Technical Details for the updated Iowa Solar Asset Mapping (ISAM) Application and Database

University of Northern Iowa GeoInformatics Training, Research, Education, and Extension Center

Funding from Iowa Economic Development Authority, Iowa Energy Center

June 9, 2024

Project Summary:

The University of Northern Iowa (UNI) GeoInformatics Training, Research, Education, and Extension (GeoTREE) Center, located in the UNI Geography Department received funding from the Iowa Economic Development Authority, Iowa Energy Center in 2021 to develop a database of modeled solar radiation values and a public facing web mapping application/portal on top of that database. The resulting database and application are titled the Iowa Solar Asset Mapping (ISAM) tool. This project led to an update to previously modeled solar radiation data in 2016 based on more recently collected topographic data.

The GeoTREE Center leveraged computing resources within the UNI Geography Department to carry out the big data processing exercise necessary to model solar radiation for the entire state of Iowa. The GeoTREE Center leveraged the Solar Radiation Modeling tools in ArcGIS Pro software along with the most recent Iowa statewide LiDAR topography data. Automated methodologies were developed to distribute computing tasks to 30-40 computers in the GeoTREE Center and the UNI Geography computing lab. The resulting modeled monthly and annual solar radiation and other products totaled multiple terabytes of data.

The GeoTREE Center updated the public facing web mapping application/portal for display and interrogation of the modeled solar radiation modeling results. The application has features for searching for addresses, interactively drawing an area of interest in order to derive statistics on the solar radiation modeling, and choice of base maps (imagery, streets).

Warning: The ISAM tool is provided as a basic screening tool for investigating solar potential. It provides a rough estimate of solar potential. It absolutely should not replace a site assessment by a qualified solar professional who can provide a thorough assessment of specific site solar potential.

Glossary:

As a reference, a few relevant definitions are provided. The source for these definitions is https://www.nrel.gov/grid/solar-resource/solar-glossary.html .

- **Insolation or solar irradiance** - The amount of solar energy that arrives at a specific area of a surface during a specific time interval (radiant flux density). A typical unit is W/m^2.

Methodology:

The ArcGIS Pro 3.1 Area Solar Radiation tool (link) was used to model incoming solar radiation across Iowa for every square meter on a monthly and annual basis. The Area Solar Radiation tool is based on methods developed by Rich et al. (1990, 1994) and further developed by Fu and Rich (2000, 2002). The GeoTREE Center carried out testing in order to develop efficient processing routines to break the state into manageable portions for processing huge data volumes. After defining the general processing routine, Python and arcpy were developed and used to distribute tasks to computers in the GeoTREE Center and the UNI Geography computing lab in order to carry out the thousands of hours of data processing necessary. The general processing steps that were carried out for thousands of separate chunks of the state were:

- Download raw LiDAR .las data
    - LiDAR is a remote sensing technology that captures detailed information from the surface of the earth (ground, trees, buildings, etc. – see Figure 1) by emitting laser light from an airplane and recording time to return. In Iowa, from approximately 2019-2021, LiDAR data was collected for the entire state. These data formed the basis of this project.

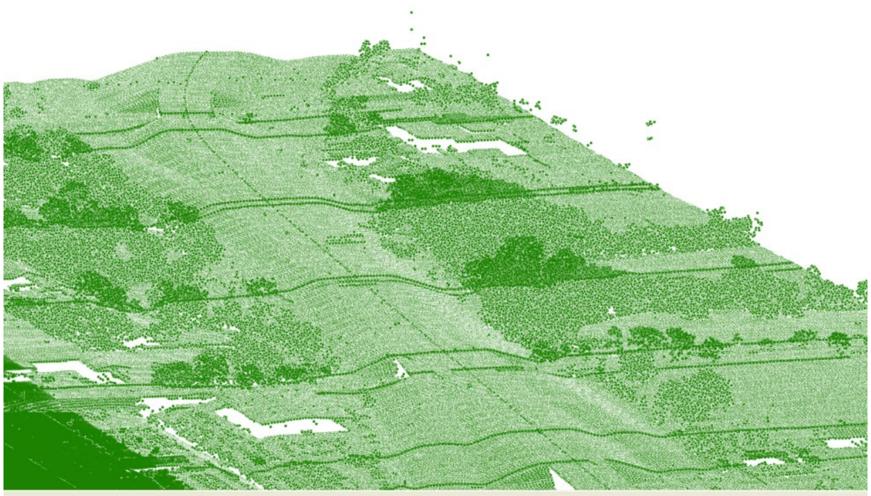


Figure 1: An example of a LiDAR point cloud dataset.

- Through arcpy/Python geoprocessing tools were automated to
    - Download raw LIDAR data (.laz) files from United States Geological Survey
    - Convert to .las files
    - Create LAS Dataset
    - Interpolate a Digital Surface Model (DSM) from LAS Dataset
    - Carry out Area Solar Radiation tool with following parameters
        - Latitude derived from DSM
        - Neighborhood sky size = 200 m
        - Run for Whole Year with Monthly Interval
        - Year = 2022
        - Time interval for sky sector = 14 days

    - Time interval through the day = 0.5
    - Calculation directions = 32
    - Zenith Divisions = 8
    - Azimuth Divisions = 8
    - Diffuse modeltype = Uniform Sky
    - Diffuse proportion = 0.3
    - Transmissivity = 0.5
- Carry out manual quality control checks to look for anomalies usually coming from raw LIDAR data
- Fix issues and rerun process. The main problems discovered were that some of the LiDAR tiles had to be reprocessed to remove outlier points.

The Area Solar Radiation tool estimates total insolation as sum of diffuse and direct radiation. An overview of the solar radiation tools in ArcGIS Pro can be found [here](). The tool calculates a hemispherical viewshed based on the topography (DSM derived from LiDAR data). This basically means for every location the algorithm looks around (360 degrees broken into 32 sections) to see if there are any trees, buildings, or other objects that are blocking potential sunlight. The viewshed is combined with estimated direct sun and diffuse sky maps for the different time periods to come up with an estimated insolation which are then aggregated to monthly and annual totals for each location (Figure 2). The output raster GIS contains an estimated total radiation in watt hours per square meter (WH/m^2) for every location.

The figure below depicts the calculation of a viewshed for one cell of a DEM. Horizon angles are calculated along a specified number of directions and used to create a hemispherical representation of the sky. The resultant viewshed characterizes whether sky directions are visible (shown in white) or obstructed (shown in gray). The viewshed is shown overlaid on a hemispherical photograph to demonstrate the theory.

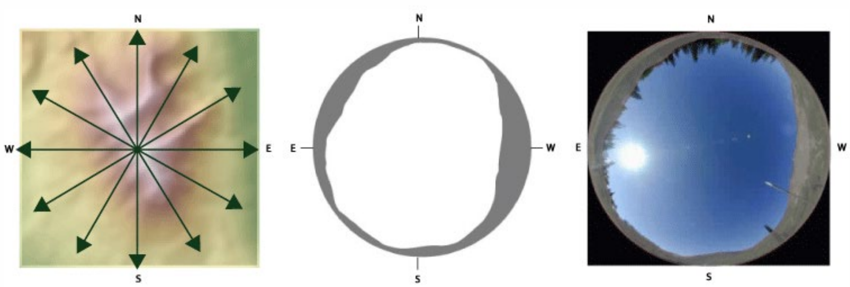
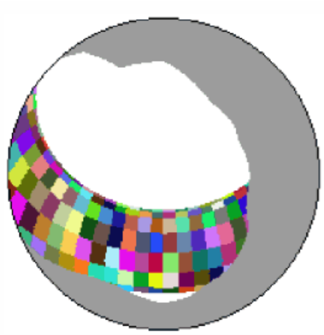
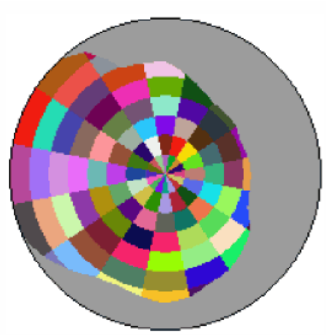


Illustration of the horizontal angles, resultant viewshed, and viewshed mapped onto sky view



Overlay of viewshed with sun map example



Overlay of viewshed with sky map example

Figure 2: Diagrams used to illustrate how the Area Solar Radiation tool works including hemispherical viewshed (top) and the sky and sun maps (below). Taken from ESRI at https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/modeling-solar-radiation.htm .

Results:

The modeling resulted in estimated solar radiation for every 1 sq. meter location in Iowa on a monthly basis and annually. The modeled results are provided publicly via the web mapping application for which a user could visit any location in the state to investigate potential solar resources. In addition, the modeled solar radiation data and also Intermediate data products (Digital Surface Model – DSM) are provided for Geographic Information Systems (GIS) uses via GDAL virtual raster (VRT) files which allow users to seamlessly visualize and analyze data across the state. The links are provided below:

- DSM VRT
- Solar Radiation VRT

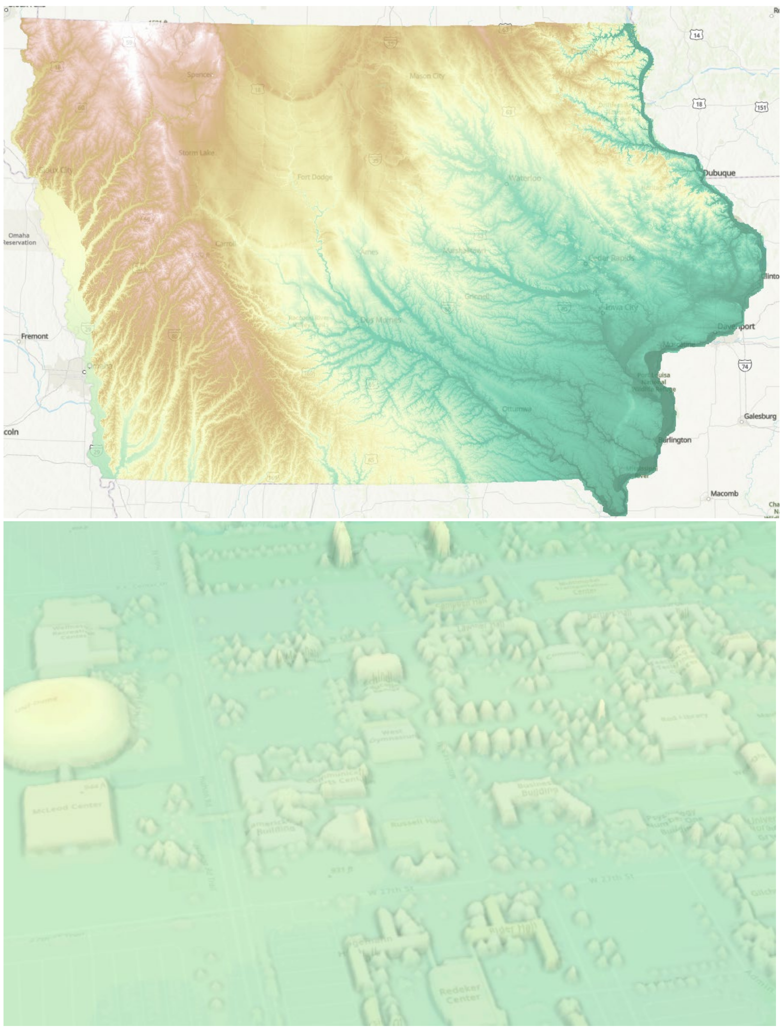


Figure 3: Statewide DSM VRT's displayed in ArcGIS Pro after download from above links – at a state level and a portion of UNI campus.

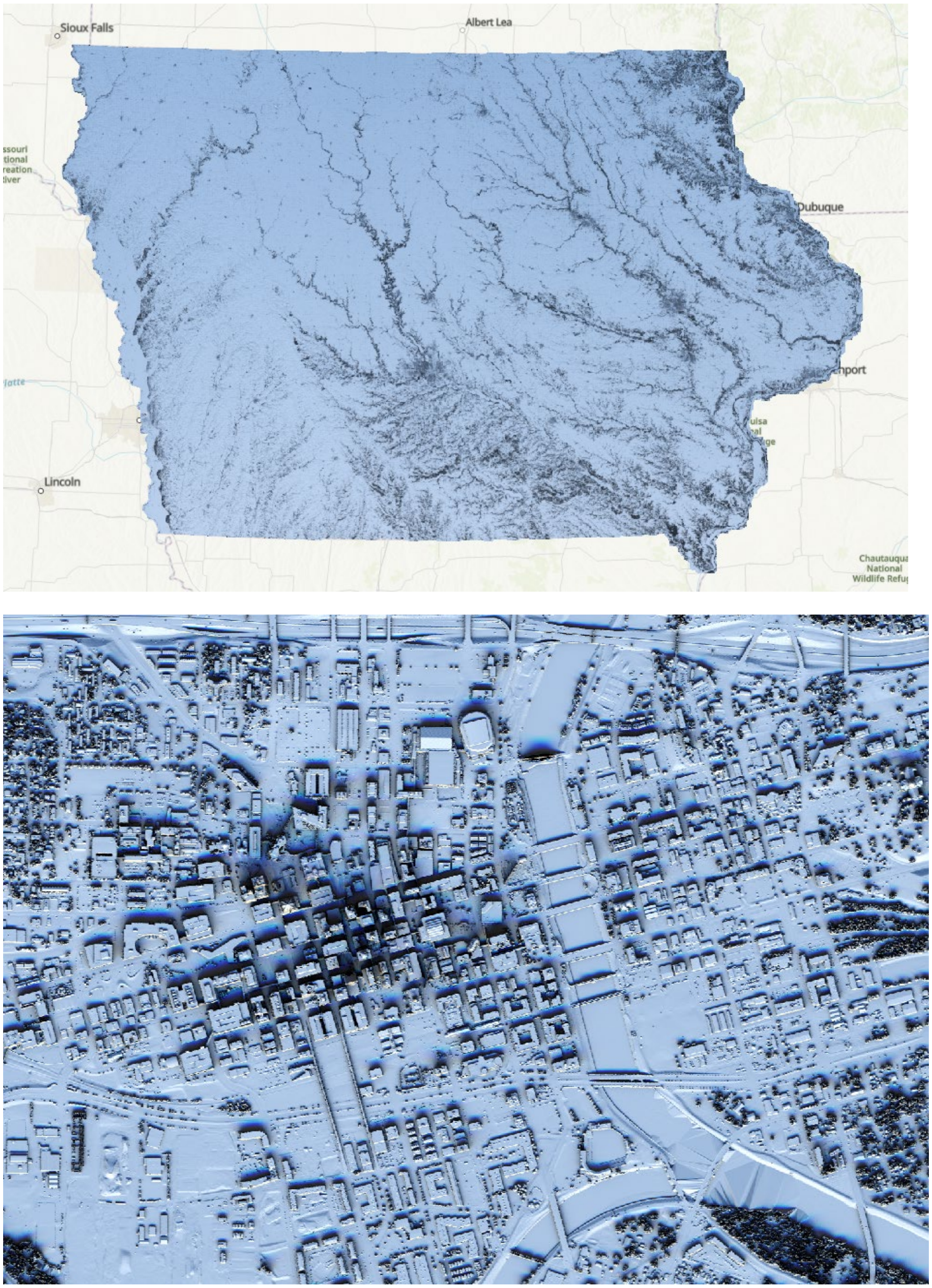


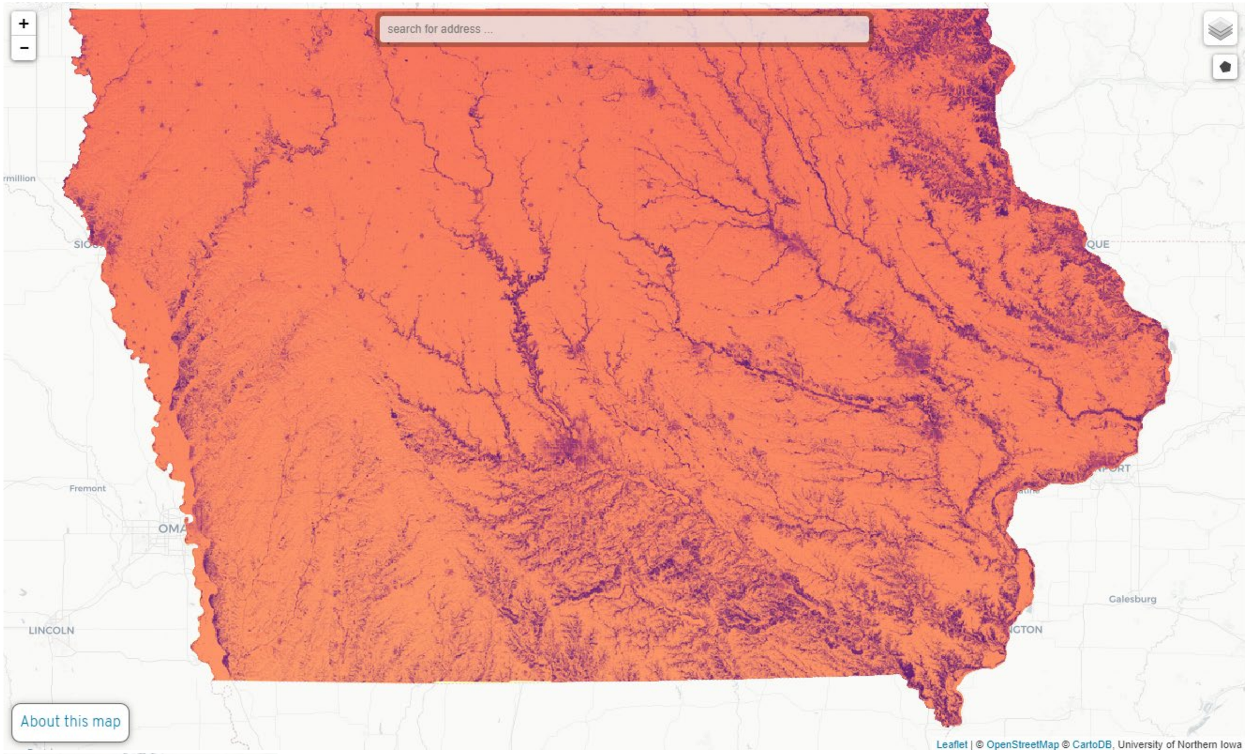
Figure 4: Modeled solar radiation at a state level and for part of Des Moines, Iowa.

The web mapping application/portal called Iowa Solar Asset Mapping is built on top of the solar radiation modeling results. The web mapping application provides the following capabilities:

- Display of annual modeled solar radiation results
- Base map choice between streets (source: www.openstreetmap.org) or aerial imagery (http://ortho.gis.iastate.edu)

- Address search capabilities
- Capability for user to draw an area of interest in order to calculate statistics from the modeled solar radiation results
- Publicly available building footprints (outlines/polygons) were compiled (~2022) from publicly available sources such as https://www.iowagisdata.org/ or directly from local government sources. These ~950,000 are added to ISAM as an overlay to the solar radiation modeling. When the user is zoomed in to a city level user can select a building footprint to calculate statistics from modeled solar radiation results.
- When statistics are calculated in the two ways above, they are presented in a popup which displays a graph of modeled monthly solar radiation (kwh), as well as average annual modeled solar radiation (kwh/m^2), total area (m^2), and total solar radiation for the whole area for the whole year (kwh).
- Finally, in the popup a link to Google Street View is created and when clicked will open that Google Street View link in a new tab. **Warning:** The link that is generated is based on the location clicked. If there is not Street View imagery available from Google close to there no imagery will be available in the link.

Figures 5 through 9 provide illustrations of the ISAM web portal.



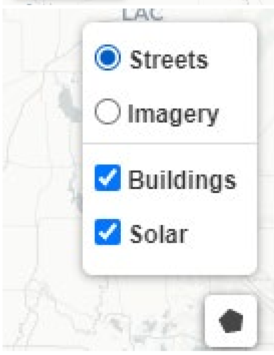


Figure 5: The ISAM web mapping portal. In the upper right corner is the layer control for turning on/off the base layers (Streets, Photo) and the solar radiation modeling results (solar) and building footprints (only visible when zoomed into city level). The  tool allows the user to click and draw an area of interest to derive statistics. See Figure 7.

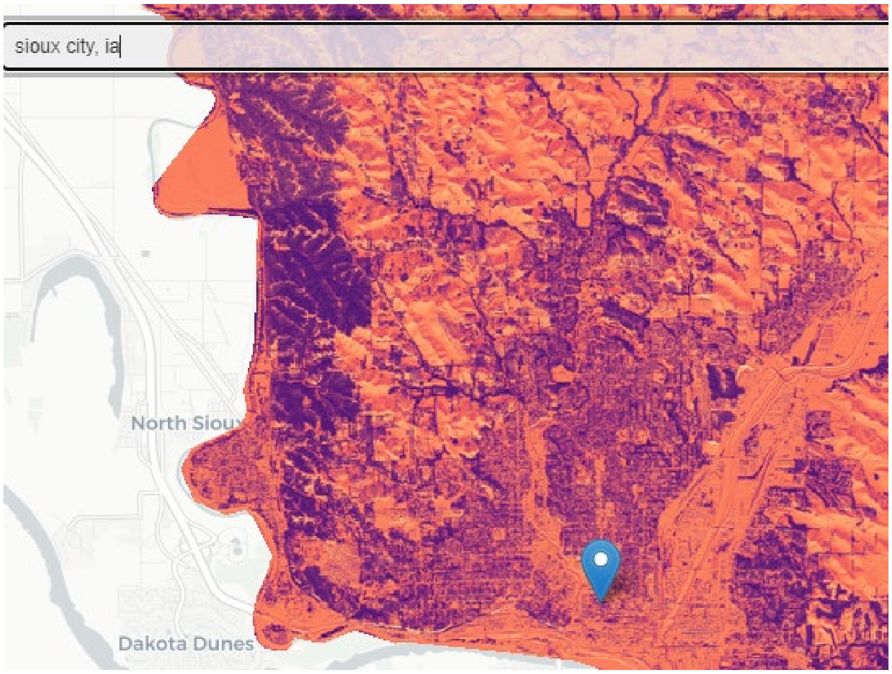
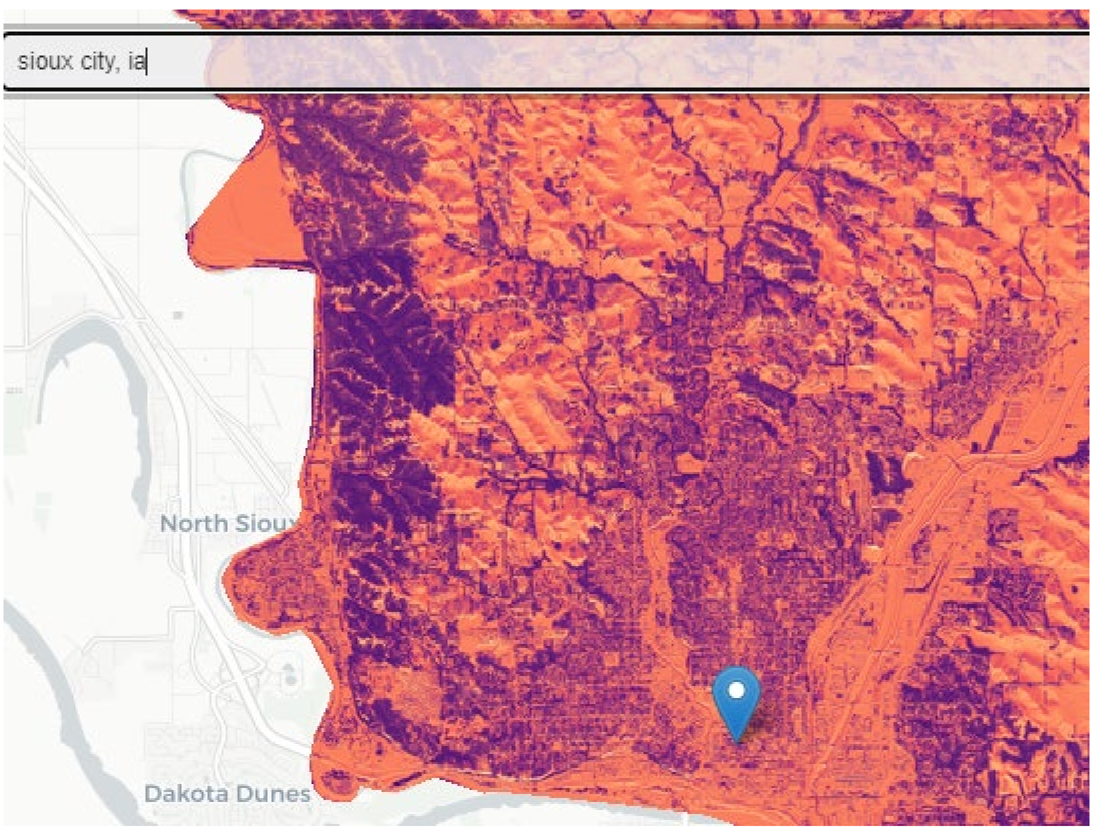


Figure 6: Address search for Sioux City, IA demonstrated.



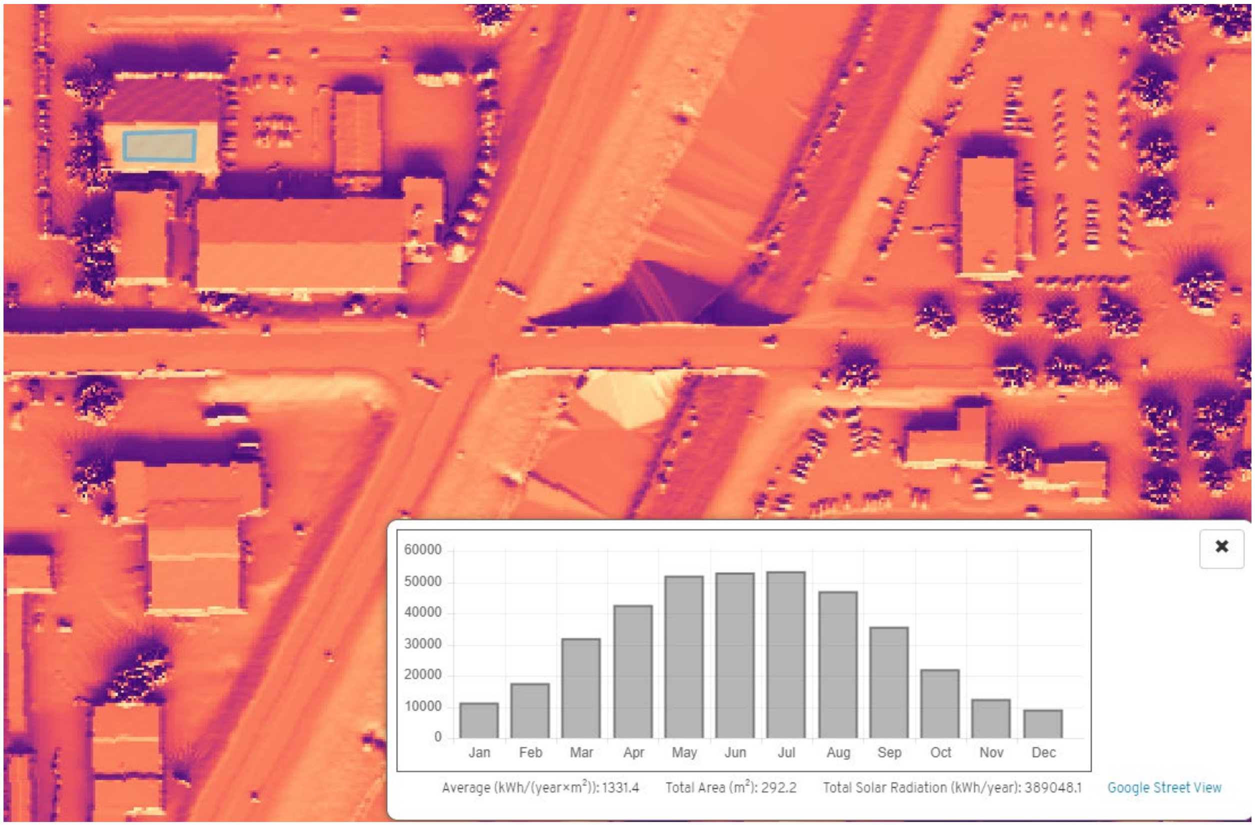


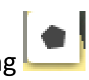
Figure 7: An example of user drawing a polygon area of interest using  and the statistics derived in popup. This example shows an area of interest drawn on an industrial building with a north or south facing roof. This results in an average annual modeled solar radiation of 1331.4 kwh/m^2 for south facing sloped roof and if a similar polygon is drawn on northward facing roof, the value is 930.9 kwh/m^2.

Figure 8: Google Street View link opened from link in popup from Figure 7.

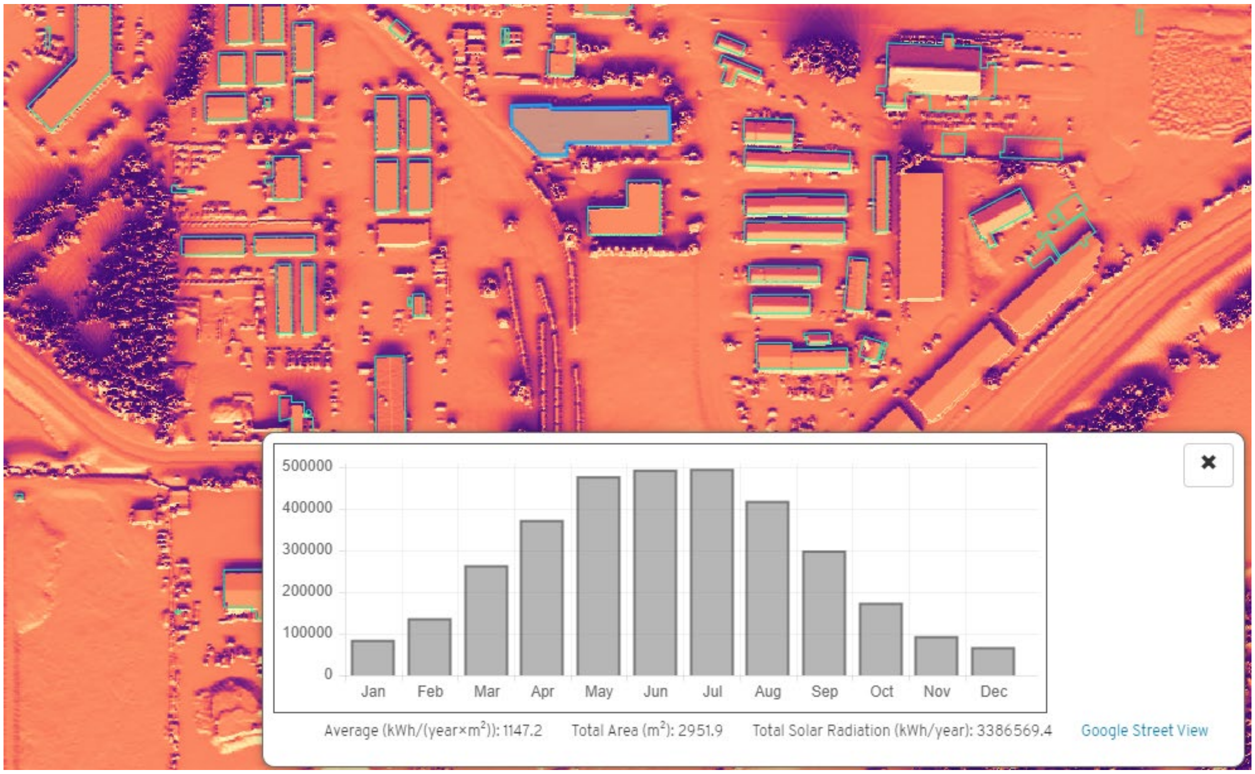


Figure 9: An example of deriving statistics for existing building footprints. In this example, a warehouse type building is chosen in Des Moines area.

Acknowledgements and Contact Information:

This web mapping application and the underlying modeled solar radiation data were produced under a project awarded to the University of Northern Iowa (UNI) GeoInformatics Training, Research, Education, and Extension (GeoTREE) Center in 2021-2023. The project was sponsored by grant funding through the Iowa Economic Development Authority, Iowa Energy Center (Agreement Number: 21-IEC-012). A full description of the procedures used to model solar radiation and more information concerning this web - application can be found by clicking the Detailed Explanation button below.

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Any concerns or questions please contact John DeGroote (Director, GeoTREE Center) at 319-273-6158 or john.degroote@uni.edu.

References:

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