Urban Tree Shade Model and Sun shadow frequency Analysis

Project goals and expected outputs:

Design and implement methods to estimate the shadow surface provided by (a) terrain surfaces (including elevated highways), (b) buildings, and (c) existing tree canopy. The purpose is to conduct the analysis every 10 minutes from sunrise to sunset over a calendar year so that we can use a raster grid to summarize the cumulative hours of shade currently provided by all 6 communities. Dr. John Wilson will specify the methods used and the general characteristics of the data, Yifan Yang will lead the effort to build these methods so we can write papers and improve our description of communities and their greening opportunities.

Manuscript submitted to the journal, describing the methods and values of the output, and the spatiotemporal raster stack we will deploy to further our work, for example, highlighting areas that could be better colored and their ownership status, as well as these candidate sites Whether you currently have a permeable or impermeable surface. These metrics will also be incorporated into the Canopy Scorecard of the Bezos Earth Fund's work over the next year.

Storage of reports, detailed explanation of related code and files.

https://github.com/rayford295/urban_tree_shade_analysis

Session 1, sunrise and sunset times

Sunrise_Sunset_2023_LA:

A file containing the sunrise and sunset time points for Los Angeles throughout the year 2023. The same times are processed into integers.

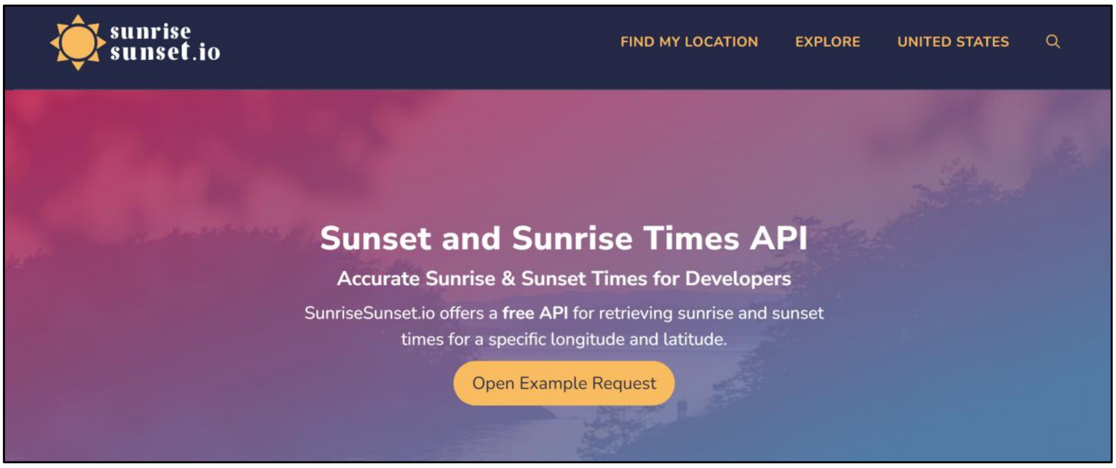
Sunrise_Sunset_Intervals_2023_LA:

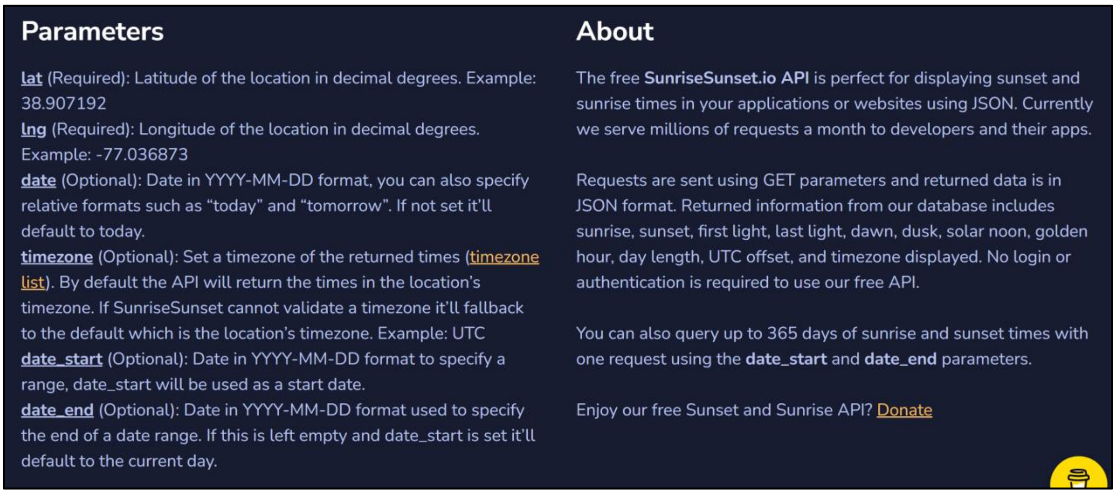
A file containing the sunrise and sunset time points of Los Angeles throughout 2023, and each day is a sheet. There are 365 sheets in total, and they are also divided every 10 minutes. Times are treated as integers.

la_sunset_and_sunrise_time.ipynb:
is a notebook-based python file whose function is to call the API to query and output the sunrise and sunset times at a certain point. This file is to query the time from sunrise to sunset every day in Los Angeles in 2023, and divides it every ten minutes; at the same time, we only take integer times here, for example, 6:54 in the morning will become 7:00, in the morning 6:48 will become 6:50. The same time at night is similar, 6:04 pm will become 6:00 pm.

API selection, official website and usage instructions

https://sunrisesunset.io/api/





Parameters

lat (Required): Latitude of the location in decimal degrees. Example: 38.907192
lng (Required): Longitude of the location in decimal degrees. Example: -77.036873
date (Optional): Date in YYYY-MM-DD format, you can also specify relative formats such as “today” and “tomorrow”. If not set it'll default to today.
timezone (Optional): Set a timezone of the returned times (timezone list). By default the API will return the times in the location's timezone. If SunriseSunset cannot validate a timezone it'll fallback to the default which is the location's timezone. Example: UTC
date_start (Optional): Date in YYYY-MM-DD format to specify a range, date_start will be used as a start date.
date_end (Optional): Date in YYYY-MM-DD format used to specify the end of a date range. If this is left empty and date_start is set it'll default to the current day.

About

The free **SunriseSunset.io API** is perfect for displaying sunset and sunrise times in your applications or websites using JSON. Currently we serve millions of requests a month to developers and their apps.

Requests are sent using GET parameters and returned data is in JSON format. Returned information from our database includes sunrise, sunset, first light, last light, dawn, dusk, solar noon, golden hour, day length, UTC offset, and timezone displayed. No login or authentication is required to use our free API.

You can also query up to 365 days of sunrise and sunset times with one request using the **date_start** and **date_end** parameters.

Enjoy our free Sunset and Sunrise API? Donate

Session 2, 3D modeling data sources and specific information, methodology

Methodology for building 3D models of buildings, freeways and trees

A. Data sources and data preprocessing.
freeway.ship. Highway line data downloaded from the website was converted into polygonal data using buffers and cropped using clipping based on the study area. The polygonal highway shape file of the study area was obtained (buffer diameter is 10 feet, height is 14 feet.).

tree.shp. The data type at the beginning of tree.shp is point. Use buffers to convert data to polygon data. At the same time, according to the attribute table, the tree does not have an exact height, but a height range. We give the tree the same height. The tree's buffer diameter is 3 and its height is 14.

Building.shp. No preprocessing is required, the data itself meets the requirements.

B. Use the 3D Features by Attribute tool.
This tool allows users to create 3D features based on their attribute values. For highway polygons, this might involve generating corresponding 3D geometry based on specific attributes of each polygon feature, such as height or floor information. For example, if each highway polygon has an associated height attribute, this tool can use this height value to convert the 2D highway polygons into a 3D geometry.

C. Use the 3D Layer to Feature Class tool.
After you have generated 3D features using the Features by Attribute to 3D tool, the next step involves saving those 3D features into a new feature class using the Layer 3D To Feature Class tool. This enables further editing, visualization, and analysis of 3D features in ArcGIS Pro. This step ensures persistent storage and operability of the 3D data, enabling users to view and analyze the resulting 3D polyhedra in a 3D view.

Data sources and content:

Lidar Point Cloud (LPC)
Download from USGS
[TNM Download v2 (nationalmap.gov)]

Freeway
Download from koordinates
https://koordinates.com/layer/96008-los-angeles-county-freeways/
This is freeway network data for the Boyle Heights area of Los Angeles. This document records in detail the paths and configurations of all freeways in the area, with each line representing a section of the freeway.

We use buffer to set the lines into polygons, and then use the same height. (The previous planning method was to use DSM-DEM to obtain height data. The results obtained after experiments were not ideal and need to be experimented again. The current method is to set the same height for polygons.) turns this polygon into a cuboid.

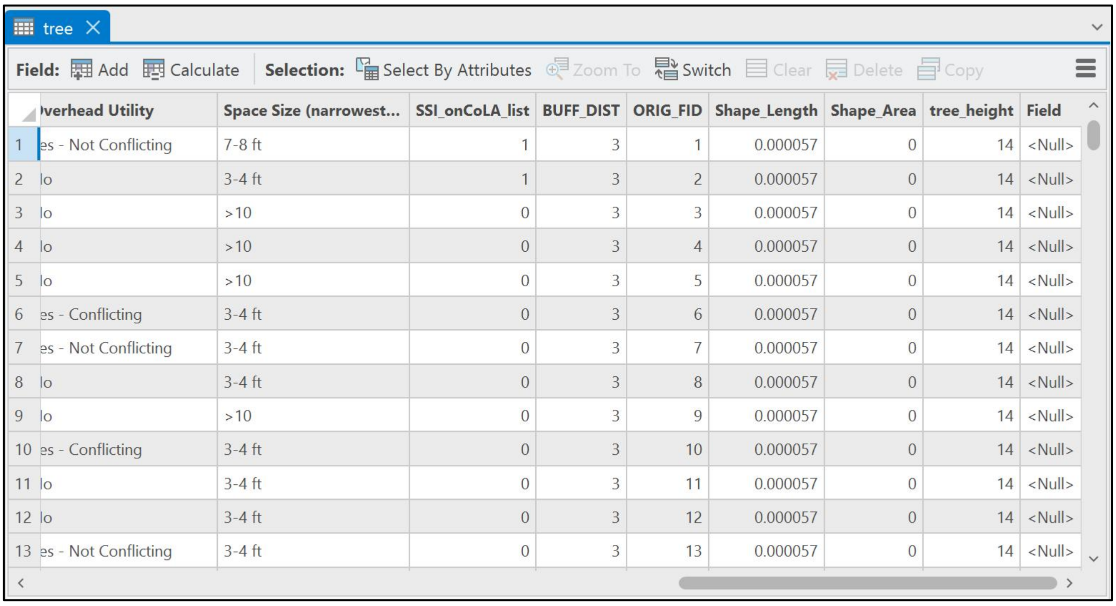
freeway

Field: Add Calculate Selection: Select By Attributes Zoom To Switch Clear Delete Copy

	_F	TYPE	BUFF_DIST	ORIG_FID	Shape_Le_1	OBJECTID	FID	COUNT	AREA	MEAN	height	Field	Shape_Length	S
1	STATE	1110	10	176	97.718821	1	<Null>	4883	4883	330.080279	14	0	97.718821	
2	STATE	1110	10	194	69.098511	2	<Null>	2778	2778	347.903528	14	0	69.098511	
3	STATE	1110	10	209	69.046793	3	<Null>	2776	2776	345.319524	14	0	69.046793	
4	STATE	1110	10	210	128.170165	4	<Null>	7131	7131	346.290843	14	0	128.170165	
5	STATE	1110	10	211	131.713608	5	<Null>	7383	7383	345.146959	14	0	131.713608	1
6	STATE	1110	10	229	82.208344	6	<Null>	3754	3754	334.932339	14	0	82.208344	
7	NARDINO	1110	10	230	93.756517	7	<Null>	4587	4587	334.039241	14	0	93.756517	
8	STATE	1110	10	232	86.185439	8	<Null>	4030	4030	335.425806	14	0	86.185439	
9	NARDINO	1110	10	233	98.287854	9	<Null>	4929	4929	335.261311	14	0	98.287854	
10	NARDINO	1110	10	234	103.479777	10	<Null>	5305	5305	331.962677	14	0	103.479777	
11	STATE	1110	10	236	86.545897	11	<Null>	4049	4049	335.190417	14	0	86.545897	
12	NARDINO	1110	10	237	88.955557	12	<Null>	4231	4231	334.890806	14	0	88.955557	
13	STATE	1110	10	238	86.646616	13	<Null>	4072	4072	334.948919	14	0	86.646616	

The data used for trees and buildings is downloaded from the files in Phase 2. The download file path of these data is below.

Tree
G:\Trees_USC_PX\Phase_2\Data\Data_Final_Working_0522\Trees_BH_only.gdb

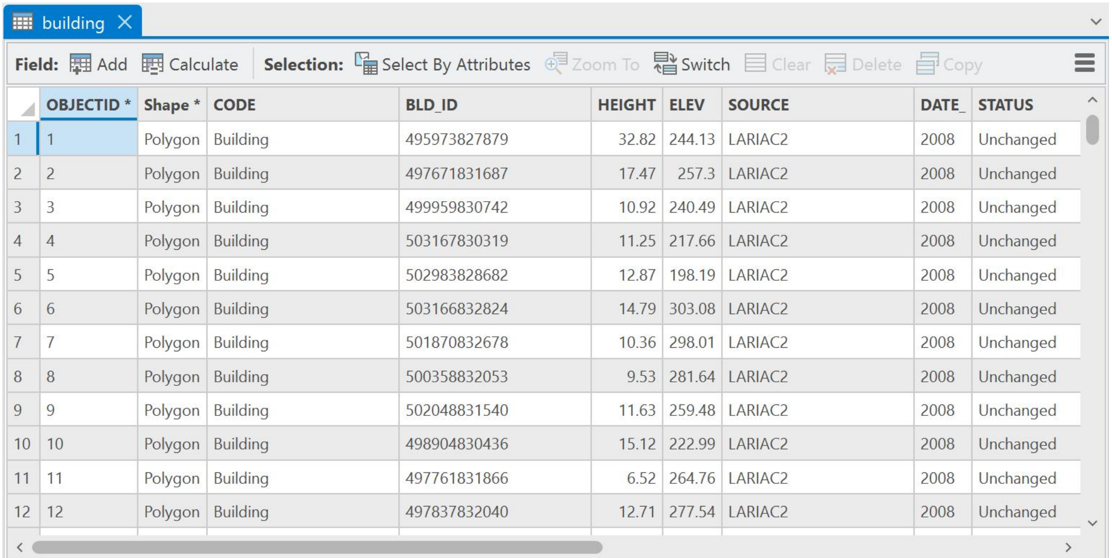


	verhead Utility	Space Size (narrowest...	SSI_onCoLA_list	BUFF_DIST	ORIG_FID	Shape_Length	Shape_Area	tree_height	Field
1	es - Not Conflicting	7-8 ft	1	3	1	0.000057	0	14	<Null>
2	lo	3-4 ft	1	3	2	0.000057	0	14	<Null>
3	lo	>10	0	3	3	0.000057	0	14	<Null>
4	lo	>10	0	3	4	0.000057	0	14	<Null>
5	lo	>10	0	3	5	0.000057	0	14	<Null>
6	es - Conflicting	3-4 ft	0	3	6	0.000057	0	14	<Null>
7	es - Not Conflicting	3-4 ft	0	3	7	0.000057	0	14	<Null>
8	lo	3-4 ft	0	3	8	0.000057	0	14	<Null>
9	lo	>10	0	3	9	0.000057	0	14	<Null>
10	es - Conflicting	3-4 ft	0	3	10	0.000057	0	14	<Null>
11	lo	3-4 ft	0	3	11	0.000057	0	14	<Null>
12	lo	3-4 ft	0	3	12	0.000057	0	14	<Null>
13	es - Not Conflicting	3-4 ft	0	3	13	0.000057	0	14	<Null>

Building

File name: LARIAC5_BUILDINGS_2017

G:\Trees_USC_PX\Phase_2\Data\Countywide_Building_Outlines_2017.gdb\d9210d3a80194defb2d4381409341a85.gdb



	OBJECTID *	Shape *	CODE	BLD_ID	HEIGHT	ELEV	SOURCE	DATE_	STATUS
1	1	Polygon	Building	495973827879	32.82	244.13	LARIAC2	2008	Unchanged
2	2	Polygon	Building	497671831687	17.47	257.3	LARIAC2	2008	Unchanged
3	3	Polygon	Building	499959830742	10.92	240.49	LARIAC2	2008	Unchanged
4	4	Polygon	Building	503167830319	11.25	217.66	LARIAC2	2008	Unchanged
5	5	Polygon	Building	502983828682	12.87	198.19	LARIAC2	2008	Unchanged
6	6	Polygon	Building	503166832824	14.79	303.08	LARIAC2	2008	Unchanged
7	7	Polygon	Building	501870832678	10.36	298.01	LARIAC2	2008	Unchanged
8	8	Polygon	Building	500358832053	9.53	281.64	LARIAC2	2008	Unchanged
9	9	Polygon	Building	502048831540	11.63	259.48	LARIAC2	2008	Unchanged
10	10	Polygon	Building	498904830436	15.12	222.99	LARIAC2	2008	Unchanged
11	11	Polygon	Building	497761831866	6.52	264.76	LARIAC2	2008	Unchanged
12	12	Polygon	Building	497837832040	12.71	277.54	LARIAC2	2008	Unchanged

BH_study area

G:\Trees_USC_PX\Phase_2\Data\Routes\Elementary School Routing\BH Elementary School Routes\BH_ES_Routing_Inputs_March2023.gdb

Session 3, Shadow area calculation, usage analysis of Sun Shadow frequency tool, and process automation.

Methodology

Determine the Urban Tree Shade Coverage

To calculate the contribution of tree shade to the overall shaded area within an urban environment using ArcGIS Pro, we follow a systematic approach utilizing raster calculations. Here's how the process unfolds:

Initial Terrain and Freeway Shade (A):

We start by calculating the shade contributions from the natural terrain and the freeways. This involves creating a 3D model of the terrain and overlaying the freeway infrastructure. Utilizing the Sun Shadow Frequency Analysis tool, we analyze the frequency and extent of shadows cast by the terrain and freeways across a specified time period. This gives us a baseline shadow coverage raster (A) which reflects the areas shaded without considering buildings or vegetation.

Adding Building Shade (B):

Next, we incorporate the buildings into our model. Using the same parameters and time period, we calculate the shadows cast by the buildings, combined with the existing shadows from the terrain and freeways. This results in a comprehensive shadow coverage raster (B) that includes both the natural and built environment.

Calculating Building Shade Contribution:

To isolate the shade contribution from buildings alone, we perform a raster calculation where we subtract the initial shadow coverage (A) from the comprehensive shadow coverage (B). The result is a raster that represents the additional shaded areas solely attributed to buildings.   Building shade = B - A

Incorporating Tree Shade (C):

We then add trees to the 3D model and repeat the shadow frequency analysis. This produces a new shadow coverage raster (C) that includes the combined effect of terrain, freeways, buildings, and now trees.

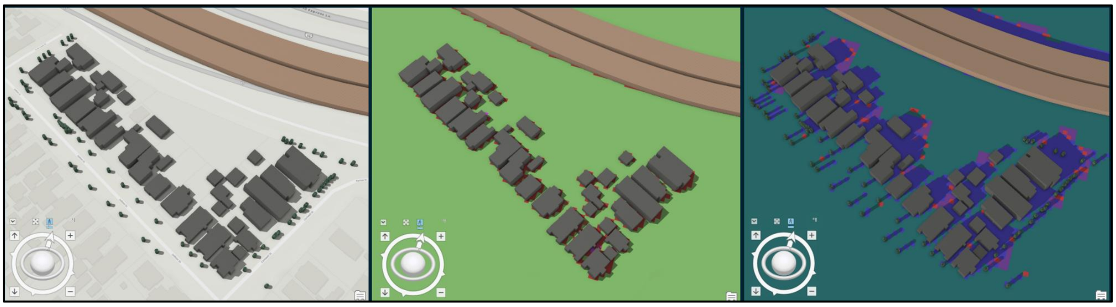
Calculating Tree Shade Contribution:

Finally, to determine the specific contribution of tree shade, we conduct another raster calculation. Since raster (C) contains the total shade with trees and raster (B) contains the total shade without trees, we subtract the cumulative shade without trees (A + B) from the total shade with trees (C). This calculation yields a raster that highlights the areas where tree shade is present. **Tree shade = C - (A + B)**

The shade contributed by the tree = (tree + freeway + building) - (freeway + building)

The shade area contributed by the tree = {(tree+freeway+building)-(freeway+building)} × area of the unit grid (square of side length)

This raster calculation method effectively isolates the individual contributions of various elements to the overall shade in an area, allowing urban planners and environmental analysts to understand and visualize the impact of vegetation on urban microclimates, particularly the beneficial cooling effects provided by tree shade.



Sun Shadow Frequency
Sun Shadow Frequency (3D Analyst)—ArcGIS Pro | Documentation
https://pro.arcgis.com/en/pro-app/latest/tool-reference/3d-analyst/sun-shadow-frequency.htm
https://community.esri.com/t5/arcgis-pro-questions/sun-shadow-frequency-general-questions/td-p/1277231

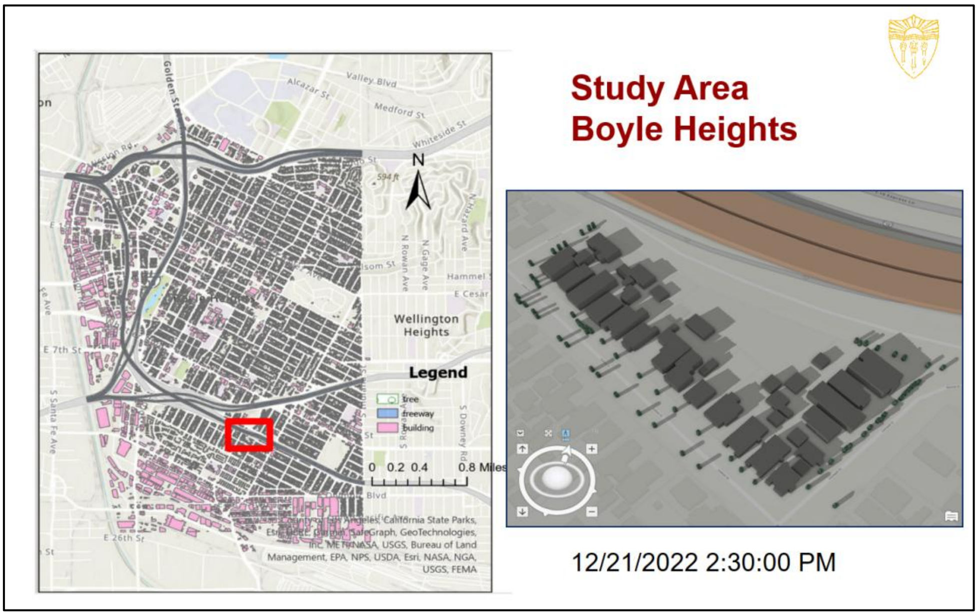
Input (Obstruction) Features:
3D Trees & 3D Buildings & 3D freeway(**multipatch**)

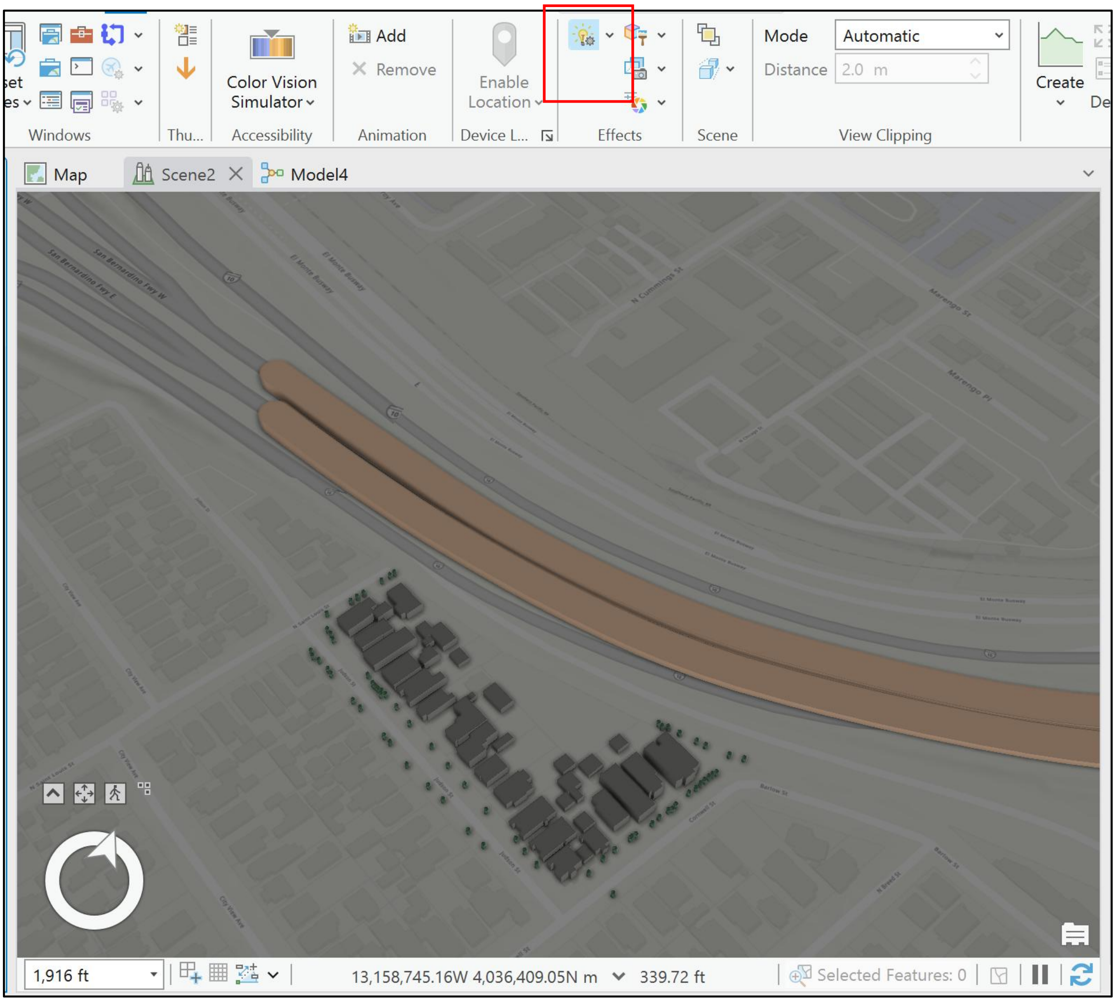
Ground Surface:
https://elevation3d.arcgis.com/arcgis/services/WorldElevation3D/Terrain3D/ImageServer
https://www.arcgis.com/home/item.html?id=3af669838f594b378f90c10f98e46a7f%2F1000

ft	1.5 foot	0.46	Cook County, Illinois, USA	ISGS	United States
	1 meter	1	Partial areas of the conterminous United States, Puerto Rico	USGS	United States
	1 meter	1	Partial areas of the conterminous United States	NRCS USDA	United States
M	3 meters	3	Partial areas of the conterminous United States	FEMA	United States
ond	0.000030864197530866 degrees	3	Partial areas of the conterminous United States	USGS	United States
	5 meter	5	Alaska, United States	USGS	United States
ond	0.000092592592593 degrees	10	conterminous United States, Hawaii, Alaska, Puerto Rico, and Territorial Islands of the United States	USGS	United States
d	0.0002777777777779 degrees	31	conterminous United States, Hawaii, Alaska, Puerto Rico, Territorial Islands of the United States; Canada and	USGS	United States

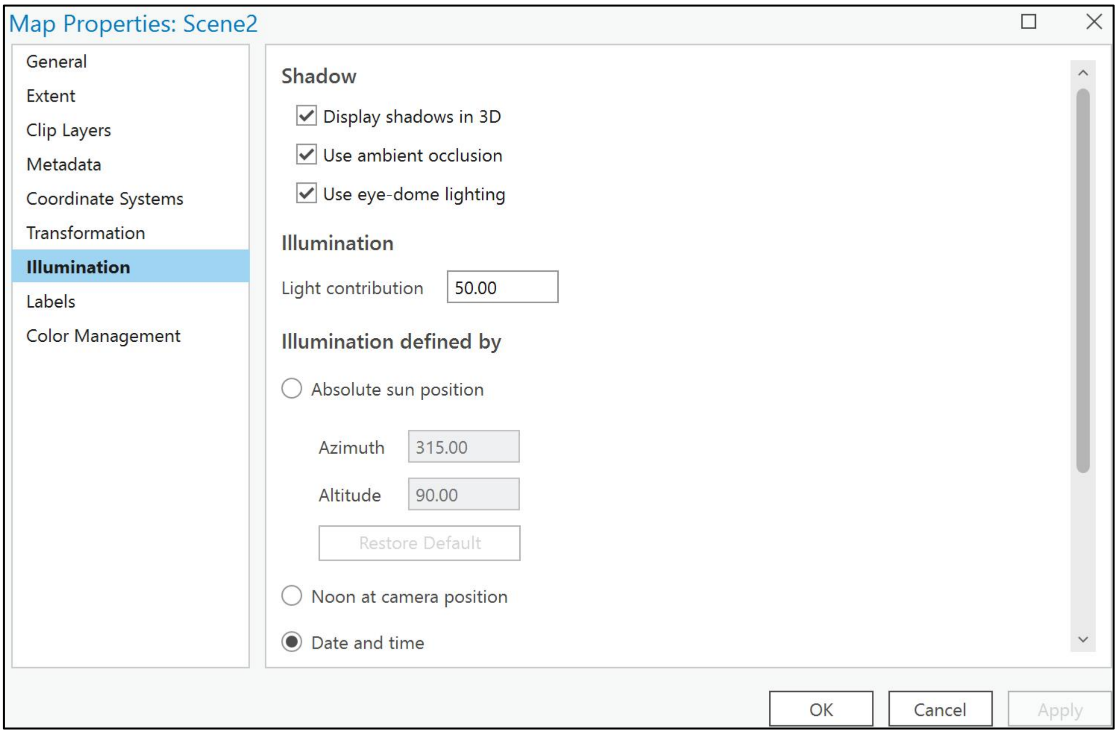
Output Cell Size: 10feet
Time Interval: 10mins
Start & End time:
The start and end time settings need to refer to the session1 file, which details each time interval - this will create an output with a binary output (0 or 1 hour of shading coverage)
For example.
Start Time: 4/1/2023 @ 7:00:00 AM (sunrise)
End time: 4/1/2023 @ 7:10:00 AM

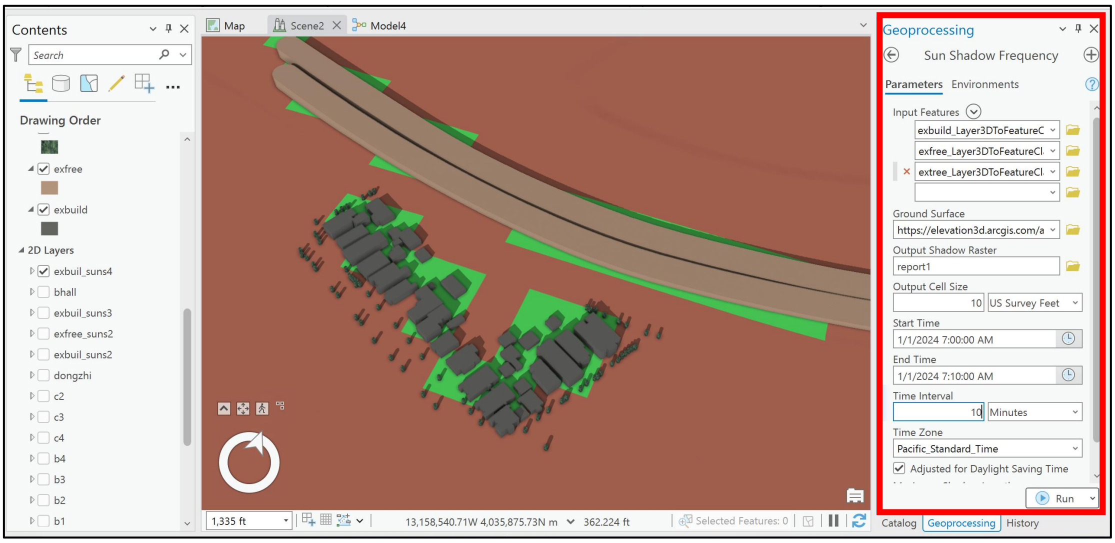
The research area where I did the neighborhood experiment was clipped from BH. It has no boundaries, only the clipped shapefiles of buildings, freeways and trees.



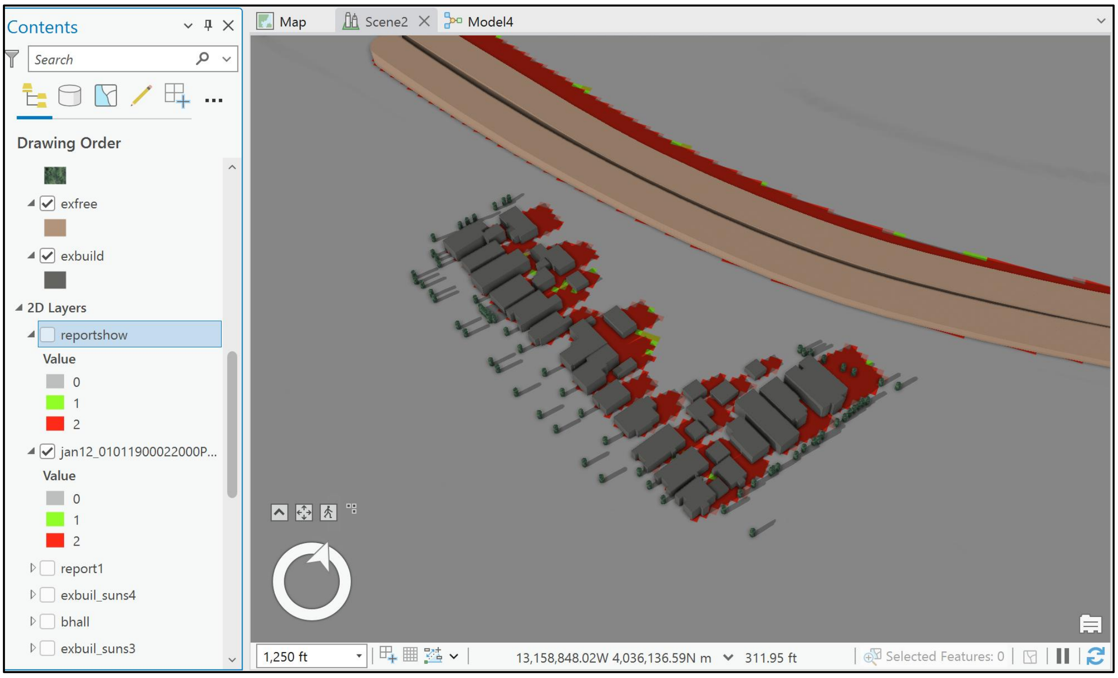


We can use illumination to simulate the results of the shadow model, and then compare them with the results of the sun shadow frequency to double confirm that the results are correct.

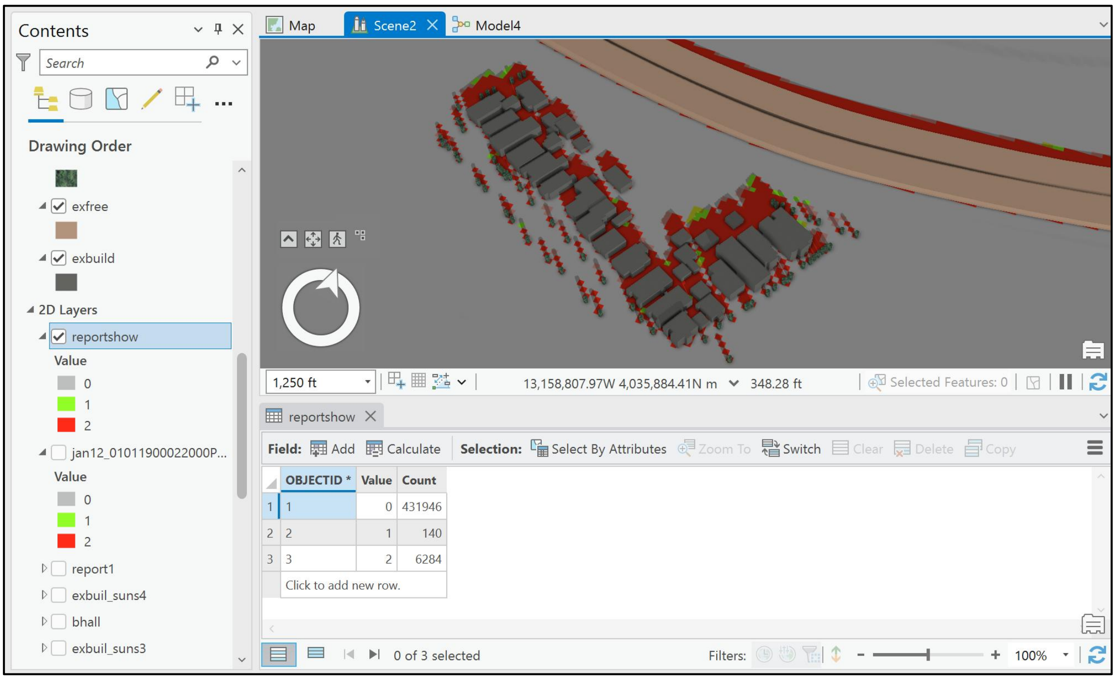




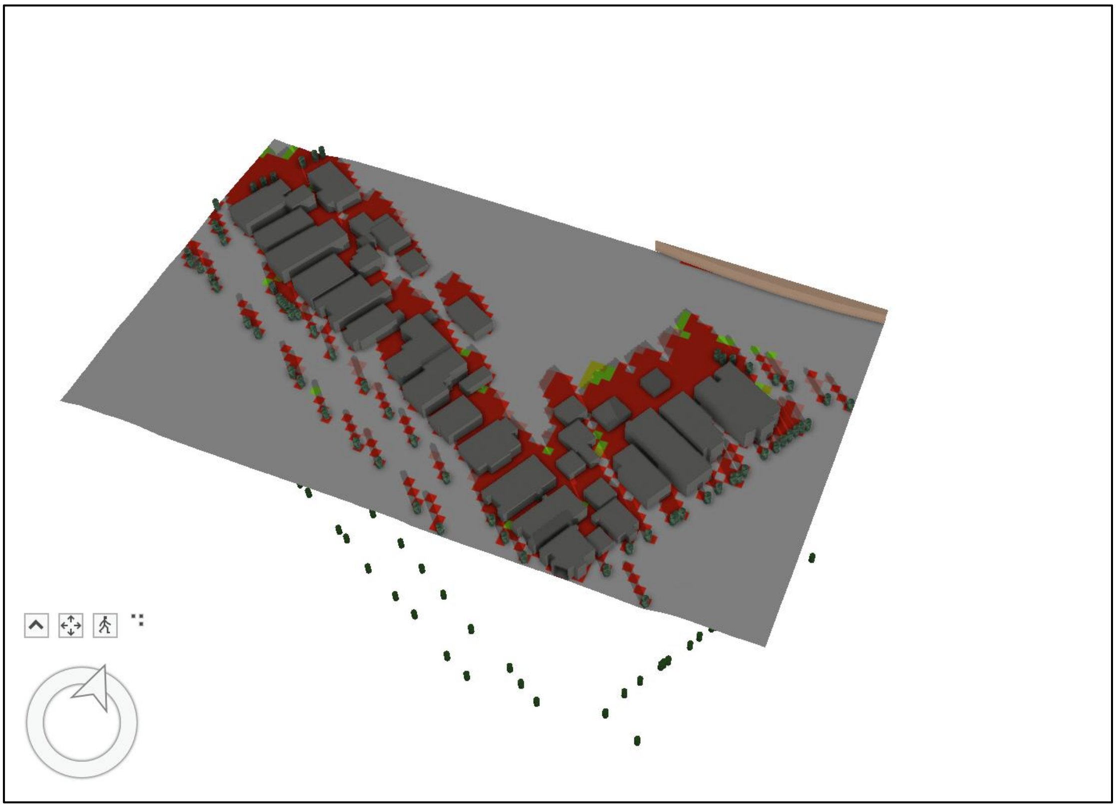
Regarding the **sun shadow frequency parameter setting**, please set it according to the method in the figure above. Because we need to calculate the results every ten minutes, we need to perform multiple calculations. We choose to use python to connect the sunrise and sunset times, let python automatically read the time period that needs to be calculated, and use this time period as the input data Part of it is letting acrpy automate the entire process using sun shadow frequency.



We compared the results of the sun shadow frequency with the results of the illumination tool. We chose the same time to view the results. Based on the image comparison, it can be seen that our sun shadow frequency setting is correct.



Open the attribute table of sun shadow frequency. Value represents the frequency of shadow appearance. When value is equal to 0, there is no shadow; the greater the value of value, the greater the value of shadow appearance. We add values greater than 0 to represent the shadow area of this area during this time period. It should be noted that the count here refers to the number of shadows. The area calculation is the number of raster data times the square of 10, where the unit is feet.



When using the Sun Shadow Frequency tool, 3D models of trees, freeways, and buildings are selected. There is no option to select the study area in the parameter settings. Therefore, the unshaded portion will be greatly increased and will be a rectangle or square well beyond the study area. The unshaded raster given (value=0) is not a BH-based boundary raster. If necessary, we can just cut out the research field based on our research field. If the value is greater than 0, there is a shaded area, consistent with the study area.

Potential problems with this approach

This method is based on CPU operation and does not support multi-core simultaneous processing. On a day-to-day basis, calculating the movement of the sun's position takes 366 times a year. For one shift in the Sun's position, we calculate that the time in the BH region is 1.5 days. Therefore, it is necessary to find ways to optimize the running speed.

auto_sun_shadowfrequency.ipynb completes the entire automation process. You only need to modify the name of the input file to automatically read the sunrise and sunset files.