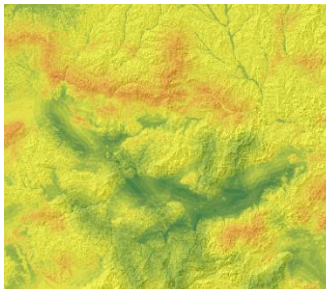
# Raster Suitability Analysis: Siting a Wind Farm Facility North Of Beijing, China



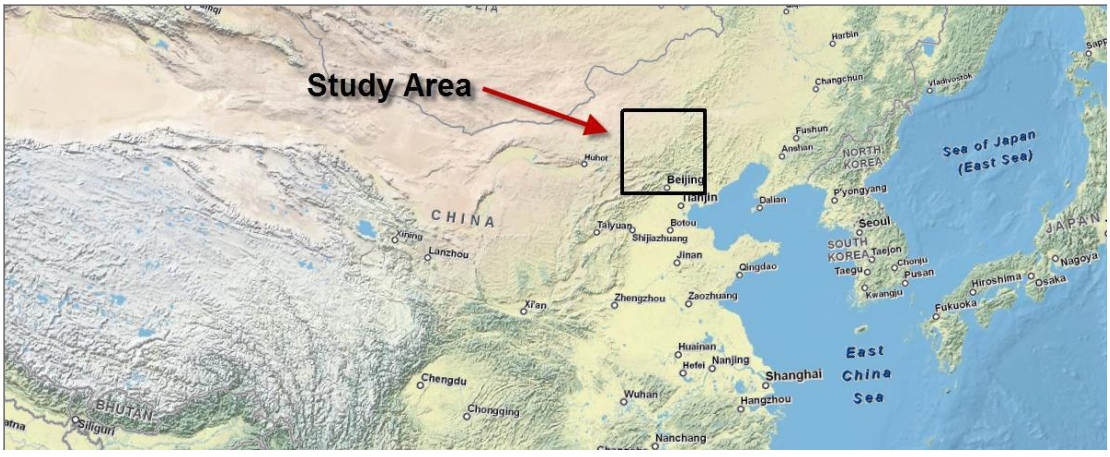
Written by Gabriel Holbrow and Barbara Parmenter, revised by Carolyn Talmadge 3/9/2018



## Introduction

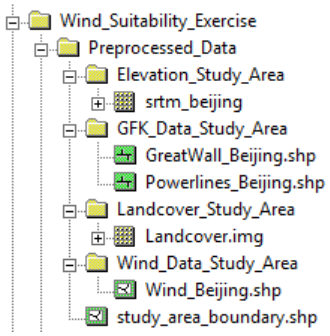
The purpose of this suitability analysis is to find optimal locations for an energy storage facility that will serve Wind Farms in the region north of Beijing. You need to find the general locations – field teams will later be sent out to explore these suggested zones in more detail. The criteria are:

- The site should be close to high wind areas
- The site should be on land that is fairly level
- The site should be close to existing transmission lines
- The site should not interfere with tourism to the Great Wall



# Preprocessed Data Sets and Sources

The data for this tutorial is organized in the Wind Suitability Exercise within the S Drive. The data sets have been acquired and pre-processed as described below. You do not need to download the data from these sources! Directions on how to access the data are in the following section, "Accessing the Data and Preparing for the Tutorial".




## Elevation

***Source***: Shuttle Radar Topography Mission (SRTM) – we used ESRI version, but SRTM data is also available for download from other sources M:\World\ESRIDataMaps93\Raster\Elevation\SRTM\
Original data set name: srtm_n_elev_e.jp2
Preprocessing:

- Clipped to study area
- Projected to UTM WGS 1984 Zone 50N

## Wind Power

***Source***: National Renewable Energy Lab
Original data set name: cn_e_50mwind.shp
Downloaded from http://www.nrel.gov/gis/data_analysis.html
Preprocessing:

- Clipped to study area
- Projected to UTM WGS 1984 Zone 50N

## Power lines

***Source***: GfK (proprietary, Tufts has license) M:\World\GfK\Asia\china\add on\
*Original data set name*: china power lines.shp
Preprocessing:

- Coordinate system defined to GCS, WGS 1984 (original spatial reference was undefined)
- Clipped to study area
- Projected to UTM WGS 1984 Zone 50N

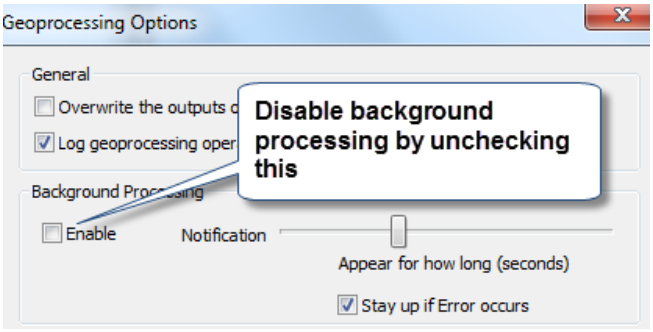
## Great Wall

***Source***: GfK (proprietary, Tufts has license) M:\World\GfK\Asia\china\add on\
*Original data set name*: china great wall.shp
Preprocessing:

- Coordinate system defined to GCS, WGS 1984 (original spatial reference was undefined)
- Projected to UTM WGS 1984 Zone 50N

## Accessing the Data and Preparing for the Tutorial

1. The data is stored in **S:\Tutorials & Tip Sheets\Tufts\Tutorial Data\WindFarm_Suitability_Exercise. Copy** the entire **Windfarm_Suitability_Exercise** folder to your H: drive.
2. You need to make the copied folder "**writable**" – to do this, *right-click* on the folder in your H: and choose **Properties**, and **uncheck** the Read-Only box. When prompted say yes to apply to subfolders.
3. Open the Windfarm_Suitability_Exercise folder and double-click on **Start_map.**mxd – this will start ArcMap with the layers already added.
4. Once ArcMap opens with the China map, click on the Geoprocessing menu, and choose Geoprocessing Options, then disable *Background Processing* if enabled as shown below:




5. Click OK.
6. In ArcMap, go to **Customize→ Extensions →** checkmark *Spatial Analyst*. **You must do this on any new computer whenever you plan to use spatial analyst tools!**
7. Take a couple minutes to explore the different data sets.

## Overview of the Analysis

We will be going through the following analysis steps to locate good potential sites for our Wind Farm Energy Storage and Maintenance Facility. This is just an overview of the process.

1. Wind zones layer → *Select by attribute* for high wind speed areas →*Euclidean distance* from high wind speed areas → *Reclassify* 1-5 for distance preferences (close to High Wind Power area is most suitable = 5)
2. Transmission power lines layer → *Euclidean distance* from transmission lines → *Reclassify* 1-5 for distance preferences (close to transmission lines is most suitable = 5)
3. The Great Wall layer → *Euclidean distance* from the Great Wall → *Reclassify* 1-5 for distance preferences (Far from Great Wall is most suitable = 5)
4. Elevation (DEM) layer→ Derive *slope* → *Reclassify* for slope preferences (low slope is best = 5)
5. Perform analysis of the re-classified data sets using *raster calculator* to create final suitability locations.

## Setting the Extent, Cell Size, and Snap Raster

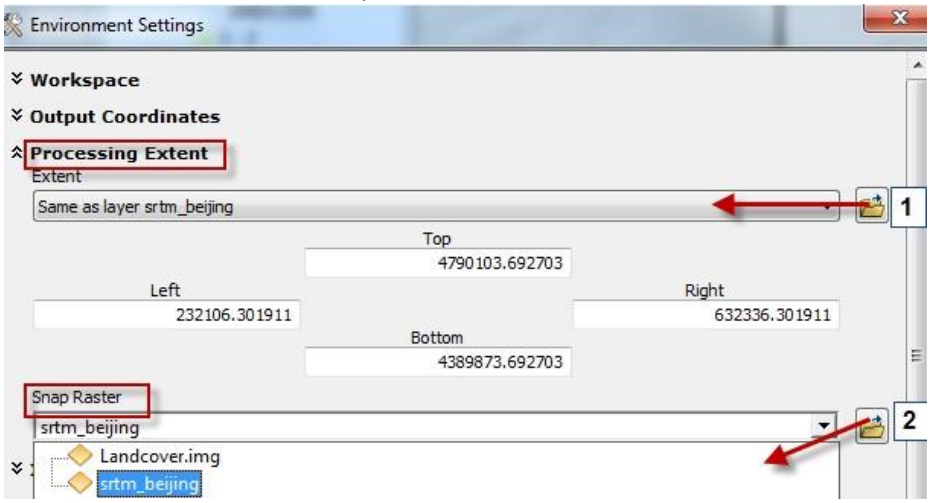
When performing raster-based overlay analysis, it is very important to set the **extent** of the analysis, the **cell size**, and to make sure that all the rasters you create will snap to each other. It also helps to specify a scratch workspace where all your results will be put. You can set these options before the analysis by going to **Geoprocessing → Environments**.

Note: You have to set this with **each session** of ArcMap you start.

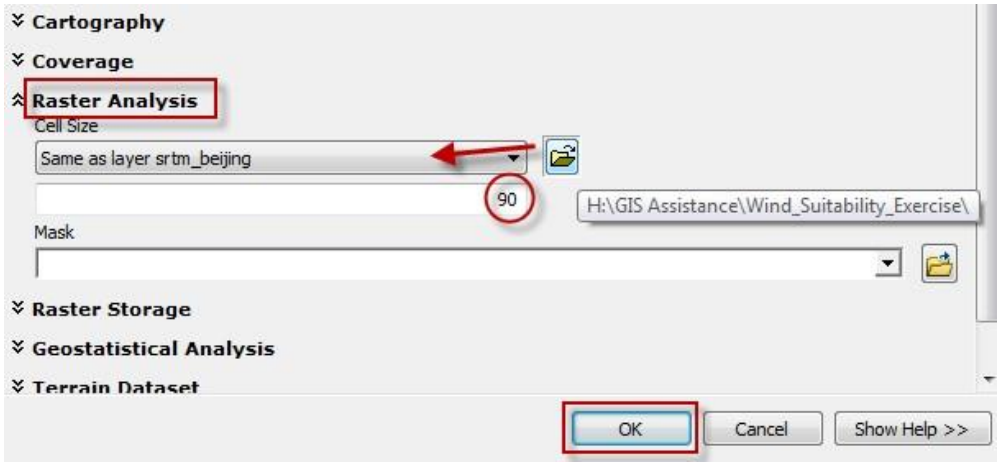
1. Click on **Geoprocessing** and select **Environments**…

2. In the Environment Setting box, click on **Workspace**.
3. Set the **Current Workspace** to your H:\Wind_Suitability_Exercise folder (don't double click on the folder, simply highlight it and press add). Set the **Scratch Workspace** to a new *Temp* folder that you create within your H:\Windfarm_Suitability_Exercise as seen below:


4. Then click on **Processing Extent** to set the *Extent* and the *Snap Raster* as follows– all the analysis result will have the same extent and snap to our SRTM elevation data set




5. Scroll down further and click on **Raster Analysis.**
6. Set the **Cell Size** to be the same as the layer *SRTM_Beijing* using the drop down(**this sets the cells to be 90 meters by 90 meters**):

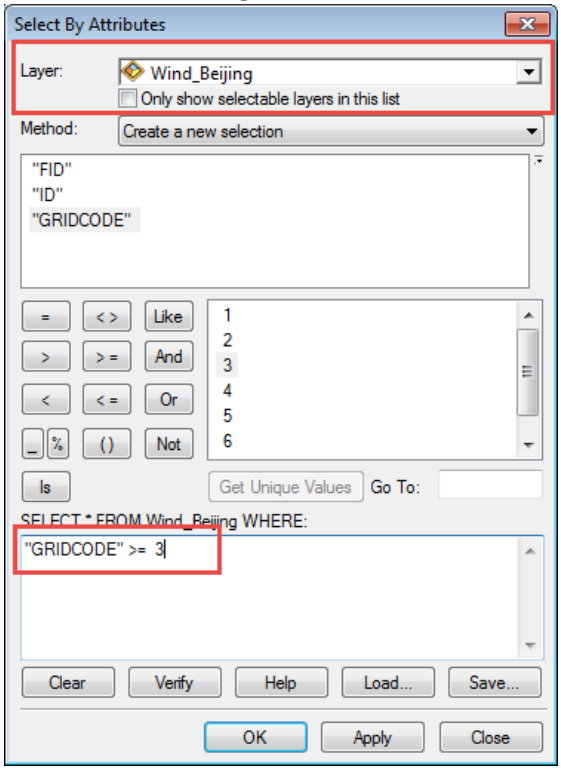



7. Click **OK** to exit back to the map.

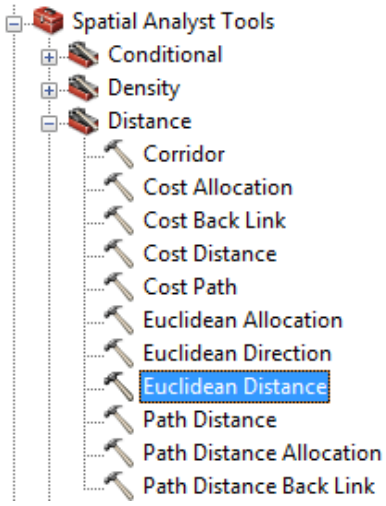
## Creating the Wind Preference Grid

The Wind_Bejing layer will be used to determine areas with **high wind power**. Its symbology is currently set to show the Gridcode, which provides information on the *wind power class*. According to the US National Renewable Energy Lab, "Areas designated as class **3 or greater** are suitable for most utility-scale wind turbine applications, whereas class 2 areas are marginal for utility-scale applications". Therefore, we need to select all areas with a **Gridcode greater or equal to 3**.

1. Turn on **Wind_Beijing.**
2. Go to **Selection** → Select by Attributes...
3. Make sure the layer is set to *Wind_Beijing* and enter **GRIDCODE >= 3** as shown below. Make sure that it is **greater OR EQUAL** to 3, not just greater than 3!

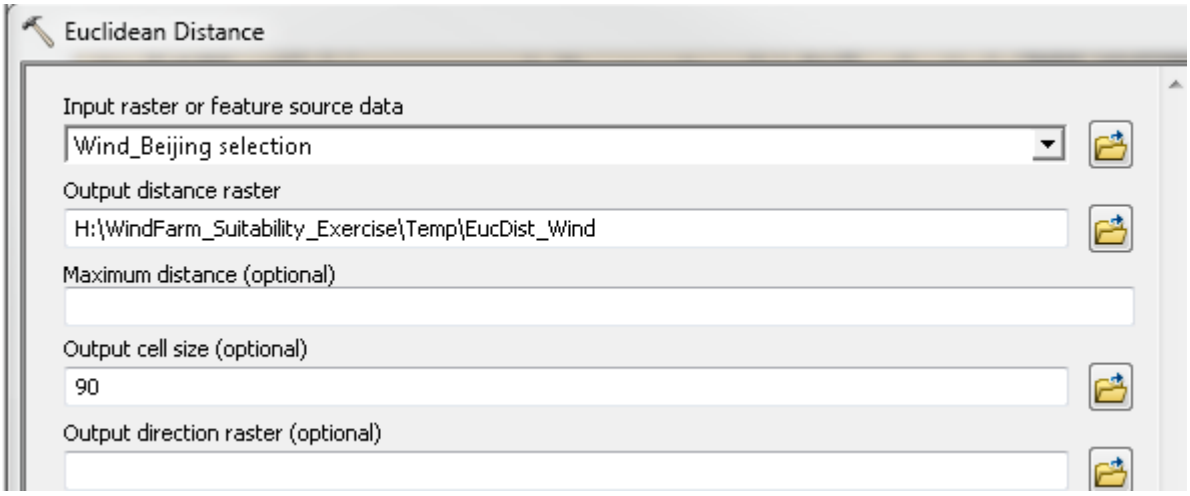



4. Create a new layer from the selected Wind_Beijing features. To do this, right-click on *Wind_Beijing*, then click **Selection > Create Layer from Selected Features**.
5. The new layer of just the selected strong wind classes appears at the top of your *Table of Contents* and is called *Wind_Beijing selection.*
6. Click the **Clear Selected Features** ( ) icon to deselect the wind and turn off *Wind_Beijing* layer.
7. Click on the **ArcToolbox** ( ) icon to open it.
8. In ArcToolbox, navigate to **Spatial Analyst Tools** → **Distance** → and double click on **Euclidean Distance**.




9. Fill the tool out as follows. For the *Input Raster OR feature source data field*, use the drop down arrow to select ***Wind_Beijing selection***. The output distance raster should automatically populate, since we set it to do that in the **Environments** earlier. Click on the folder next to the output field to change the name of the new raster to **EucDist_Wind.** Accept the other defaults, which should also auto populate based on our **environments** preferences. .

   **Note**: it is VERY important that there are no spaces or weird characters in the name or proceeding folder names. It most also be less than 9 characters, or the tool will not run correctly.



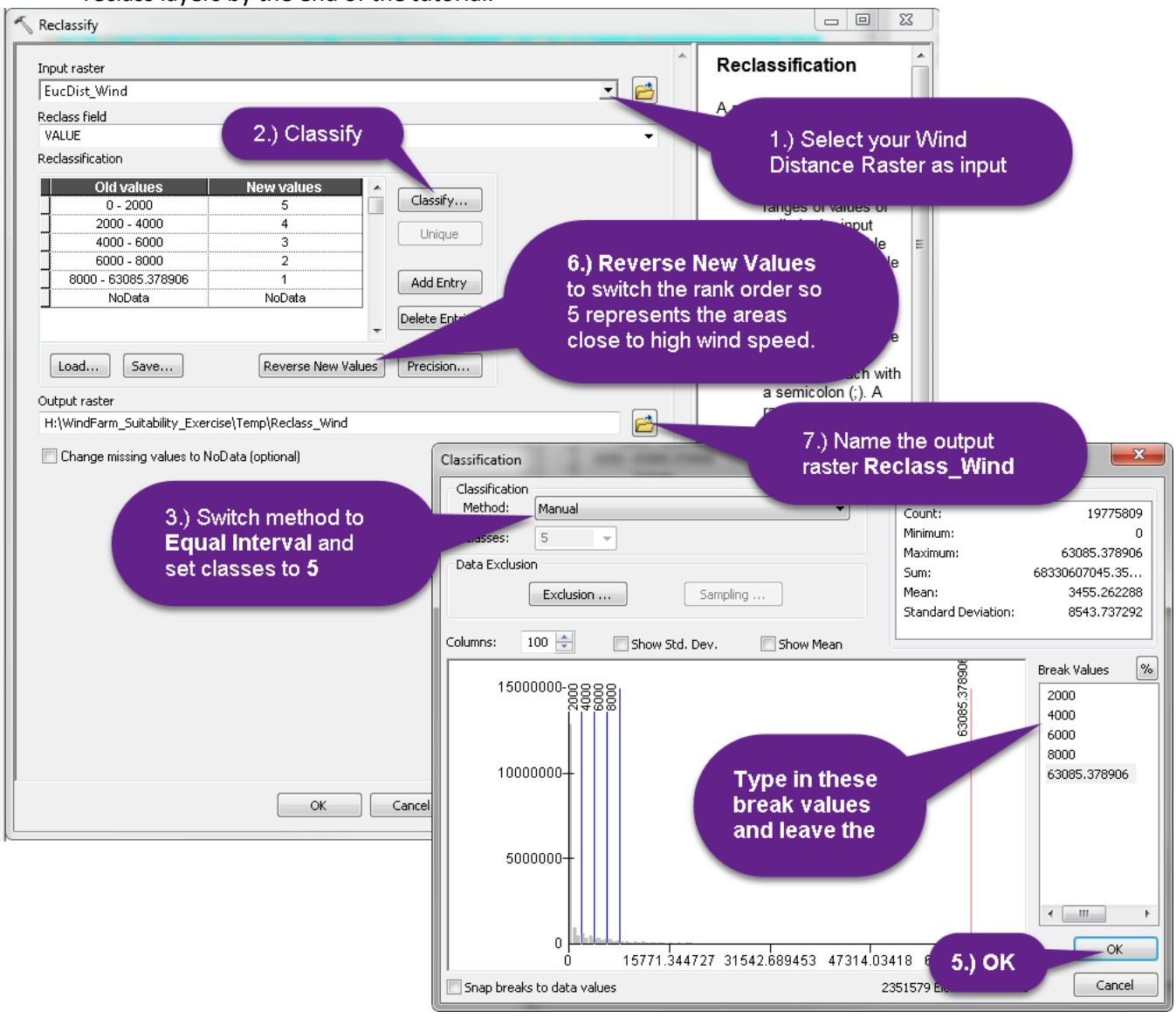

10. After the process is completed, you will see the **EucDist_Wind** included in your ArcMap Table of Contents. The result is a **raster** grid, in which each grid cell is the distance in meters from the areas of strong wind (GridCode =>3). Move it to the top to see it clearly.

11. We will now use the **reclassify** tool to *rank* areas based on their distance to high wind speeds. This tool will create a brand new raster with values from **1 to 5**, where we set cells close to high wind power as highest preference/high rank (5), and cells that are far from high wind speed areas as low preference/low rank (1).
    In ArcToolbox, navigate to **Spatial Analyst Tools → Reclass → Reclassify.**

12. Follow these steps to set up the reclassify tool. Examine the diagram (below) for further clarification:

    - Set *input raster* to **EucDist_Wind.**
    - Keep the *Reclass field* as **Value.**
    - Click *Classify* to set the class values.
    - Change the *Method* from Natural Breaks (jenks) to **Equal Interval**

- Set the number of *classes* to **5.**
- Set the **Break Values** (located on the right) to 2000, 4000, 6000, 8000, and leave the max as 63085.398906.
- Press OK to exit out of the Classification box.
- Click **Reverse New Values**. This is **IMPORTANT** because we need to make sure cells with a short distance to wind power (0-2000m) a high score (5), while longer distances (8000m – Max) get a low score (1).
- Name the output **Reclass_Wind**. It is important to change the name because there will be a lot of reclass layers by the end of the tutorial.




13. Close the processing window when complete.

14. The *Reclass_wind* will appear automatically in your ArcMap session, but uses colors that aren't helpful to interpretation. Double click on the layer and then the **symbology** tab, assign a sequential color ramp – such as red to green (you can select the green to red ramp and then flip the colors by clicking on **Symbol → Flip Colors**). The reason we are flipping the colors is so we are showing highly suitable areas (5s) as good (green), and low suitable areas (1) as red (bad!).

15. Save your map file in your H Drive with a new name, **Suitability1.mxd**
    **Note: It is VERY important to save. FREQUENTLY during this tutorial. Arcmap can crash while running these tools and if you don't save, you will lose a lot of work and have to restart! Trust us.**

# Creating Preference Grids for Power Lines and the Great Wall

## PLEASE READ THIS ENTIRE SECTION BEFORE YOU BEGIN!

Use what you learned above (starting at Step 8), and create a distance grid to show **distance *from* Powerlines** and another one to **show distance *from* the Great Wall**. It may help to turn off the Wind layers you were just working with but DO NOT DELETE THEM. **Turn on the power lines and the great wall layers as you run these tools. Make sure the outputs make sense!**

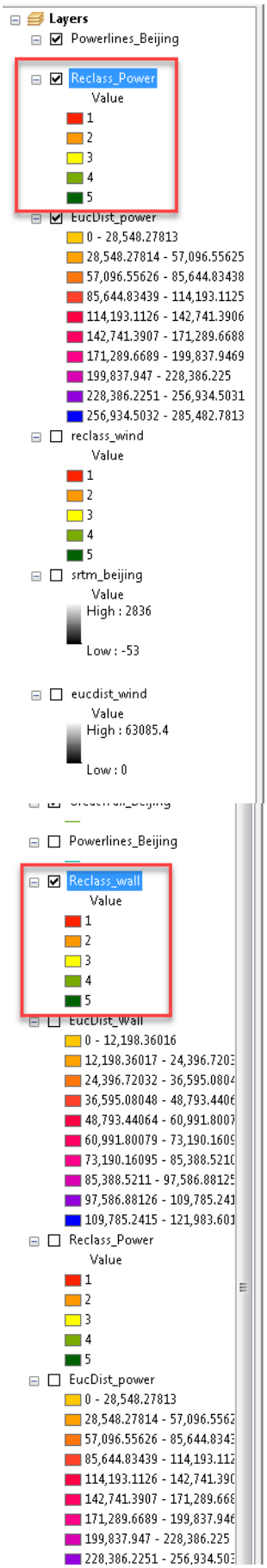
1. Use the **Euclidean Distance** tool to create a distance raster for both suitability factors, Powerlines_Beijing and GreatWall_Beijing.
2. Then **reclassify** each distance grid on a scale of 1 to 5 where 5 is the most suitable and 1 is the least suitable, using the break values listed below, just as you did for wind distance grid. Name each grid appropriately (e.g, Reclass_power and Reclass_Wall).

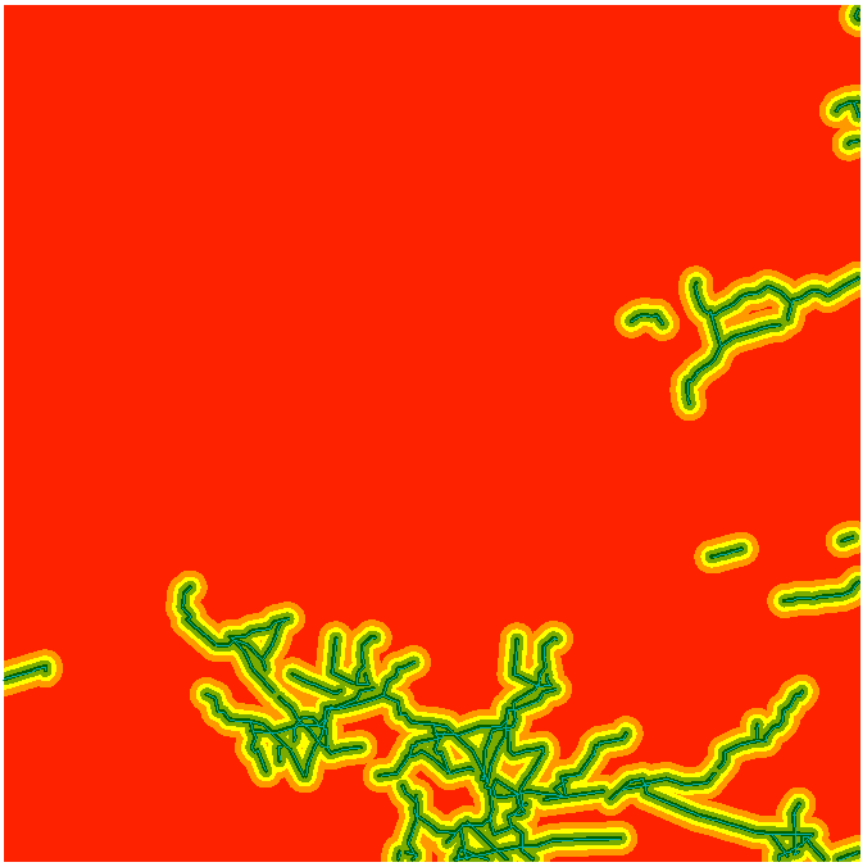
Remember that you want the wind farm facility to be **close to *powerlines*** (the wind-produced energy has to be sent onto major cities) but **far from the *Great Wall*** (you don't want to interfere with the tourist experience of China's history).

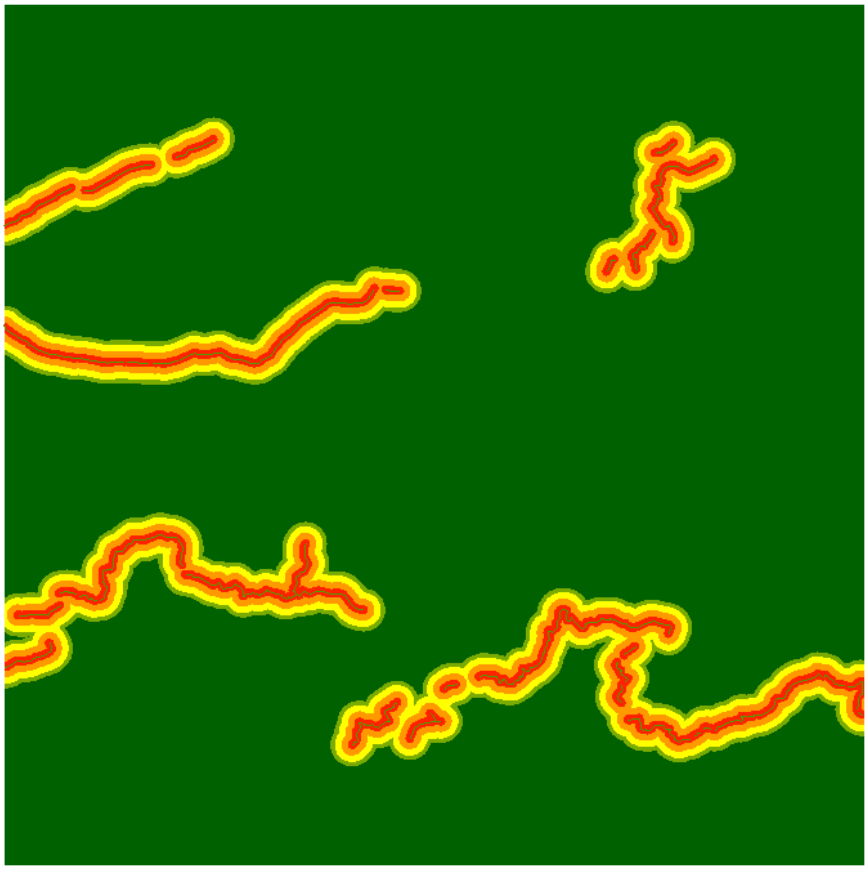
Below are the values to use when reclassifying the data. **Make sure you rank the values correctly, or your results will be flipped! Check carefully that the rank value matches the distance break values.**

| **Distance to Power Lines (meters) Close is GOOD!** | **Reclass Values (ranking)** |
|---|---|
| 1000 | 5 – Good |
| 3000 | 4 |
| 5000 | 3 |
| 8000 | 2 |
| Max distance - 285482.78125 | 1 – Bad because you are far from transmission lines |

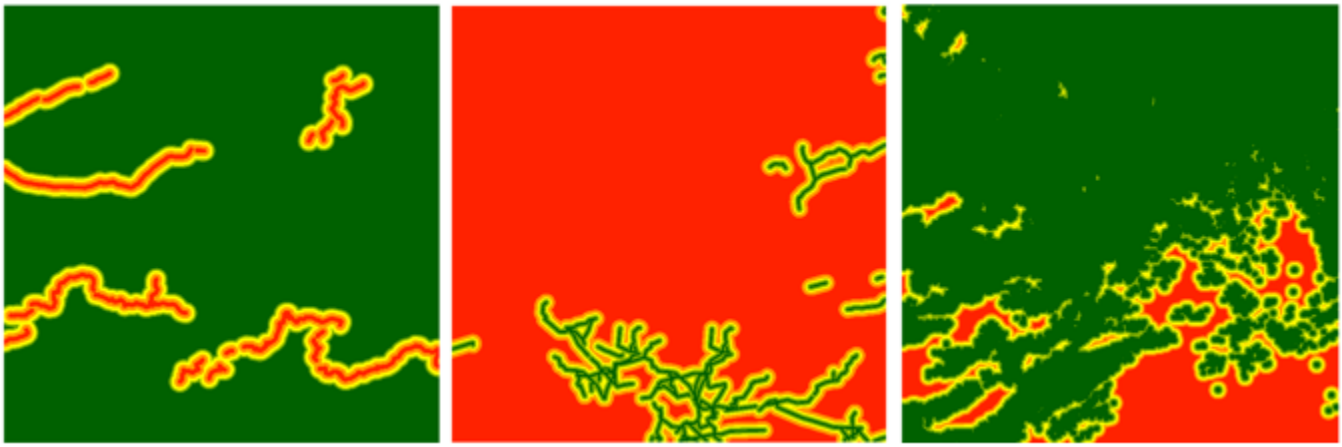
| **Distance from the Great Wall (meters) Close is BAD!** | **Reclass Values (ranking)** |
|---|---|
| 2000 | 1 – Bad because we are close to the wall |
| 5000 | 2 |
| 8000 | 3 |
| 10,000 | 4 |
| Max distance - 121983.601563 | 5 – Good- Far from Wall |


Layers
Powerlines_Beijing
Reclass_Power
Value
1
2
3
4
5
EucDist_power
0 - 28,548.27813
28,548.27814 - 57,096.55625
57,096.55626 - 85,644.83438
85,644.83439 - 114,193.1125
114,193.1126 - 142,741.3906
142,741.3907 - 171,289.6688
171,289.6689 - 199,837.9469
199,837.947 - 228,386.225
228,386.2251 - 256,934.5031
256,934.5032 - 285,482.7813
reclass_wind
Value
1
2
3
4
5
srtm_beijing
Value
High : 2836
Low : -53
eucdist_wind
Value
High : 63085.4
Low : 0
Powerlines_Beijing
Reclass_wall
Value
1
2
3
4
5
EucDist_Wall
0 - 12,198.36016
12,198.36017 - 24,396.7203
24,396.72032 - 36,595.0804
36,595.08048 - 48,793.4406
48,793.44064 - 60,991.8007
60,991.80079 - 73,190.1609
73,190.16095 - 85,388.5210
85,388.5211 - 97,586.88125
97,586.88126 - 109,785.241
109,785.2415 - 121,983.601
Reclass_Power
Value
1
2
3
4
5
EucDist_power
0 - 28,548.27813
28,548.27814 - 57,096.5562
57,096.55626 - 85,644.8343
85,644.83439 - 114,193.112
114,193.1126 - 142,741.390
142,741.3907 - 171,289.668
171,289.6689 - 199,837.946
199,837.947 - 228,386.225
228,386.2251 - 256,934.503





When you finish with this section, you should have 3 reclassified layers that represent distance to the Great Wall, distance to Power Lines, and distance to high wind speed areas. If you set the color ramps, they should look EXACTLY like the images below with **greens representing the 5s (Highly suitable areas) to reds representing the 1s (Low Suitable Areas).** If they do not look the same, you've done something wrong and will need to redo those tools. Save your map file!

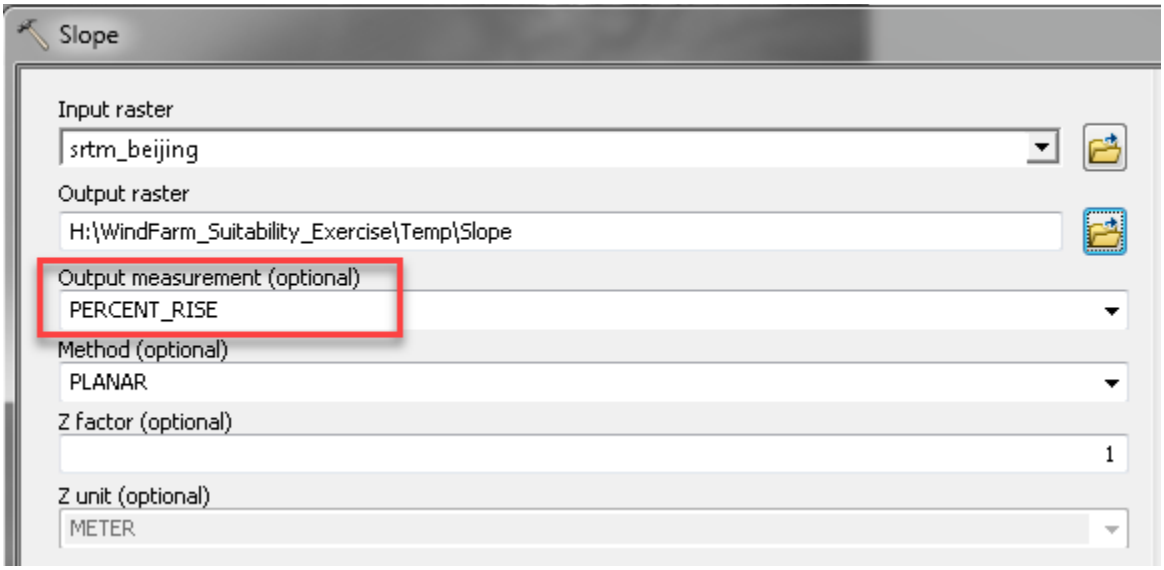


Reclass_Wall Reclass_Power Reclass_Wind

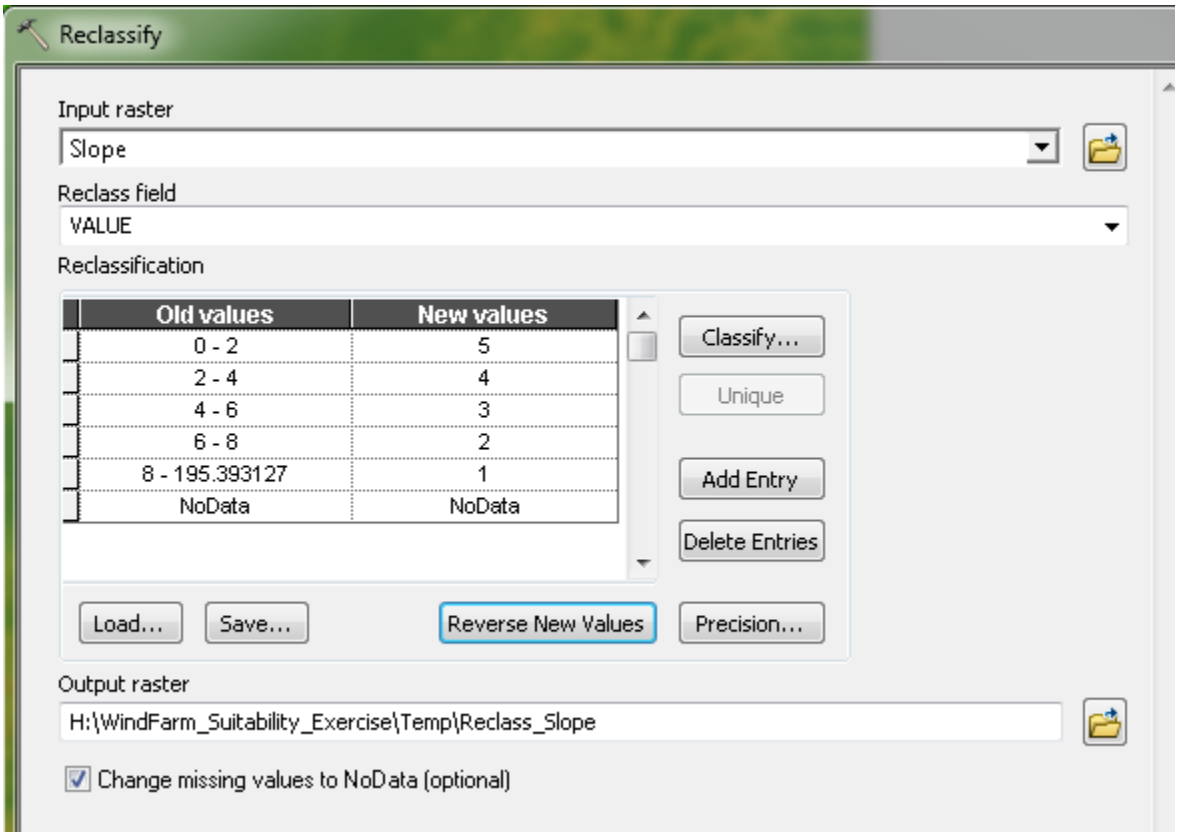
## Creating a Slope Raster

The energy facility is going to be fairly large and needs to be on a level, flat slope. You'll make a **slope** raster from the elevation data (SRTM_Beijing), and then ***reclassify*** it into a slope preference grid. The slope tool measures how steep the incline of the ground is using an elevation layer.

1. Turn on **strm_beijing** and turn off the other layers so you can see it.
2. In ArcToolbox, navigate to **Spatial Analyst Tools** → **Surface** and double-click on **Slope**.
3. Fill out the dialog box as you see here - be sure to give it a name like *Slope*. You want a slope grid that shows **PERCENT_RISE**, not Degrees. Click OK.




4. The result is a slope raster grid where each cell is the percent rise from the adjacent cell.
5. Now ***reclassify*** your slope layer using the break values below to show your slope preferences, where a low slope is highly suitable (5) and a high/steep slope is not suitable (1).




6. Save your map file!

## Using Raster Calculator to Create a Suitability Map

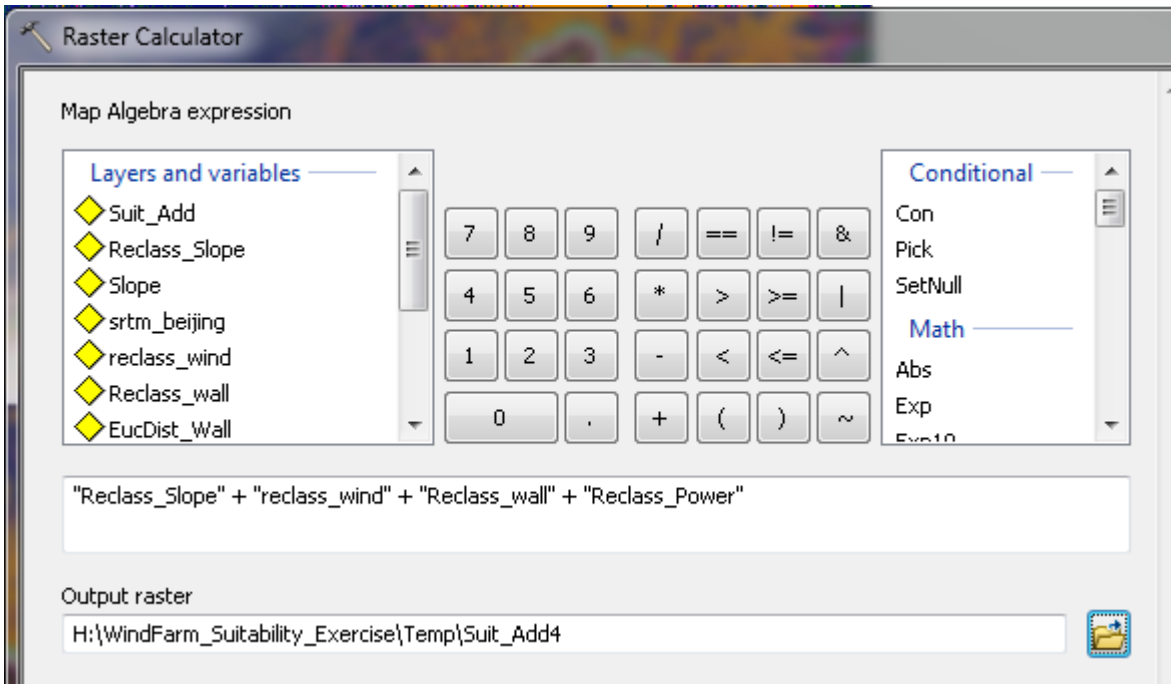
Now that we have the criteria or factor layers reclassified using the same ranking scale, 1(low suitability) to 5 (high suitability), we can use the **raster calculator** to combine the layers to create a **suitability score.**

We will use a tool called **Raster Calculator** to combine our reclassified grids.

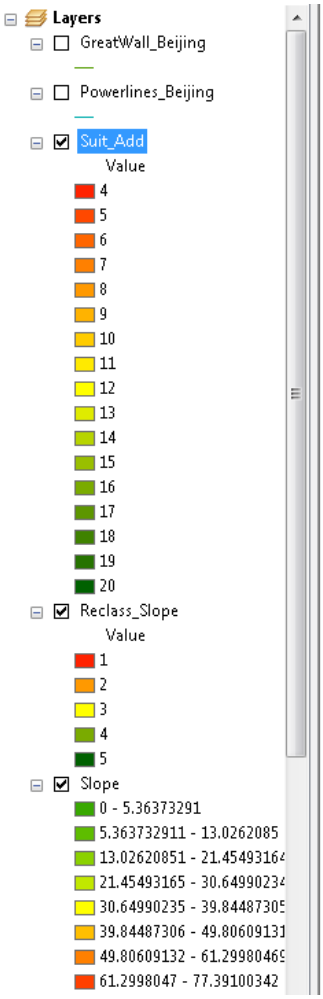
1. In ArcToolbox, navigate to Spatial Analyst Tools→ **Map Algebra** and open the **Raster Calculator** tool.
2. Follow the diagram below to create an "**Additive" model** where we are simply adding the 4 reclassified layers together to get a score of 4(low suitability) to 20 (high suitability).

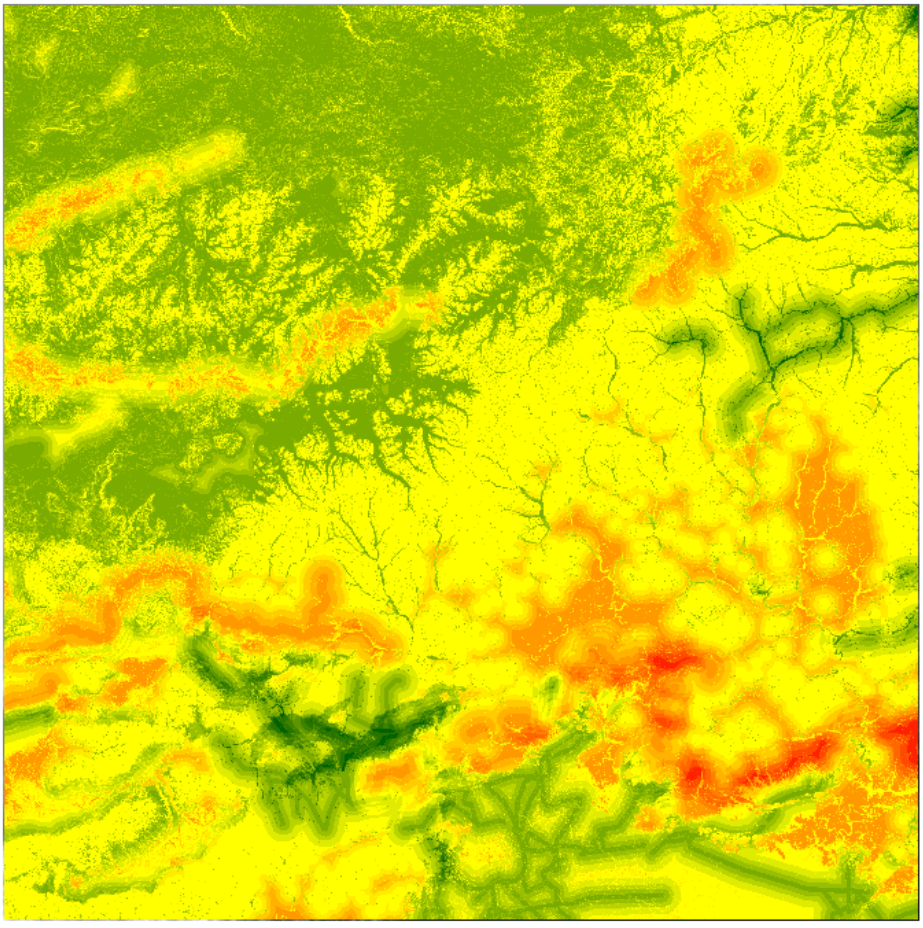
   In the tool, double click on the **layer** you want to add to the expression box then click the button for the "+" sign. Continue until you have added all 4 layers to the expression box. Always using the "buttons" because the SQL language can be very picky with spacing.

   Give the layer a meaning ful name, such as **Suit_Add4**




3. Run the calculator process – the raster will be added to your map after a couple of minutes.
4. It's a wild mess of colors – but you see the values go from 4 (1+1+1+1 = worst score possible) up to 20 (5+5+5+5 = a perfect score for our wind facility). You can assign a better color ramp as shown below:

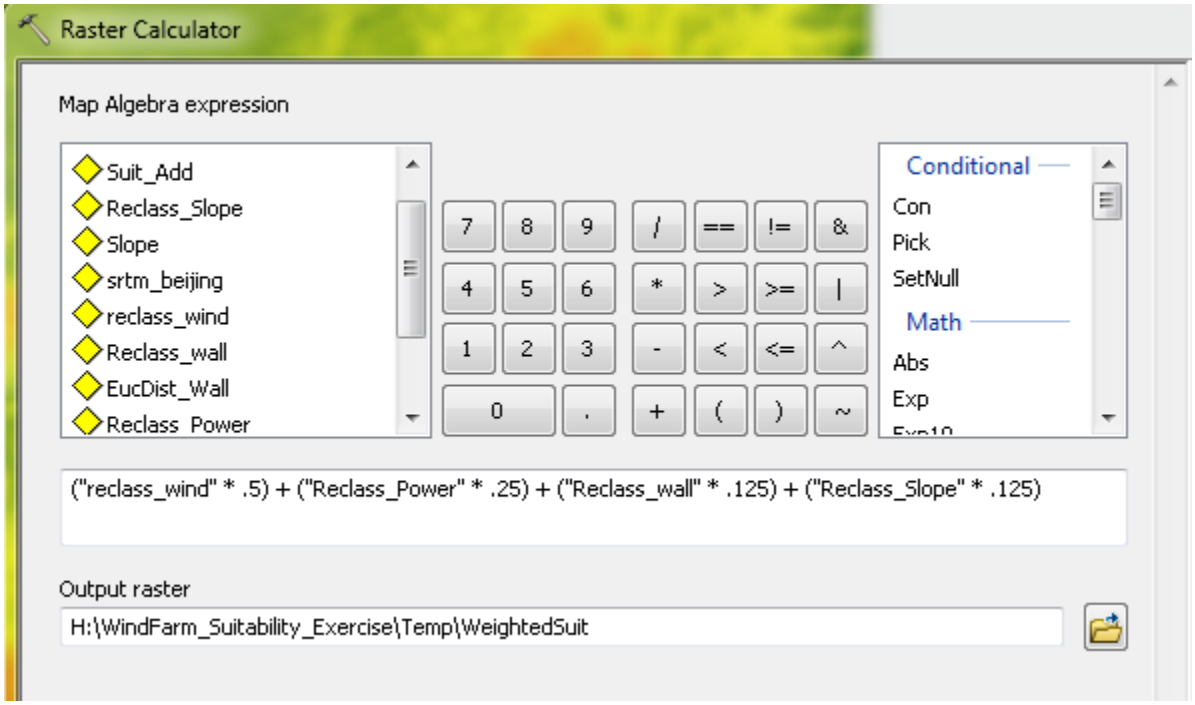


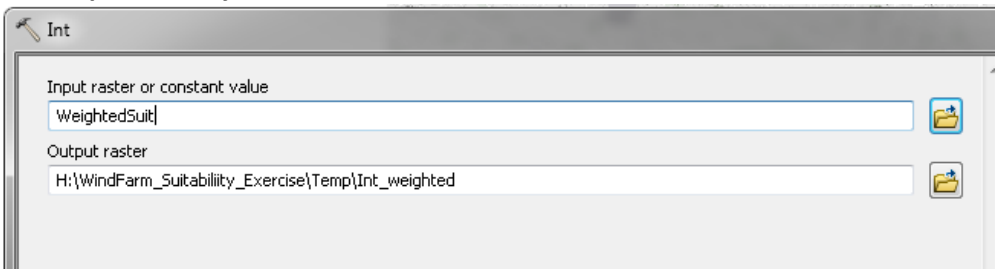
**Note**: It is helpful to choose the same color ramp (dark green to red) as used above to compare. If your map does not look **EXACTLY** like this one, something went wrong (probably a reclassify error). If this happens, you need to check each of your reclassified layers to make sure they are correct.

## Creating a Weighted Suitability Score

1. If one factor is more important than another, we can create what's called a **weighted** grid. We can use the **Raster Calculator** again to give different *weights* to each reclassified layer to create a weighted grid – as follows:
   - Distance to High Wind Power is the most important factor (weighted 50%)
   - Distance to power lines is the next most important factor (weighted 25%)
   - Distance from the Great Wall is less important (weighted 12.5%)
   - Slope is less important (weighted 12.5%)
2. Open the Raster Calculator again and add the new expression. Remember to use the "buttons" to minimize errors in the expression! Give it a good name, like **WeightedSuit**

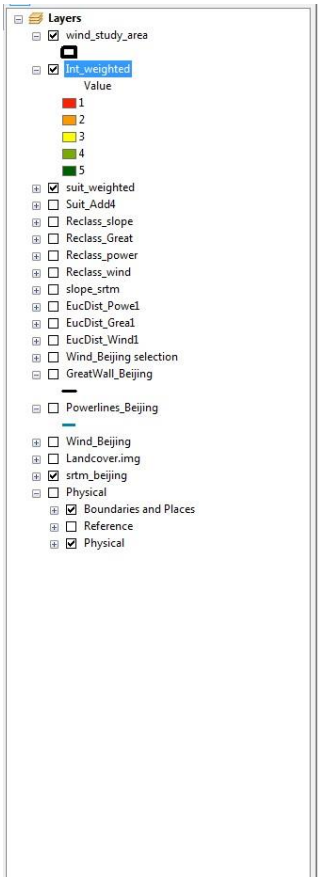


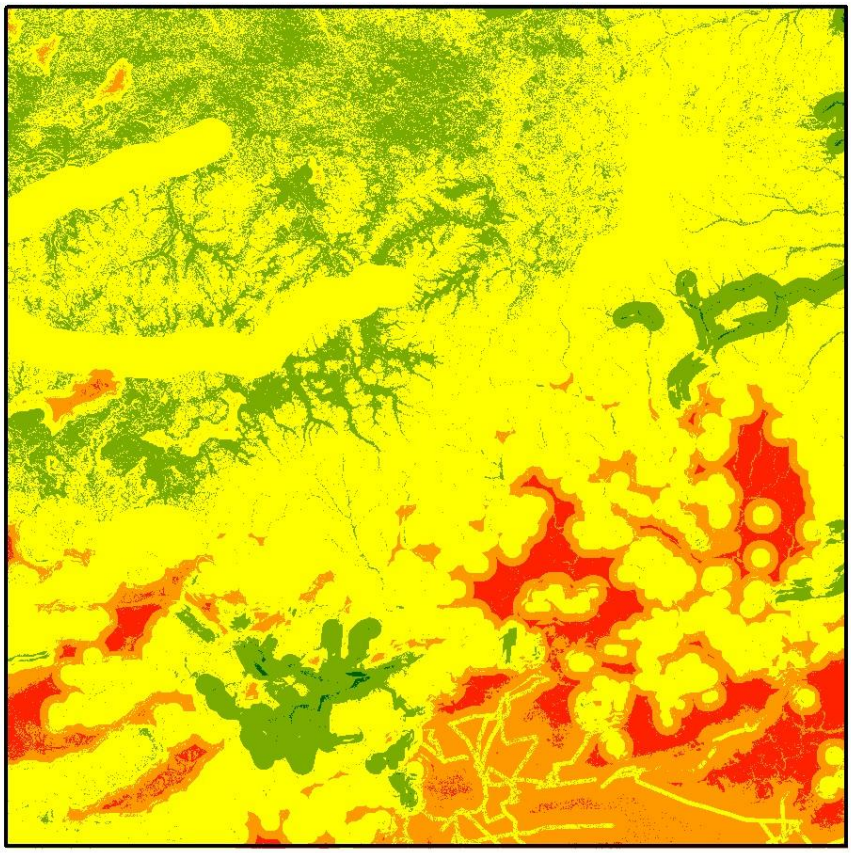

3. The result is a grid where the values have a *continuous* value from 1 to 5 (meaning the scores are not just whole numbers but have decimals). This isn't a problem for visualization but might be for further analysis where we need each cell to be an integer. There is a tool for converting a continuous number grid back to integers by truncating the decimals (e.g 1, 2, 3, 4, 5).
4. Go to **Spatial Analyst Tools → Math → Int.**



Notice how in the **Math** Toolbox, there are other operations such as “Round Down” or “Round Up” that convert decimals back to whole numbers using a different method.

6. To confirm you performed the final analysis correctly, open the attribute table for the **Additive Model** and the **weighted suitability model**. Both layers should have a **cell count of 18861 for Value 20 and Value 5**. If they do not, something was incorrect in one of the steps in the analysis (most likely a reversed reclassify).



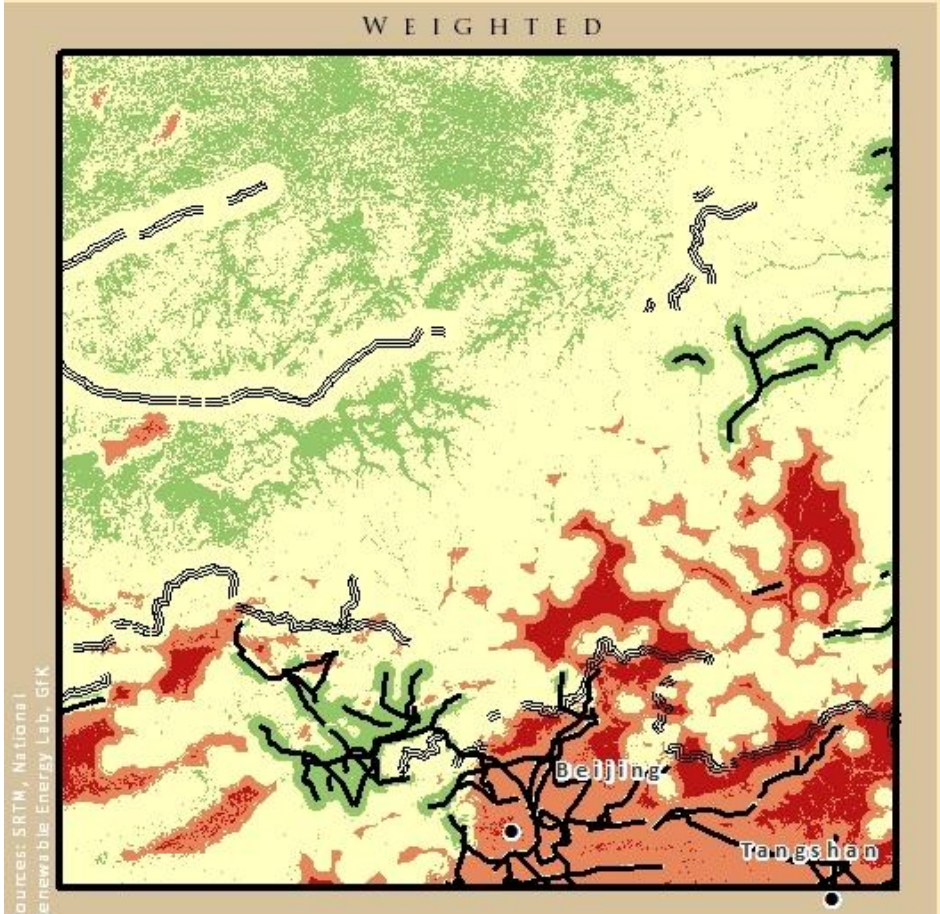
7. That’s it! Now we can clearly see areas that are highly suitable for siting a wind farm all the way down to areas that are not suitable at all! Think about what other factors that should be included in this type of analysis as well, such as land use, protected areas, zoning information, etc.

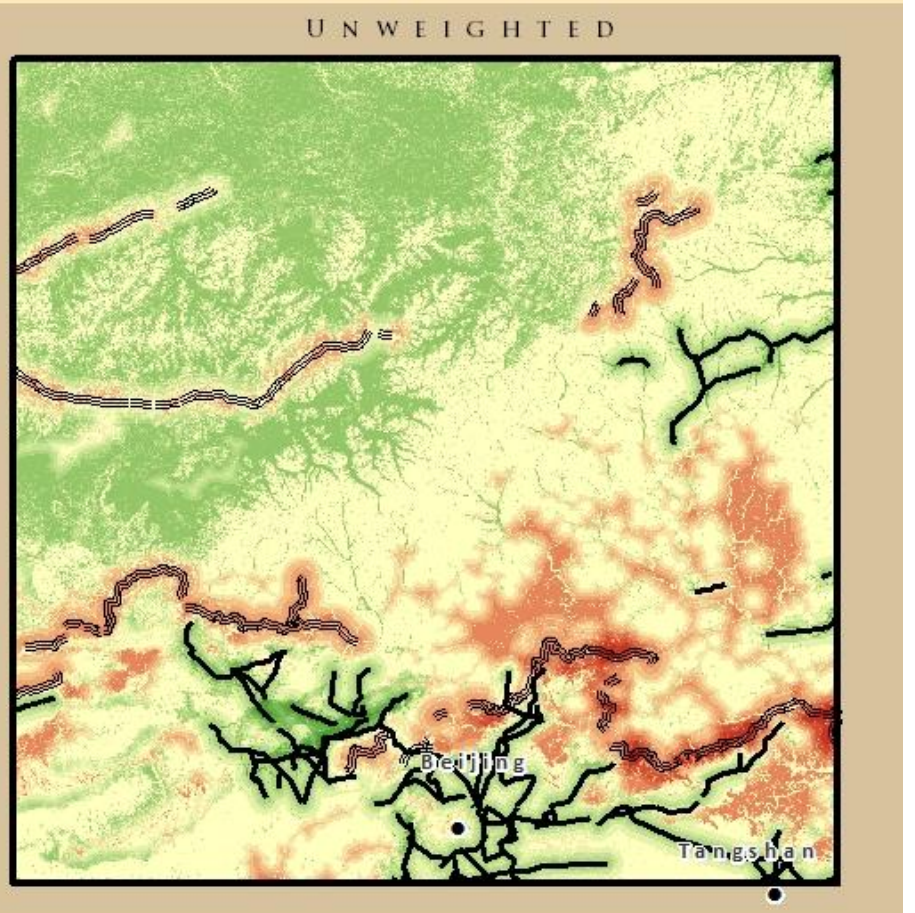
## Save your final map!

Below is an example of how to make this into an excellent final map deliverable. Think about how you would design this map and how to best deliver all the information.

# SITING A WIND FARM FACILITY NORTH OF BEIJING

## CHINA - 2017





**Suitability Rating**

- Poor Suitability
- Low Suitability
- Suitable
- Good Suitability
- Ideal Suitability

- Study Area
- Great Wall of China
- Powerlines
- Cities

This map shows the weighted and unweighted suitability analysis for a new wind farm facility to be constructed north of Beijing, China.

Criteria examined in this assessment included sites:

- Close to high wind areas
- Land that is fairly level
- Close to existing transmission lines
- Far from the Great Wall of China

Gaia Bonini
MCM591
10/31/17

N

0 100

Kilometers

Tufts Data Lab