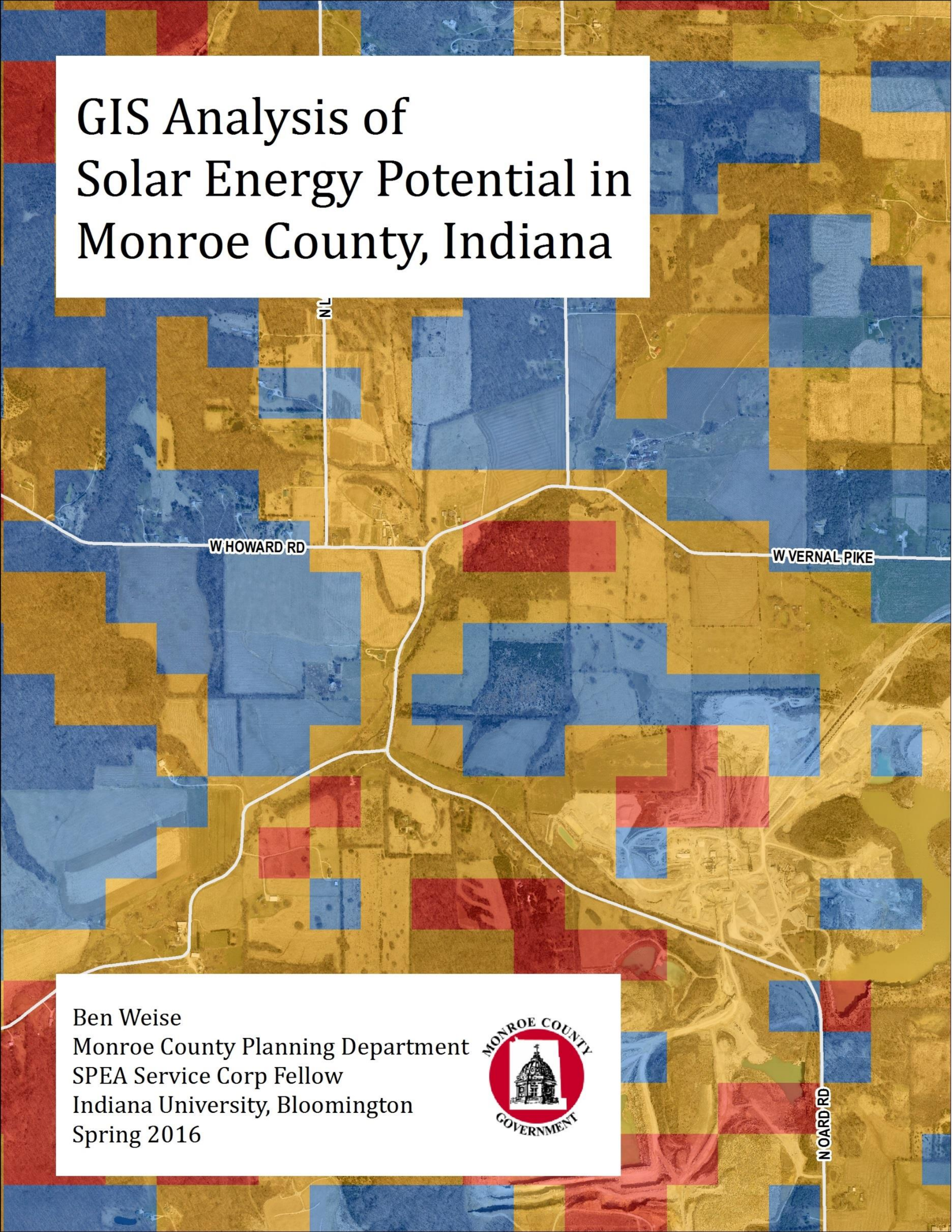

GIS Analysis of Solar Energy Potential in Monroe County, Indiana

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Purpose of Study

The purpose of this study is to identify the potential suitability of solar panel installation within Monroe County and to provide guidance on areas most suitable for large-scale or small-scale panel installation. Utilizing the Solar Radiation analyst tools from the ArcGIS Spatial Analyst toolbox and a digital elevation model, we generated a map that quantifies the amount of solar potential that falls within the county. We categorized solar panel potential across the county in three classes: areas that are suitable, less suitable, and unsuitable.

This project is by Ben Weise, a graduate student in Natural Resource and Environmental Management at Indiana University, Bloomington, and in conjunction with the Monroe County Planning Department. Ben currently holds a Service Corp Fellowship with the Planning Department as an Environmental Policy Analyst. Ben would like to thank Planning Department staff, and County GIS Coordinator Kurt Babcock, for their guidance on this project.

Background Information

Renewable energy technology, specifically solar panels, are improving in efficiency and availability to residents of the United States. In December 2015, the federal budget included a provision that extended the renewable tax credit system, increasing incentives for the construction of renewable energy systems. With a significant barrier of cost of construction now reduced, demand is expected to increase for solar panel installations. The incentives for residents to utilize solar technology ranges from reducing household reliance on fossil fuels to reducing home energy costs long term.

Recently, the Monroe County Commissioners and the Monroe County Planning Department passed ordinance amendments to promote renewable energy technologies in the form of solar energy and solar photovoltaic panels by defining and regulating solar farms. This report builds off the research conducted to create those ordinance amendments. Ultimately, this report seeks to provide a tool to Monroe County residents interested in incorporating solar panel systems into their home, business, or land.

Determining solar panel suitability of a particular site involves a combination of external factors. These factors include, but are not limited to: slope, tree and vegetation cover, and climate. When conducting a site visit to determine suitability, a contractor will start by noting the direction the house, roof, or hill is facing. South facing structures and hills are the best to build on in the Northern Hemisphere as the angle of the sun gives more direct sunlight to these conditions. West facing slopes and hills are also suitable for solar panels because they produce energy when it is needed most. After determining direction, the contractor can use a variety of tools to determine suitability. One such device is a photovoltaic installer's tool. The tool has a reflective surface that is placed where a potential solar panel would go to determine how much available light and shade occur at a particular position. The contractor then takes pictures of the reflection and later analyzes these images and computes how much blockage occurs because of telephone lines, trees, etc. With this information, the contractor presents the customer with their final determination. Typically, changes can be made to improve the suitability of a site. For instance, trees can be trimmed, or in extreme cases, moved or cut down. Based on industry research, solar contractors will recommend a site for solar panel installation if it could generate at least **70%** of the solar potential that a comparable, unshaded and unobstructed property would generate.

Project Data

We used LiDAR data from 2010 to complete our analysis. This data was collected in April 2010 by a contracted business for use by the Monroe County Government to support the county's stormwater utility initiative. LiDAR, or Light Detection and Ranging, is acquired by placing a laser on the wing of an airplane and flying over a specified location at a certain height. The laser then emits and receives thousands of laser pulses per second for the purpose of calculating the distance to an object, in this case the surface of Monroe County. This LiDAR data, in the format of a 3D terrain model, was converted using ArcGIS 3D Analyst into a digital elevation model (DEM) that produces a raster representation of the county. Despite not being in the jurisdiction of Monroe County Planning Department, the incorporated areas of Bloomington and Ellettsville are included in this model. Both the DEM and LiDAR data have a resolution of ~29000 m^2 (171m x 171m) or 7.5 acres per raster tile. The 2010 data is still representative of the county today. The purpose of this study is to inform Monroe County residents interested in solar photovoltaic system about the potential and feasibility on their property. However, this tool is not meant to replace a full scale analysis and any conclusions reached using this tool are subject to assumptions, related to weather, shade and correct operation of panels. Any resident interested in solar power should consult with a solar specialist.

Project Design

Utilizing the Solar Radiation analyst tools within the ArcGIS Spatial Analyst toolbox and the DEM Data, we modeled solar potential across the county for the calendar year 2015. The tool derives incoming solar radiation to a raster dataset, or a matrix of values of points and slopes. This tool models the path of the sun, relative to the geographic coordinates within the dataset, and calculates the amount of solar radiation that lands on a surface. The tool produces an output of a new raster layer that ties floating points to each DEM cell. These points have an output in the units of watt hours per square meter per duration of time (Wh/m^2/time). In other words, this tool calculates the amount of sunlight that would fall on a particular location in the county for a specified time period. With our DEM data resolution of 171m x 171m, we created 36,060 unique cells that each have a value in $Wh/m^2/yr$ representing the total solar potential that would occur in 2015.

We chose to calculate <u>annual</u> solar radiation, rather than monthly totals, because we concluded that an annual solar radiation map would be more beneficial to citizens and private industry. Annual values fluctuate minimally while the monthly values fluctuate greatly due to seasonality. Given the size of the solar radiation for a calendar month or year, we decided to convert the data into more manageable scale of units. We converted the output of $Wh/m^2/yr$ to kilowatt-hour per meter squared ($kWh/m^2/yr$). Using the Times tool in the Math Toolset of the Spatial Analyst Toolbox, we multiplied the raster layer by 0.001, since there are 1000 watts in 1 kilowatt. To arrive at a $kWh/m^2/day$ estimate, we divided the data set by the number of days in a year.

With each output created, we needed a way to classify the data for display. After collecting information from solar installers, contractors, and providers throughout the state of Indiana, we decided on the following breakdown. Current technology in photovoltaic panels yields an efficiency of 15-18%. This means that a solar panel operating unobstructed in ideal conditions (south facing, flat, clean, etc.) will typically capture 15%-18% of the available solar radiation. Using the Times tool again, we multiplied the data set by 0.165 to represent the average efficiency of 16.5%. Research from the solar industry also yielded that typically, solar contractors will *not* recommend a project be implemented if the solar radiation captured at a site is 70% or less of a comparable, unshaded and unobstructed site. For our purposes, we chose a comparable site to mean the best site in the county, i.e. the site with the most solar potential. We then displayed our data on a map using the classification ranges of 0-70%, 70%-80%, and 80%-100%. These ranges were chosen to represent various recommendations to those interested in solar power on their property. While our model does not account for shade or obstructions, the model is a good generalization of county conditions.

- 0-70%
    - Property in these ranges are <u>unsuitable</u> for solar panels because they often occur on the north side of hills. It is important to remember that these estimates are before any site assessment which will help determine loss of solar potential due to shading and other obstructions.
- 70%-80%
    - Property in these ranges are <u>less suitable</u> for solar panels. Property owners in these ranges should consult solar contractors and providers to get an estimate of solar loss due to shade and obstructions. With marginal obstruction like little to no tree cover, these sites and projects may still be suitable.
- 80%-100%
    - Property in these ranges are <u>suitable</u> for solar panels. Projects in these ranges should consult solar contractors and providers to get an estimate of solar loss due to shade and obstructions. With major obstruction like significant tree cover, these sites and projects may still be suitable.

The methodology described here follows other, similar projects and research throughout the world such as Kausika et al. (2015) in the Netherlands, Santos et al. (2014) in Spain, and Li et al. (2015) in San Francsico, CA. Full citations can be found in the References section of this document.

Screenshots of discussed ArcGIS tools are shown in the Appendix.

Results and Discussion

Maps are included in the Appendix of this document. The maximum amount of solar radiation that could possibly be collected in the best possible sites in Monroe County is 1707 kWh/m^2/year. Given current technological constraints, this means roughly 281 kWh/m^2/year could be collected at the most suitable sites. This then sets our categorizations as stated above at 0 – 196 kWh/m^2/yr (Red on the map), 197 – 225 (Yellow), and 226 – 281 (Blue). These categorizations represent an ideal unobstructed, unshaded site and only rely on LiDAR and DEM data. Loss of solar potential can occur across all sites due to cloud cover and haze and on some sites because of tree cover. This model favors sites on south-facing slopes as shown on Figure 3 in the Appendix. Further analysis and site visits will need to occur to fully determine if solar photovoltaic panels are suitable on a specific property.

As an example, Figure 3 shows specific parcels within the county that demonstrate all three classes of suitability. The most suitable portion of this parcel occurs on a south-facing hill, as directly opposed to the unsuitable portion of the parcel that is the very steep, north-facing slope. Based on our analysis, if solar panels were properly installed and maintained on this property, the parcels in blue would yield 226 kilowatt-hours per meters squared of electricity in one year while the area in red would receive 195 kilowatt-hours per meters squared of electricity in one year. The areas of the parcel in yellow would receive anywhere from 205-217 kWh/m^2 of electricity in one year.

From our data source, we know that there are 34,421 Raster Cells with a resolution of 562.25 ft by 562.25 ft or ~171 m x 171 m. Of these 34,421 cells representing 411.32 mi^2, 29,933 cells receive 70% of the maximum available solar that could be collected. In land area, this is nearly 352 mi^2. These sites range from less suitable to suitable. Further, 10,131 cells receive 80% or greater of the maximum available solar that could be collected. In land area, this is nearly 109 mi^2. These sites are suitable for solar panels and could represent opportunities to be further explored. Our analysis also shows that only 4,488 cells, or 57 mi^2, are unsuitable for solar panels. Figure 1 in the Appendix is a representation of this data.

It is important to note that these calculations do not exclude sites that may not be able to accommodate solar power installations such as lakes, ponds, rivers, etc. Further, these calculations and interpretations run on a number of additional assumptions: weather does not interfere (cloud cover not considered), the panels are fully operational and always clean, and that there is no shade interference.

Theoretically, if we covered the entire county in solar photovoltaic panels, and 1) there are no shade obstructions and 2) there is no cloud interference, we could potentially collect ~868 gigawatt-hours per meters squared per yet (GWh/m^2/yr) of usable energy in one year. If we covered areas in the 70%+ classification, we could generate 768 GWh/m^2/yr in one year. If we covered areas in the 80%+ classification, we could generate annually 262 GWh/m^2/yr. <u>In comparison, in 2012 residents and industry in the City of Bloomington (in Monroe County) used 1,501 GWh/m^2/yr.</u>

Though it is not realistic to cover the entire county with solar panels, this analysis does illustrate that solar photovoltaic panels could be incorporated and make a significant contribution as a non-renewable energy source. Our report concludes that nearly three-quarters of the county is suitable for solar panels. Many Monroe County residents have the opportunity to reduce their energy costs and support renewable energy by implementing solar panels where suitable.

Future Steps

This project is the first of its kind to inform Monroe County residents about solar photovoltaic potential within Monroe County. As such, there are various directions for this project moving forward. Certainly the map layer that shows solar potential should be prepared for integration into the county web map, already available online and free to Monroe County residents.

Future analysis could focus on lands currently owned or managed by the Monroe County and examine the solar suitability of those sites. Primarily this could focus on lands that lay idle like on Superfund sites. Other analyses could look at lands at the Monroe County airport, publicly owned parking lots, and other public owned/maintained lands.

Appendix

Figure 1. Solar Potential in Monroe County

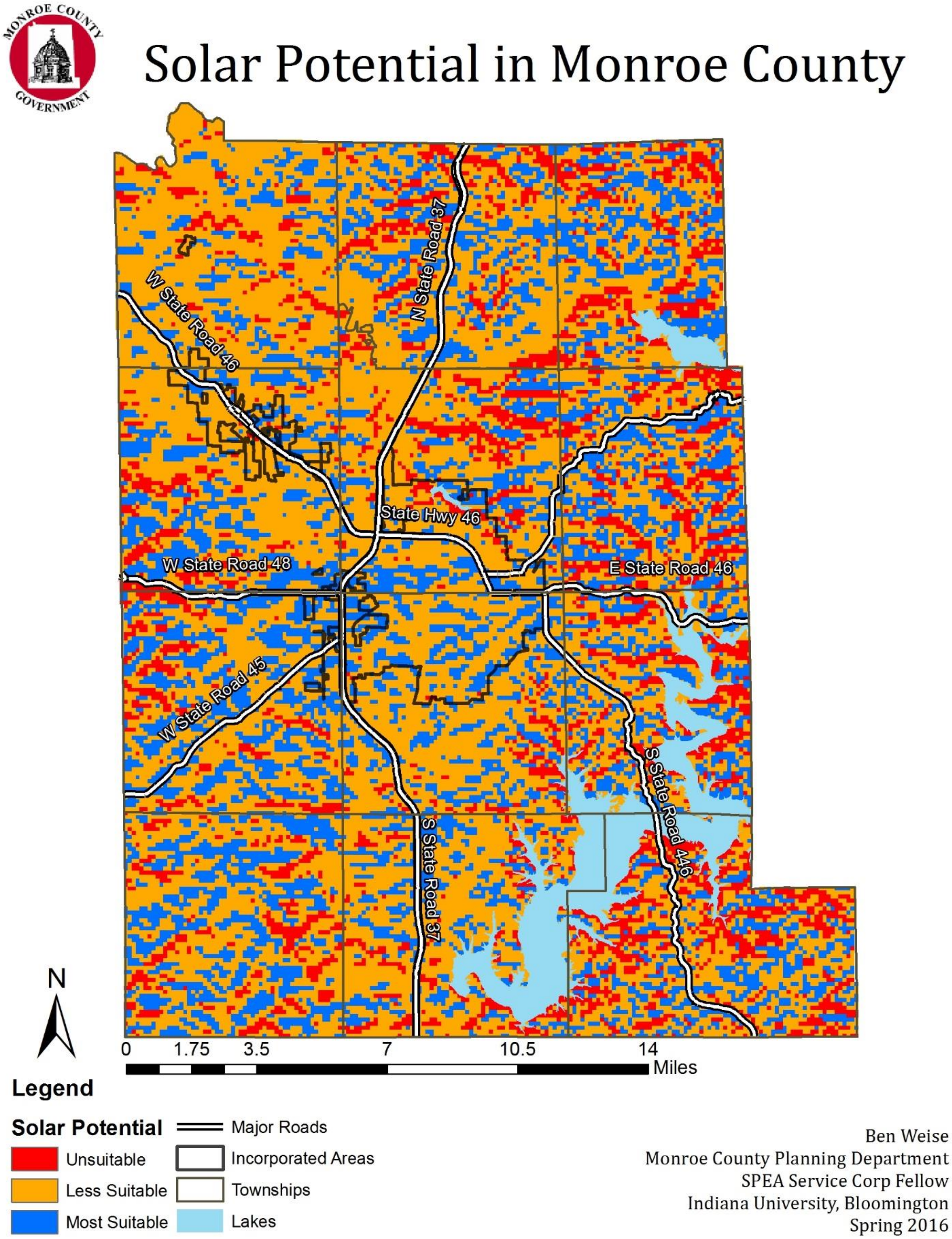


Figure 2. Solar Potential at scale of property parcels

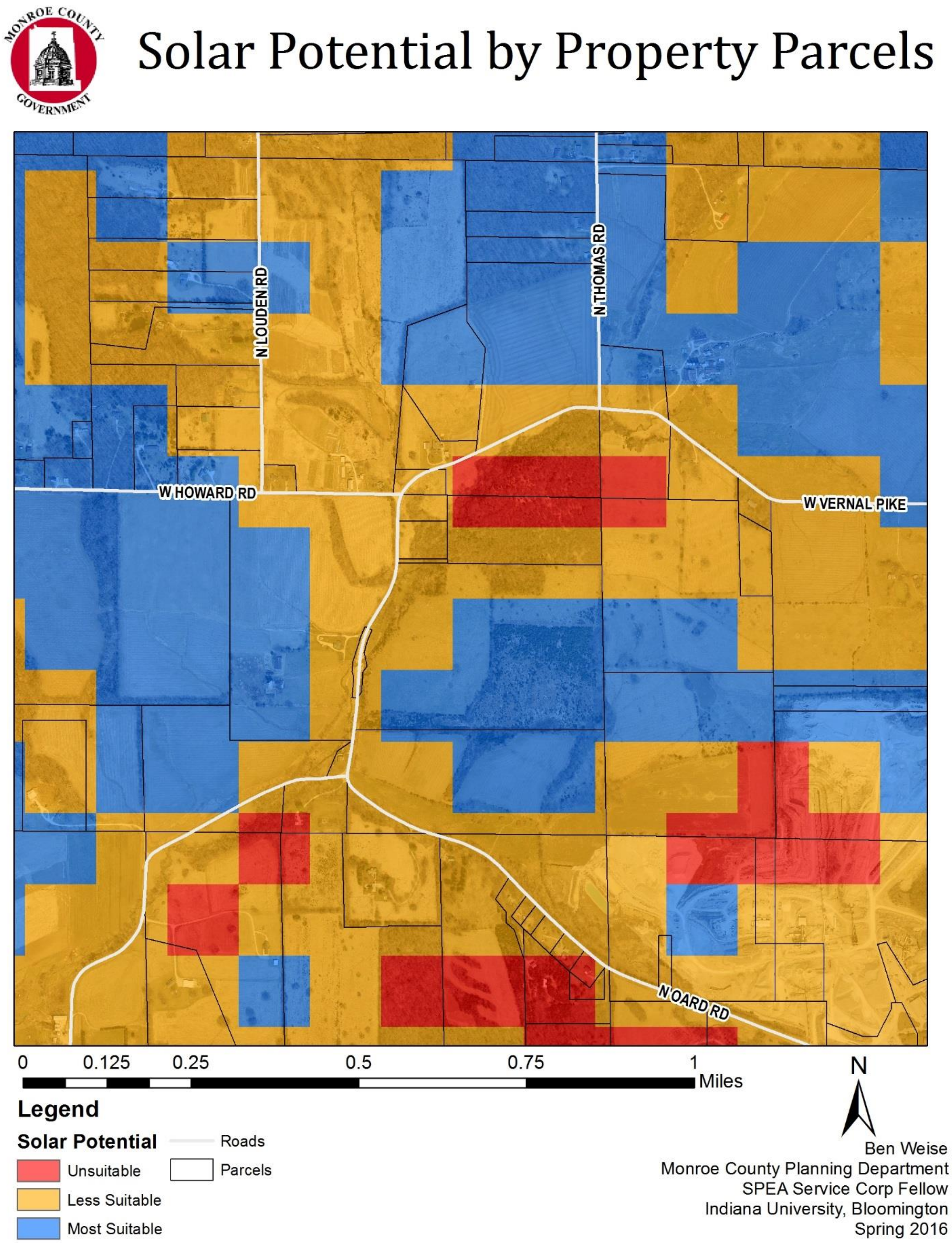


Figure 3. Solar Potential at property scale with contours

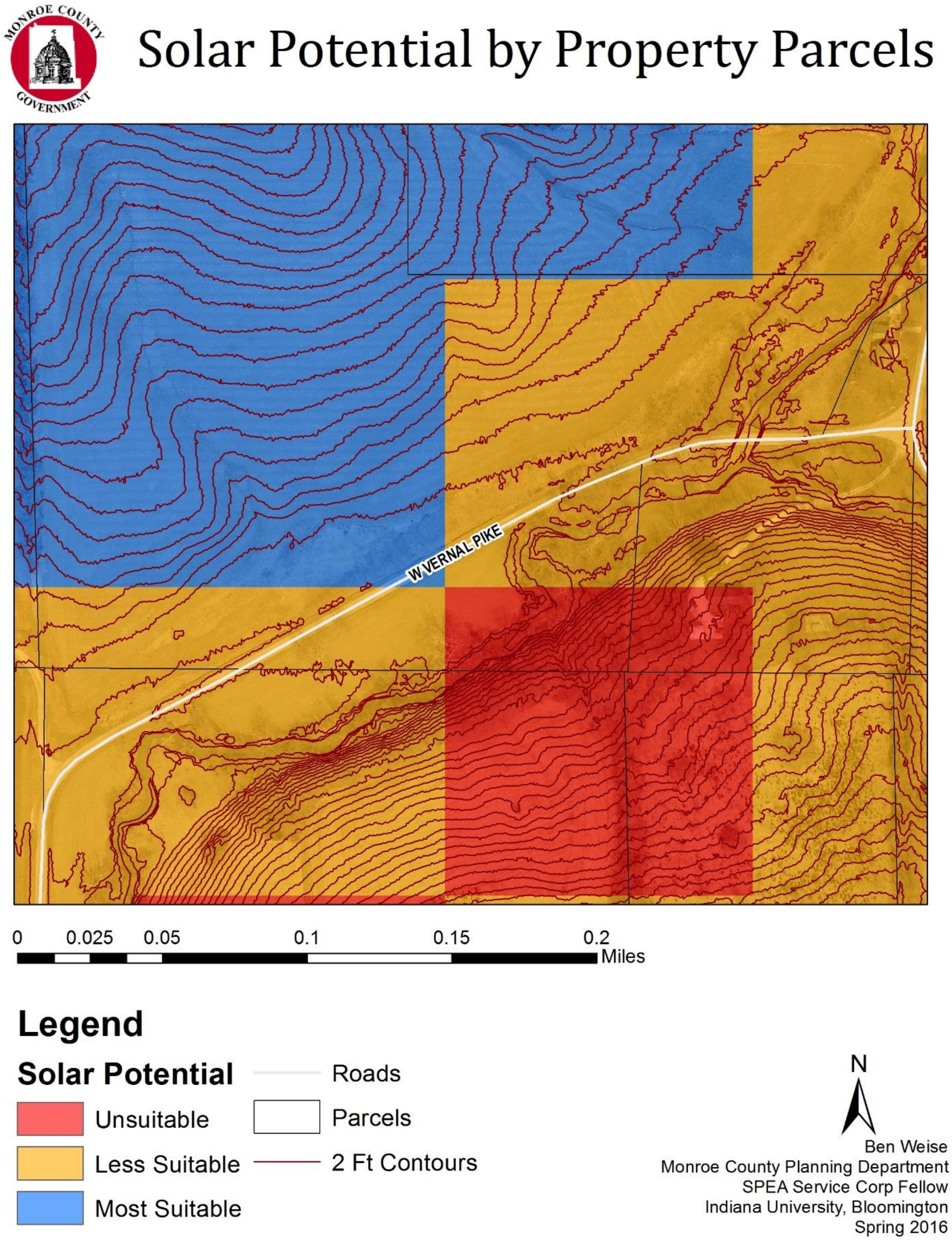


Figure 4. Histogram of Raster Cell Counts by Solar Potential Integer

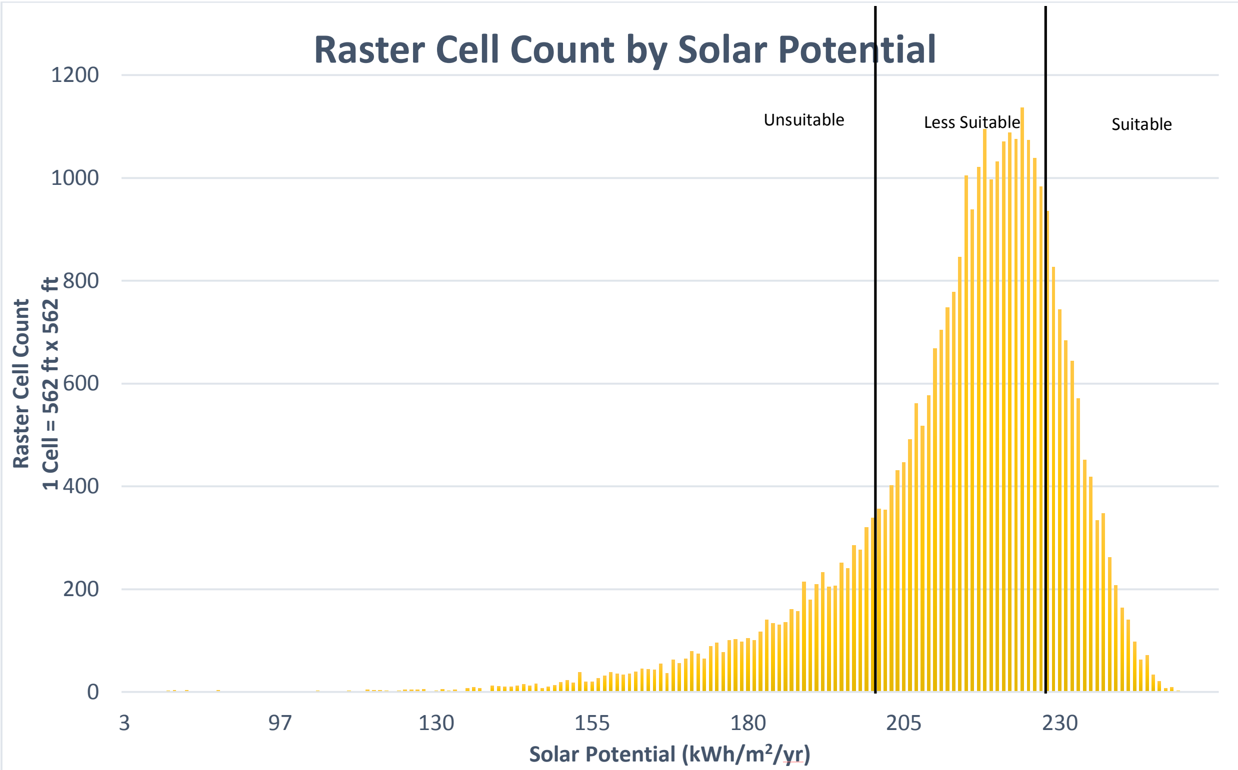


Figure 5. An example of solar panel installations in Monroe County taken near Lake Lemon on December 10, 2015

Figure 6. Solar Radiation Tool in ArcGIS Spatial Analyst

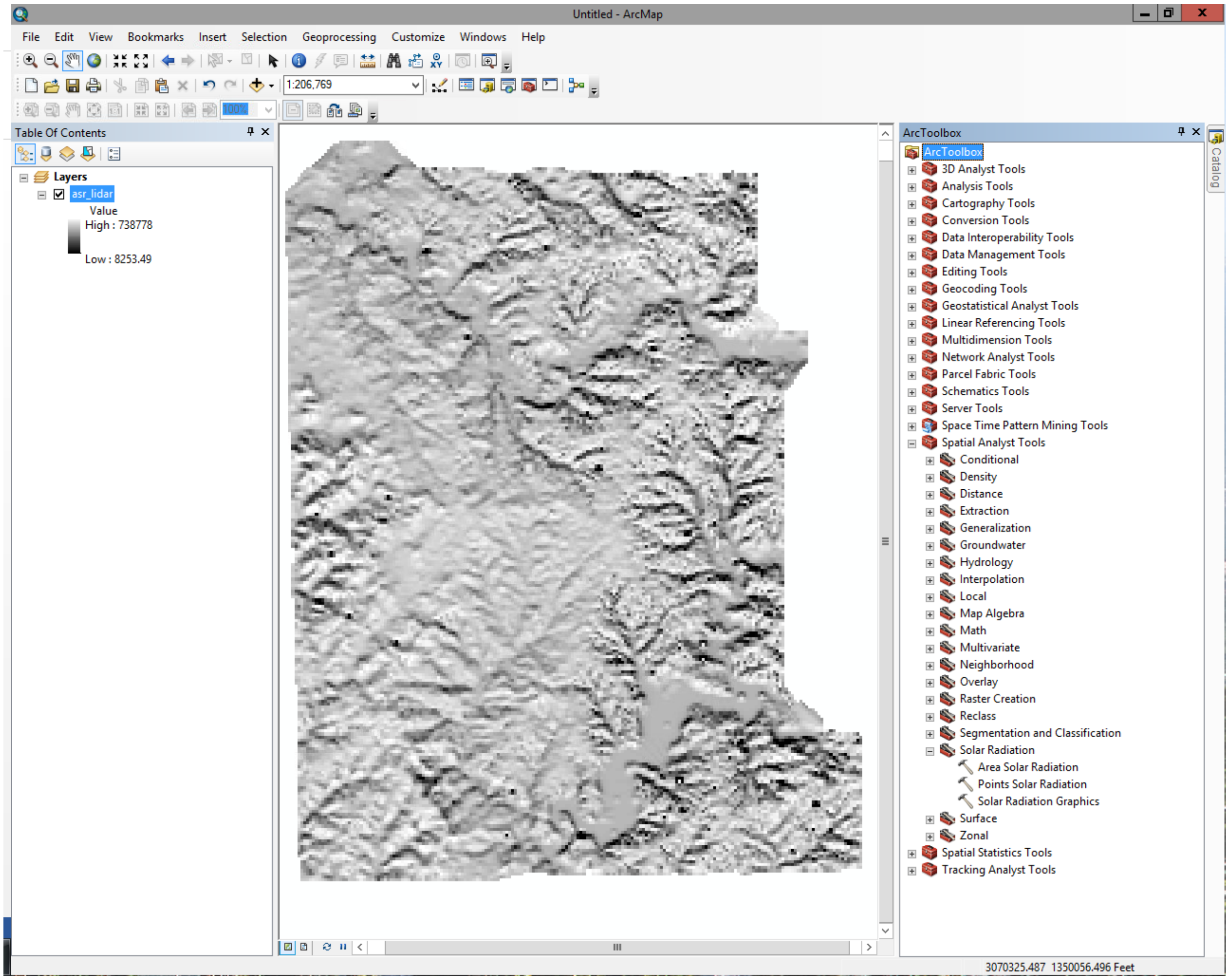


Figure 7. Area Solar Radiation Tool Command Box

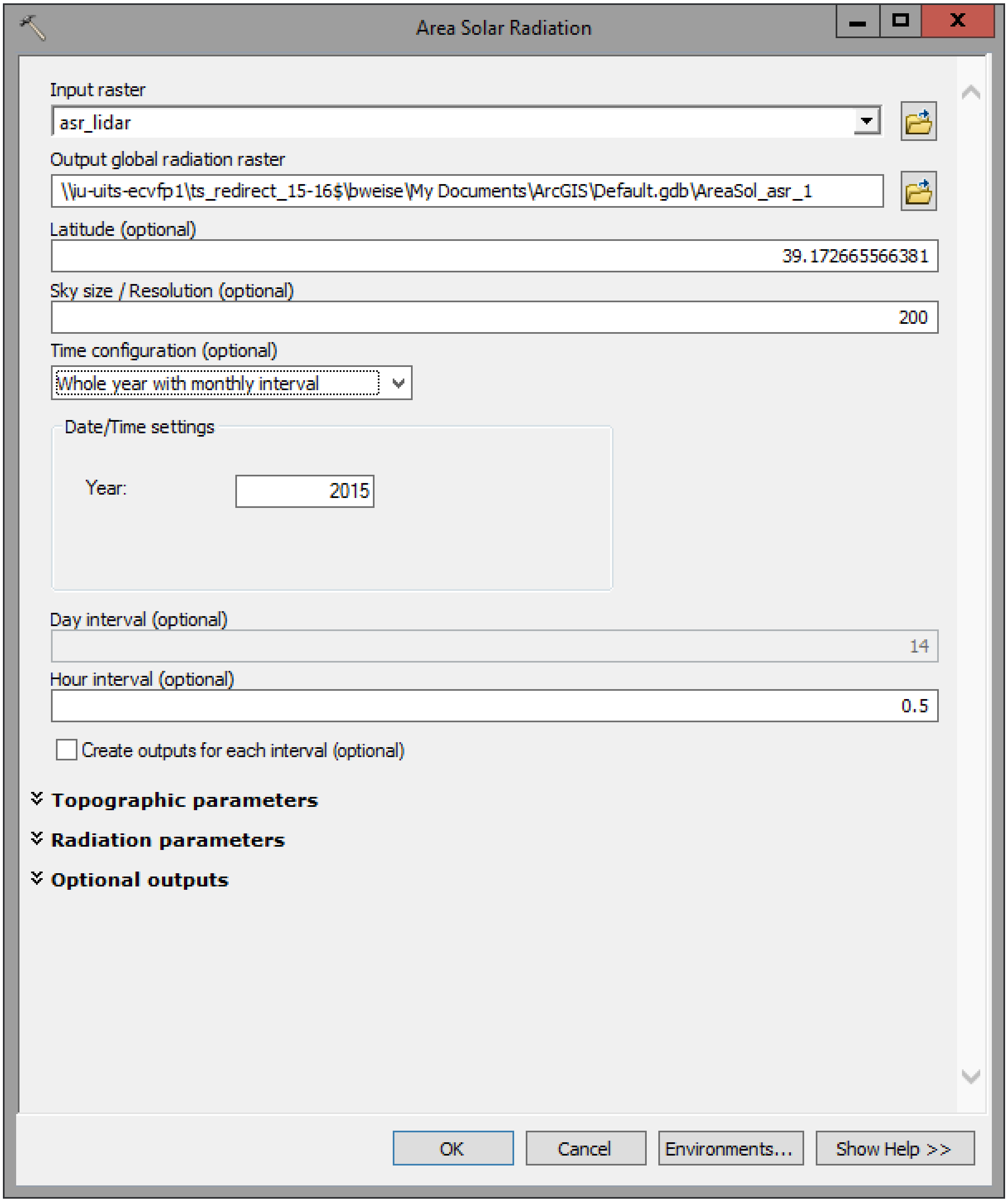
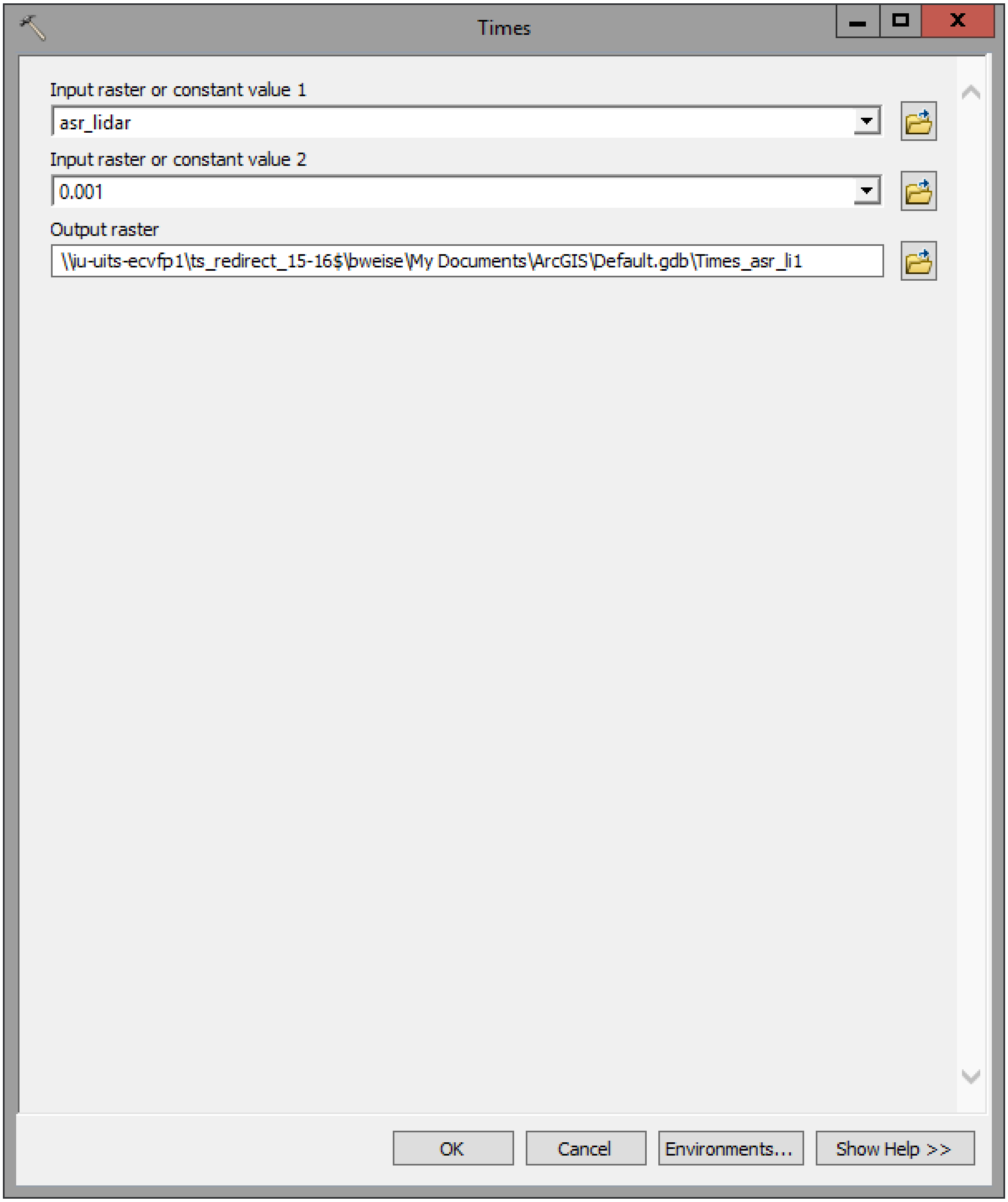


Figure 8. Times (Multiplication) Tool Command Box



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