urban areas are totally excluded from the calculations (NoData-hollow).

The distances from water bodies on the other hand should use the Fuzzy Small membership option since the closer the cell to the water areas the better it would be suited for a natural wildlife habitat. Here, for the sake of demonstrating the effect of changing the Spread value, calculate the fuzzy membership for the water distance with a Midpoint value of 800 and three Spread values: 1, 2 and 5. Name the outputs as **Membership_Water_800_1**, **Membership_Water_800_2**, and **Membership_Water_800_5** respectively.

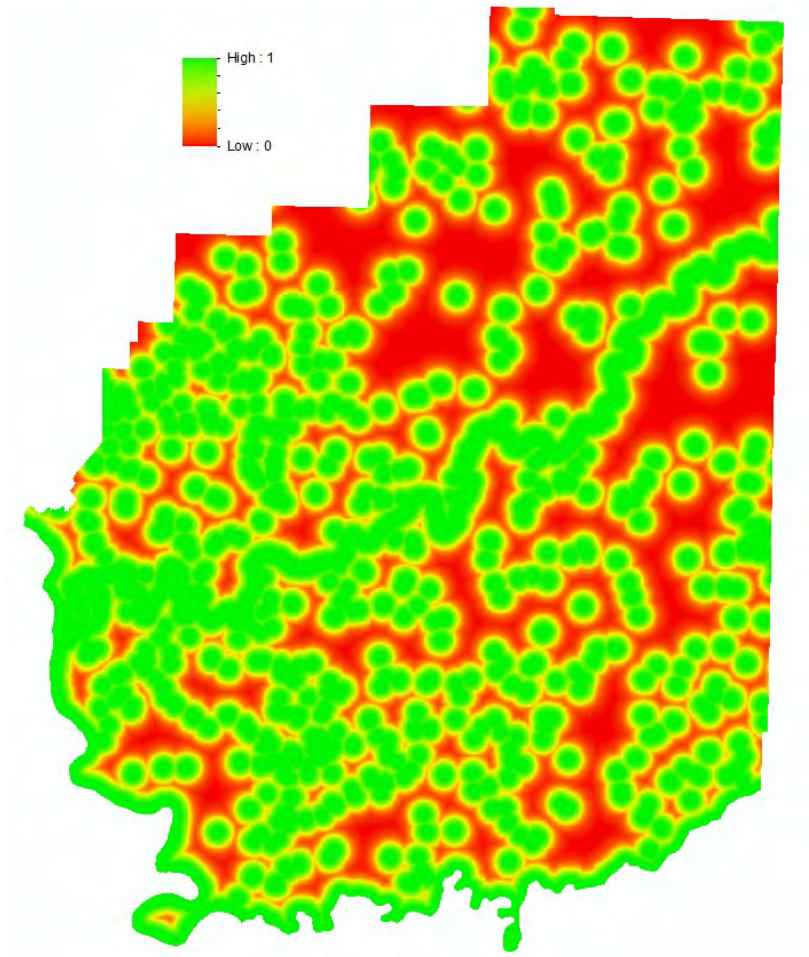
The resulting Fuzzy Small membership layers for the water distance are presented in the following figures.



Fuzzy Small applied to the distances from the water bodies. Here the spread value is set to 1, the curve is flatter and data are spread smoother to add more fuzziness to the distance factor. This is a looser definition of the suitable boundaries which is reasonable to use in the fuzzy overlay process later on.



Fuzzy Small applied to the distances from the water bodies. Here the spread value is set to 2, the curve is relatively distinctive and data are spread less smooth than the spread value of 1. The closer the distance of the cell to the 800 meters distance the more suitable the site is.



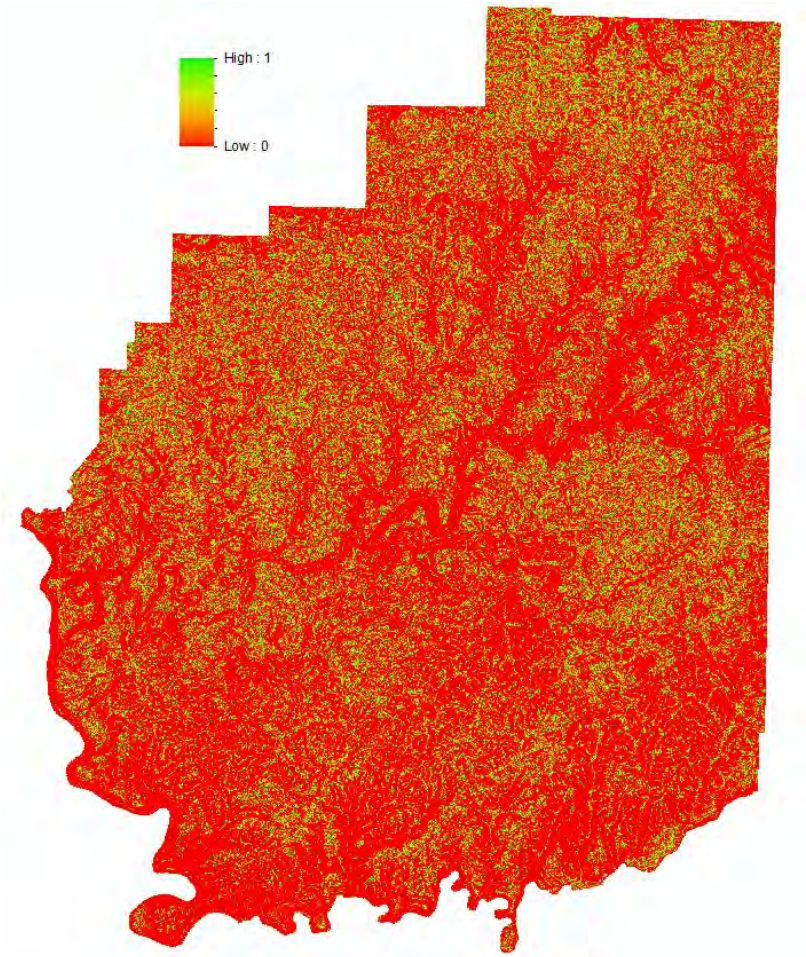
Fuzzy Small applied to the distances from the water bodies. Here the spread value is set to 5, the curve has more vertical tendency and therefore data become stricter to areas very close to the specified Midpoint (800 meters).

The first result (Midpoint 800 and Spread value of 1) represents a looser definition of the suitable boundaries and is believed to be more realistic since some of the wildlife might be able to travel further distances than others to reach a water bodies, others are more tied with streams and ponds for their existence, therefore the distance from water bodies can be loosened up to fit both instances.

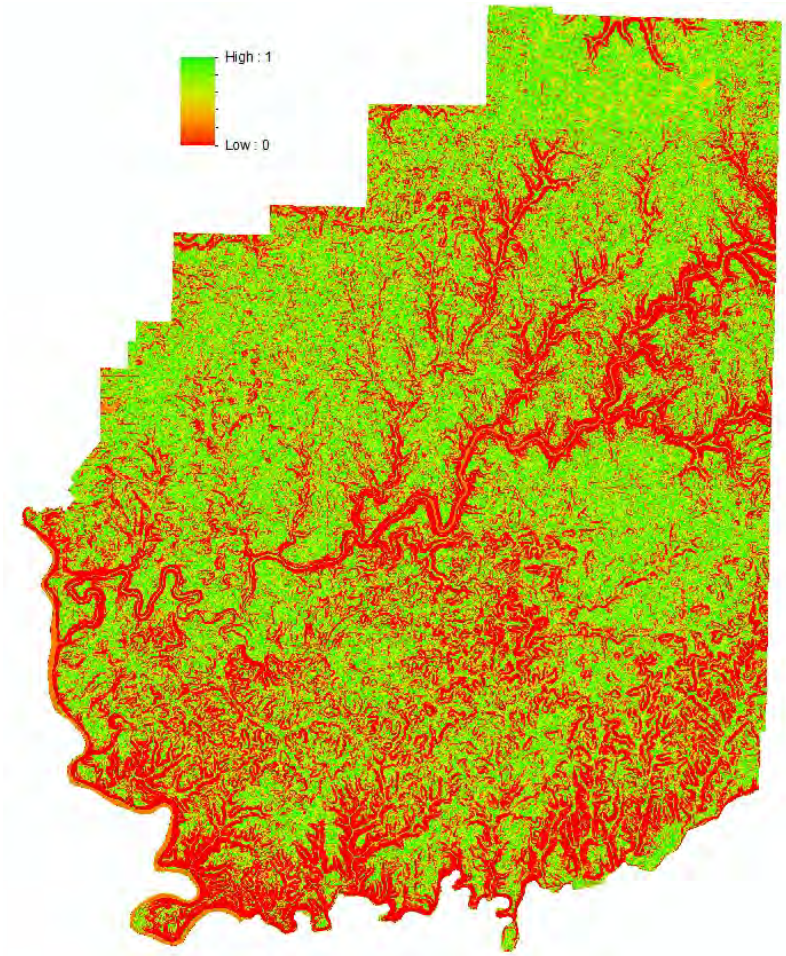
The Fuzzy Gaussian method would be best suited for the calculation of the slopes membership layer, since there would be, according to the given criteria, some values below the average slope as well as above it that would not be totally preferred for most wildlife in the area (assumption?). Therefore, a bell-shaped curve would best portray the suitability membership of the slope data where the Midpoint would lie at 4%. By changing the Spread value is strict to the 0.01-1 range, which would affect how tight or loose the curve around the mean value. In this exercise, let's try three different values 1, 0.1 and 0.01. Name the resulting rasters as

Membership_Slope_4_1, **Membership_Slope_4_01**, and **Membership_Slope_4_001** respectively.

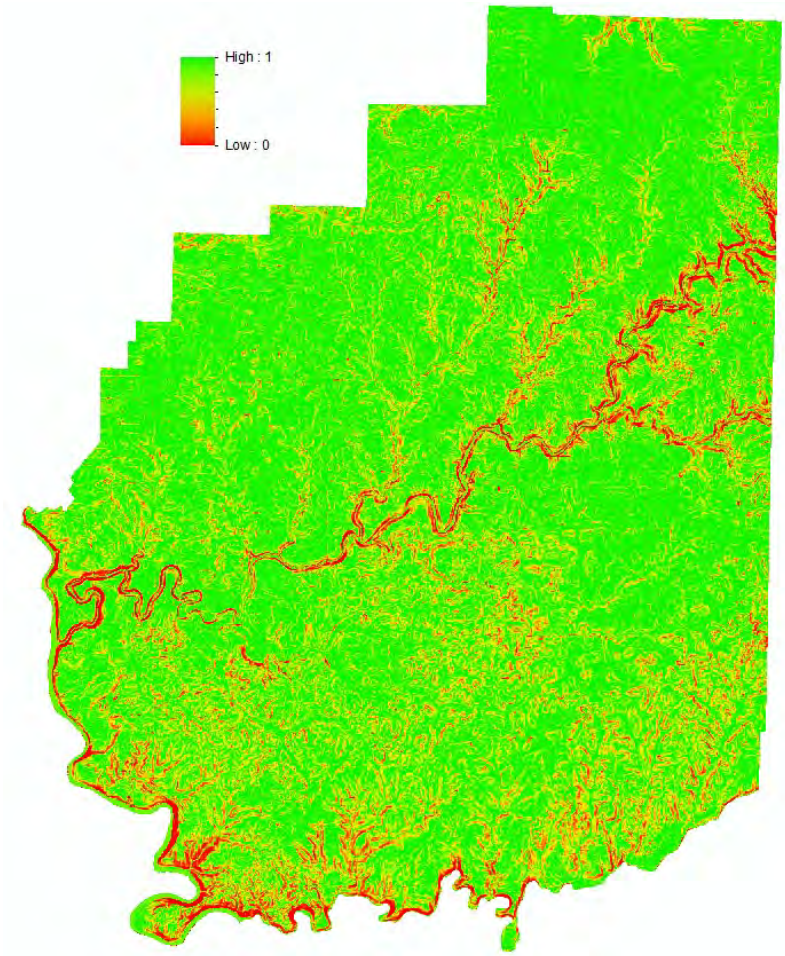
The resulting Fuzzy Gaussian rasters for the different spread values should be similar to the following figures.



With a Fuzzy Gaussian with a spread value of 1, the bell-curve of the data distribution around the average 4% slope tends to be tighter, very little number of cells qualify as suitable (higher membership value) with this setting.



The Fuzzy Gaussian calculated for the slopes with a spread value of 0.1 around the 4% Midpoint loosen up the bell-curve that represents the data and adds a significant number of cells to the more suitable areas. This is a moderate view of the effect of the slopes on the distribution of the natural wildlife in the County of Clarion, this result is reasonable and would be a moderate way of looking at the slopes as a factor in the fuzzy overlay method.



The Fuzzy Gaussian calculated for the slopes with a spread value of 0.01 around the 4% Midpoint extremely loosen up the bell-curve that represents the data and considers most cells in the raster dataset as high members of the suitable range. Very little data (around rivers and streams) are excluded with this setting.

The moderate setting of a spread value of 0.1 in the Fuzzy Gaussian method will be adopted in the further fuzzy overlay analysis since it represents a moderate view of the effect of the slopes on the distribution of the natural wildlife habitats in the county. It is neither too strict nor too loose.

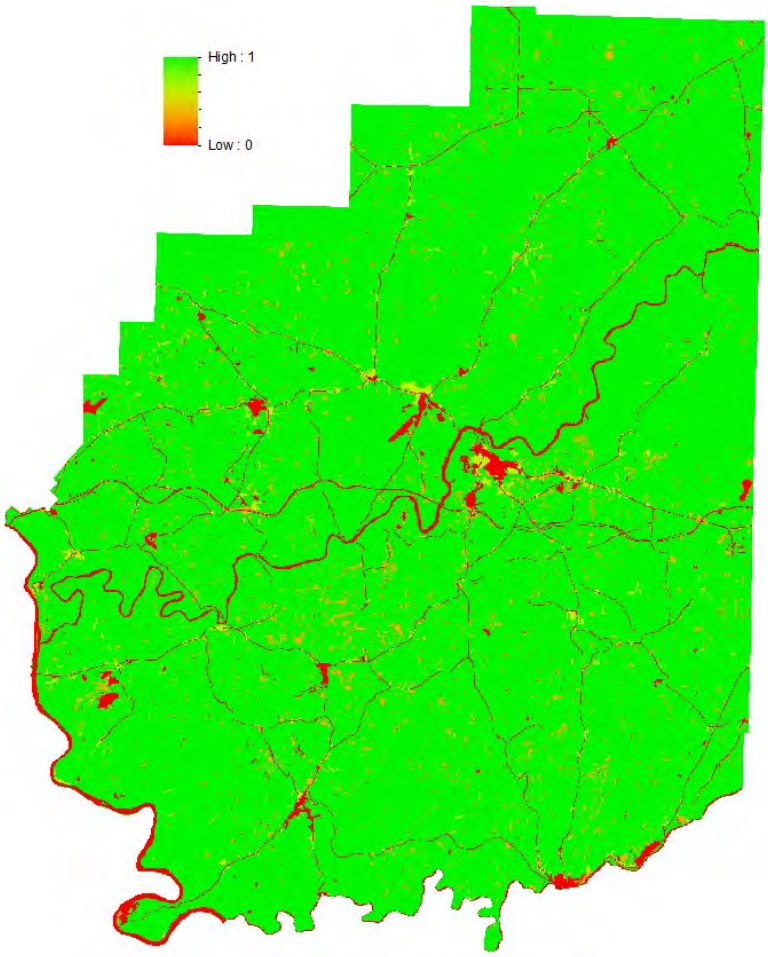
Finally, the land cover membership raster would only be calculated using a Custom Fuzzy Membership method using the classified scheme of the previous assignment (weighted overlay) as a guide to suitability of the original land cover group of classes as summarized in the following table:

	Land Cover Code Description	Original Code	Suitability
1.	Roads	14	1
2.	Residential Land; 5-30% impervious	111	3
3.	Residential Land; 5-30% impervious; Deciduous tree cover	1111	3
4.	Residential Land; 5-30% impervious; Evergreen tree cover	1112	3
5.	Residential Land; 5-30% impervious; Mixed tree cover	1113	3
6.	Residential Land; 31-74% impervious	112	1
7.	Residential Land; 31-74% impervious; Deciduous tree cover	1121	1
8.	Residential Land; 31-74% impervious; Evergreen tree cover	1122	1
9.	Residential Land; 31-74% impervious; Mixed tree cover	1123	1
10.	Residential Land; 74% < impervious	113	1
11.	Residential Land; 74% < impervious; Deciduous tree cover	1131	1
12.	Residential Land; 74% < impervious; Evergreen tree cover	1132	1
13.	Residential Land; 74% < impervious; Mixed tree cover	1133	1
14.	Institutional/Industrial/Commercial Land; 5-30% impervious	121	2
15.	Institutional/Industrial/Commercial Land; 5-30% impervious; Deciduous tree cover	1211	2
16.	Institutional/Industrial/Commercial Land; 5-30% impervious; Evergreen tree cover	1212	2
17.	Institutional/Industrial/Commercial Land; 5-30% impervious; Mixed tree cover	1213	2
18.	Institutional/Industrial/Commercial Land; 31-74% impervious	122	1
19.	Institutional/Industrial/Commercial Land; 31-74% impervious; Deciduous tree cover	1221	1
20.	Institutional/Industrial/Commercial Land; 31-74% impervious; Evergreen tree cover	1222	1
21.	Institutional/Industrial/Commercial Land; 31-74% impervious; Mixed tree cover	1223	1
22.	Institutional/Industrial/Commercial Land; 74% < impervious	123	1
23.	Institutional/Industrial/Commercial Land; 74% < impervious; Deciduous tree cover	1231	1
24.	Institutional/Industrial/Commercial Land; 74% < impervious; Evergreen tree cover	1232	1
25.	Institutional/Industrial/Commercial Land; 74% < impervious; Mixed tree cover	1233	1
26.	Airports	124	1
27.	Row Crops	21	4
28.	Pasture/Grass	24	5
29.	Golf Courses	241	4
30.	Deciduous Forest	41	5
31.	Evergreen Forest	42	5
32.	Mixed Deciduous and Evergreen	43	5
33.	Water	50	1
34.	Forested Wetlands	61	5

	Land Cover Code Description	Original Code	Suitability
35.	Emergent Wetlands	62	5
36.	Bare; Unclassified Urban/Mines, Exposed Rock, Other Unvegetated Surfaces	70	2
37.	Active Mines/Significantly Disturbed Mined Areas	750	1

First Reclassify the land cover raster to the given 5 classes (or use the one created in the previous assignment **LandCover_Reclass**).

Convert the resulting **LandCover_Reclass** to float data (supports decimal values) using the Float tool (Analysis tab >> Geoprocessing >> Tools >> Toolboxes >> Spatial Analyst Tools >> Math >> Float), name the result as **LandCover_Float**. Then using the Divide tool (Analysis tab >> Geoprocessing >> Tools >> Toolboxes >> Spatial Analyst Tools >> Math >> Divide), divide the **LandCover_Float** Input Raster by the constant value of 5, name the output **Membership_LandCover**. The output should be similar to the following figure.



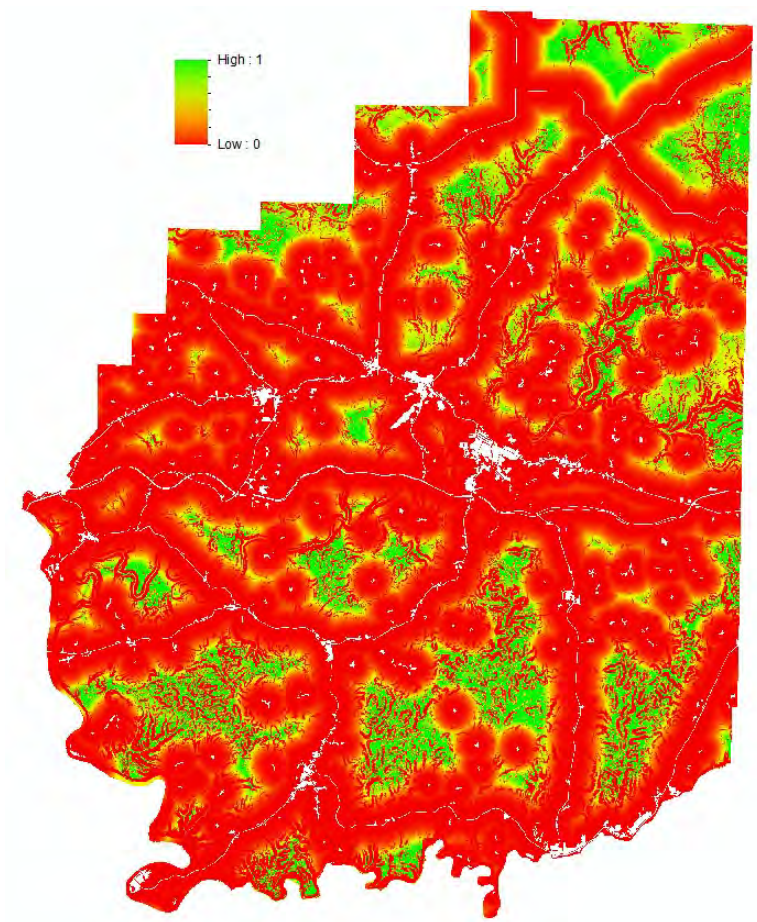
The Custom Fuzzy Membership method using Reclassify, Float and Divide tools to create the membership raster for the level of suitability of each group of land covers would result in most areas would be suitable and only those that are classified as urban with very low tree cover are marked as red (very low membership value).

VI. Applying the Fuzzy Overlay

Running the Fuzzy Overlay tool is straightforward (Analysis tab >> Geoprocessing >> Tools >> Toolboxes >> Spatial Analyst Tools >> Overlay >> Fuzzy Overlay). The tool asks for the Input Rasters (all fuzzy membership rasters that were created in the previous step), the Output Raster and the Overlay Type). There are different types for overlaying fuzzy membership layers, we discussed earlier **AND** and **OR**, you may want to consider the other available methods for further analysis (Sum, Product, and Gamma). In this case, we are going to experiment with the AND and the OR types.

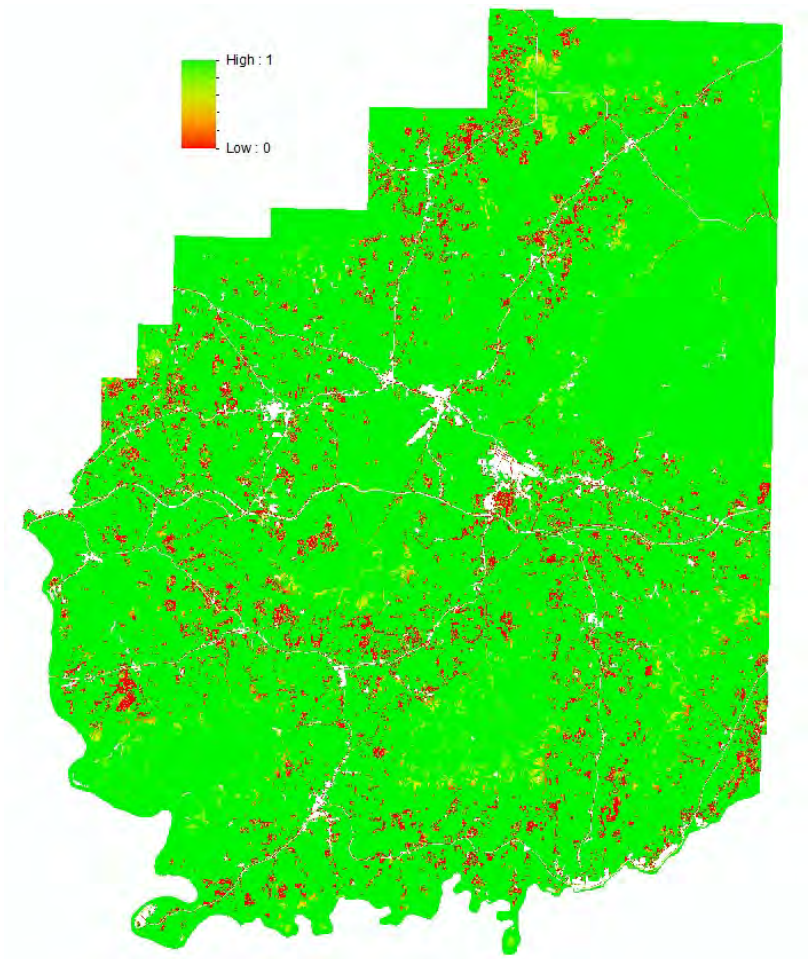
First, we are going to explore how AND and OR work if we equally add all membership layers in each. Then we are going to use a little bit of logic and use the OR method on a couple of inputs then use the output as an input in an AND function with the remaining set of inputs.

First, the **AND** method is exclusive, it is stricter and the lowest membership value in all inputs will be returned in the output, i.e. all cells has to be high in order for the output cell to be high (name your output as **FuzzyOverlay_AND**. Applying the AND method to all of our membership inputs will result in a map that is similar to the following figure:



The AND method in the Fuzzy Overlay function is strict and all inputs need to have high membership value in order for the output to be classified as high. The minimum value of all inputs is returned, therefore, limited areas are ranked as suitable while most of the county is classified into the no to less suitable areas for natural wildlife habitats.

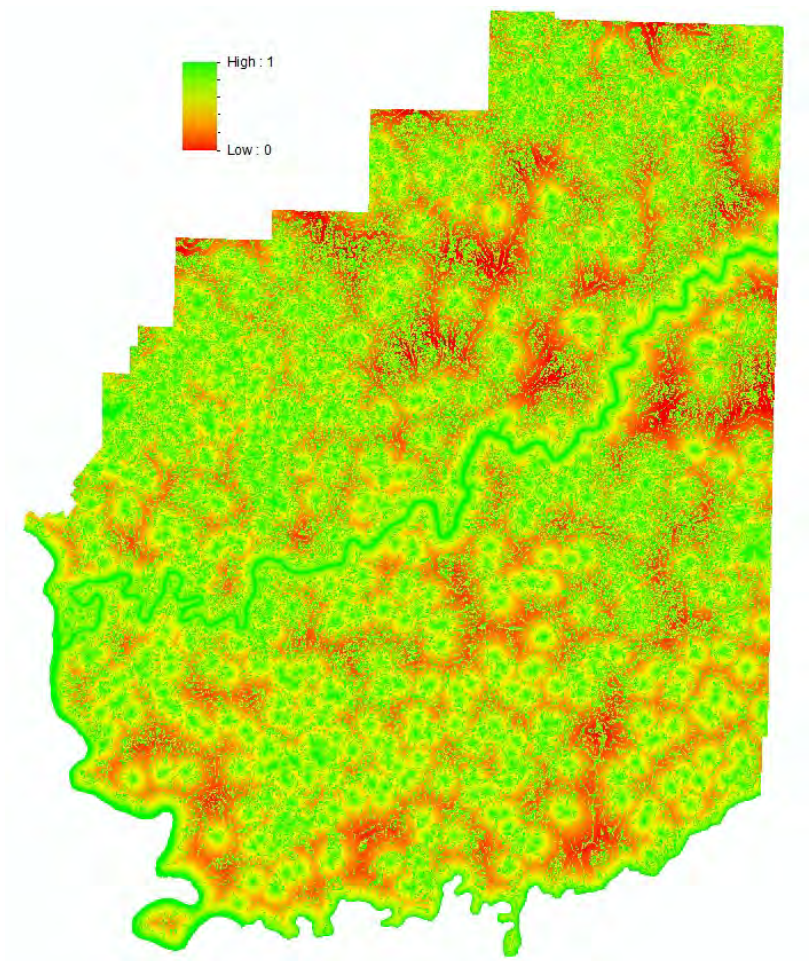
The **OR** method, on the other hand, is inclusive, it is much looser than the AND method, since the highest membership value in all inputs is returned regardless of its low value in others. It is expected that the result from the **OR** method to include most of the County's cells as highly suitable, since only one membership raster layer from the inputs needs to have high membership value (name your output as **FuzzyOverlay_OR**). The following figure depicts this result.



In contrast with the AND method, the Fuzzy Overlay OR function is much looser, only one input needs to have a high membership value in order for the output to be classified as highly suitable. Most of the county is ranked as suitable.

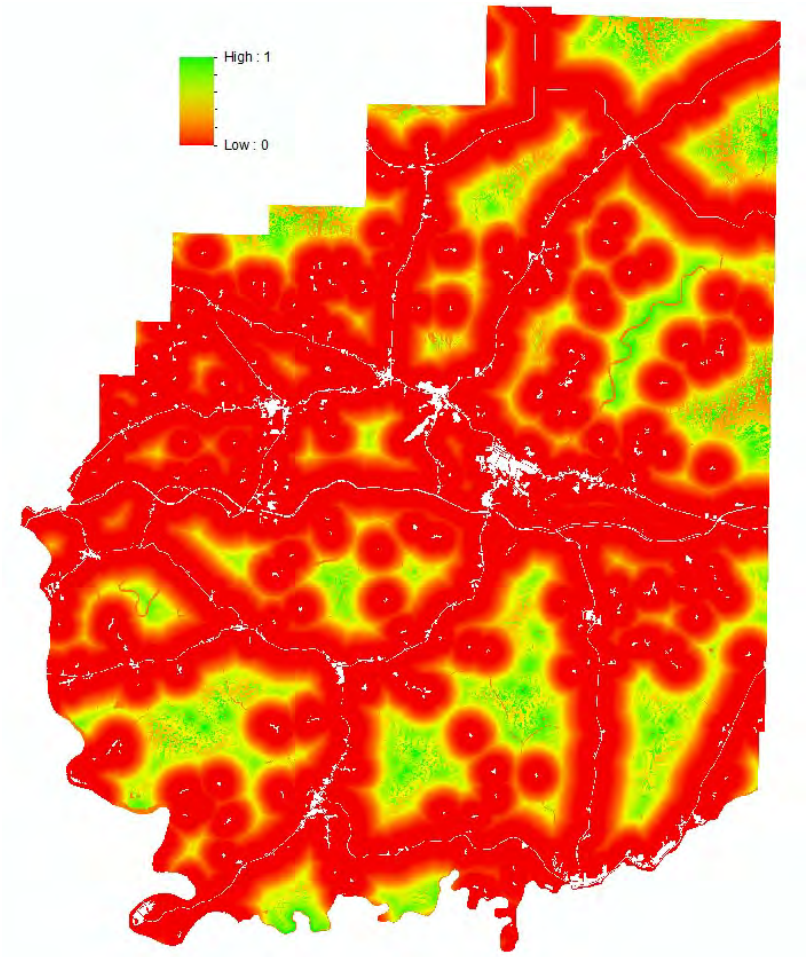
A more reasonable way is to re-think the given set of criteria and the aim of this analysis. Since the aim is to identify areas that would qualify as the best for natural wildlife habitat, the natural conditions can be very loose; for example, if the area is closer to waters but is steep, or vice versa (far from water bodies but flat), the area would be favorable to most wildlife species. But most of them would not prefer to be close to man-made environments (urban areas and

roads), and would prefer to remain in relatively natural land cover type. Therefore, we can use the OR method to create another membership dataset (**FuzzyOverlay_Natural_OR**), then fuzzy overlay the resulting membership dataset with the remaining membership rasters with an AND method (name the output **FuzzyOverlay_OR_AND**). The result of overlaying the natural areas with an OR function would look similar to the following figure.



The OR method of the Fuzzy Overlay is used to combine the areas that are suitable either from the slope distances or proximity to water bodies. Only those areas that are not suitable in either inputs are highlighted in red (low suitability).

The following figure represents the result of using the Fuzzy Overlay AND method on the **FuzzyOverlay_Natural_OR** with all other raster membership inputs.



The AND option is used in the Fuzzy Overlay of the resulting OR overlay of natural criteria together with all of the other inputs (land cover, urban distance, and roads distance membership layers). Notice the difference between this figure and the one that shows the result of combining all the membership layers including the natural ones in one step with the AND option. Obviously, more areas in the green spots qualify as a good natural habitat, less areas are excluded because of the slopes condition.

VII. Assessing the results

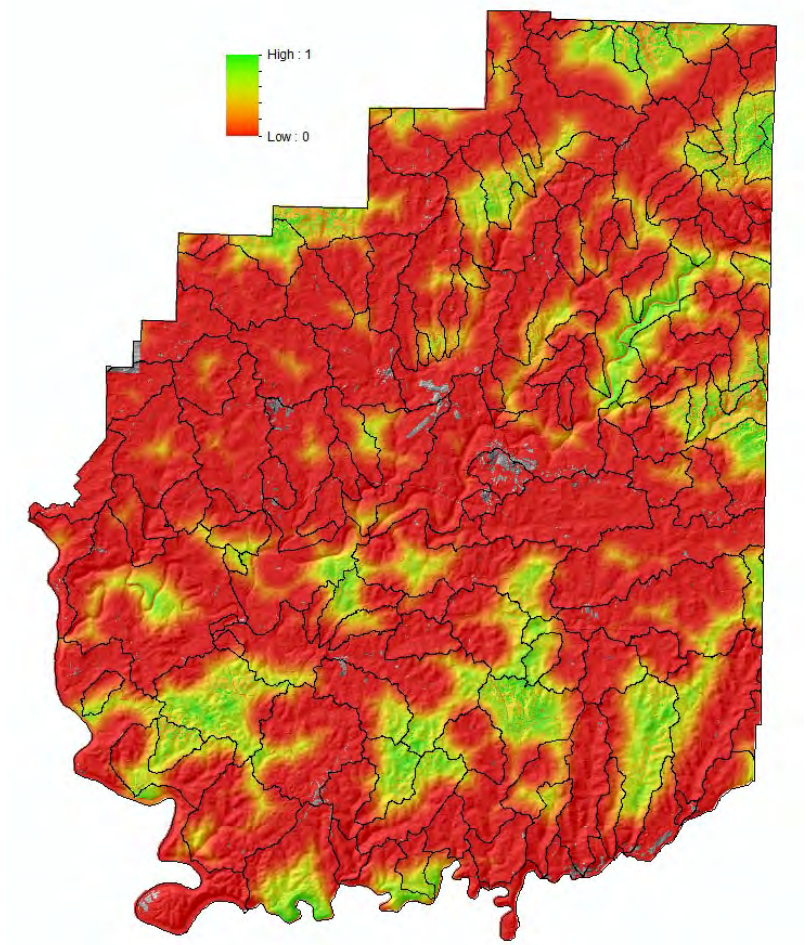
The result of all analysis methods is subjective and the overlay methods can return various solutions and site suggestions based on the given criteria as well as the methods used in preparing the inputs as well as the analysis procedure itself. The fuzzy overlay method is no different, and you should be planning, after performing the analysis, to determine how valid it is and whether it needs to be refined or corrected.

The best way to assess your result is to compare it with existing research, make random field checks, and to seek advice from the experts in the area of study. Your methods can be tweaked using different parameters for the fuzzy membership layer creation (midpoint and spread values) as well as the overlay option or combination of options.

VIII. Reporting the results

Saving the steps of the calculations of each of the fuzzy membership layers together with those of the fuzzy overlay methods would be useful in order to document your steps. You may consider experimenting with the optimum classification method for your data and results, making sure that the classification scale for all of your data is comparable (i.e. same color gradient for the same value of different layers).

Also, you may use some other ancillary data to complement your result display. Data such as a hillshade (shaded relief) or watersheds would be useful in adding additional information to your result, either about the nature of the landscape or the location of patches of suitable/non-suitable sites.



Adding the hillshade layer of Clarion county calculated from the County's DEM using the 3D Analyst surface tools in ArcToolbox to the map would add a third dimension feel and look to your result. Also adding the watershed layer (download from PASDA for all PA and extract those in Clarion county) would give a sense of location to the distribution of suitable and non-suitable cells.

Finally reporting your steps is essential in order to share your methods with fellow GIS analysts. The best way to accomplish this is to summarize your methods in the form of a flowchart or a model diagram. Include all steps as well as the different variable settings for each of the steps, the flow of your processes should be portrayed clearly in such diagrams.

A. Your Turn

Now, using similar procedures, and using the same given datasets, you are asked to perform a similar analysis to select those locations that match the following criteria:

1- Consider sites that have a slope between 0% and 10%;
2- Fall within a distance of 100 Meters from existing streams;
3- Located in a Forested, Grassland or pasture land;
4- Optimum location would be between 2 Kms (2000 Meters) and 5 Kms (5000 Meters) from Interstate 80; and,
5- Is within 250 Meters of all other roads for accessibility.

Those conditions are suitable for a stream remediation plan where proximity to the existing stream network is necessary for site reclamation, and proximity to existing roads is important for accessibility. The process would possibly include the construction of settling ponds, so the landscape needs to be relatively flat. We also need to avoid the proximity to heavy and high speed traffic Interstate for the safety of crew while maintaining the site away from any possible heavy road treatment that might affect the water chemistry in the treatment site.

You are required to create a PDF report (start in any word processing software (e.g. Word), then save it as PDF) of the procedures and results. Also, include your geodatabase with only the main steps that you followed in order to reach the final result. Create a ZIP file for your exercise folder and submit the zipped report and geodatabase to the corresponding assignment dropbox.

Report Content

- Include a cover page with a selected title “Raster Analysis: Fuzzy Overlay for Stream Remediation Site Selection” or something similar, your name, class number and date of the report.
- No text is necessarily required, only the figure captions of every step you make during the analysis.
- Make sure to save all of the essential steps using the same raster dataset file naming convention used in the demonstration exercise.
- Add a flowchart to summarize the steps with explanation of details for each step.
- Extract all of the necessary information from the given data.
- Apply the different necessary re-classifications for all inputs.

- Take screen snapshots (Alt + Prnt Scrn) of your ArcGIS Pro window every time you make a step or an action that changes the result on the screen and paste the resulting clipboard image in your word processing software (e.g. Word), **DO NOT** crop or resize the pasted image, I would like to be able to see your table of contents organization of layers. You may create a 1 column 2 rows table; past the image inside the top cell and insert your text in the lower one. if you can't see the details of the snapshot screen capture images very well... I won't either!
- Under each pasted image, type in a brief description on how did you reach this step and what does it show.
- Show at least 3 different methods for your result, compare them and add your argument for the reason of selecting the midpoints, spread and different overlay methods or method combinations. You may summarize the results in the form of tables and graphs as well as maps.

B. Grading Rubric

Grading for this exercise will be according to the following rubric:

Criteria	Score From
Cover Page	5
Data Preparation for County borders	10
Fuzzy Membership layer production	30
Application of Fuzzy Overlay Methods	25
Result Assessment	15
Final Results Reporting (Map/Table/Graph)	10
Overall Report Presentation Quality	5
TOTAL	**100**

Partial completion of any of the grading criteria will be graded according to the level of completeness/quality based on the following scheme for every criterion:

Level	%
Excellent	100
Very Good	75
Good	50
Fair	25
Absent	0

IX. Readings

- Applying fuzzy logic to overlay rasters: https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/applying-fuzzy-logic-to-overlay-rasters.htm
- How fuzzy membership works: https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/how-fuzzy-membership-works.htm
- How fuzzy overlay works: https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/how-fuzzy-overlay-works.htm