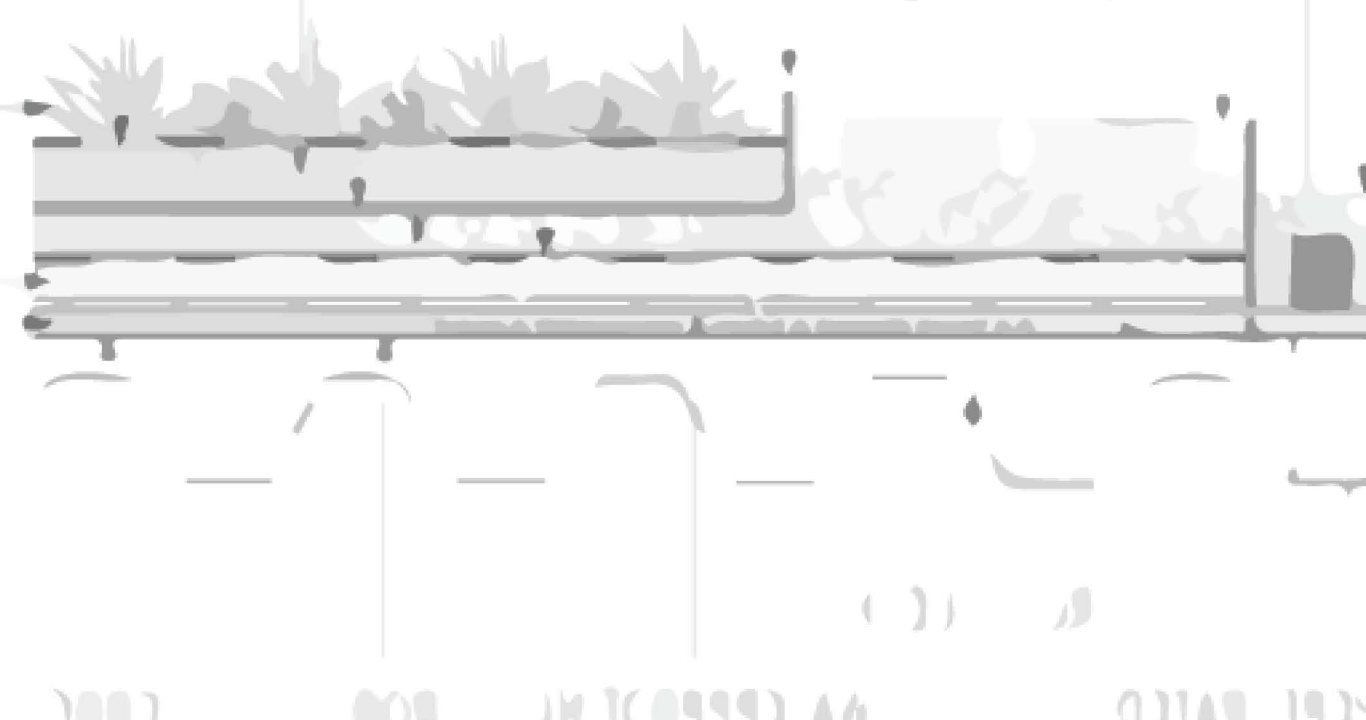
# CAN WE HAVE MORE GREEN ROOFS?

A Geographical Information System-Oriented Research Project for Green Roof addition in Queens, NYC, 2021



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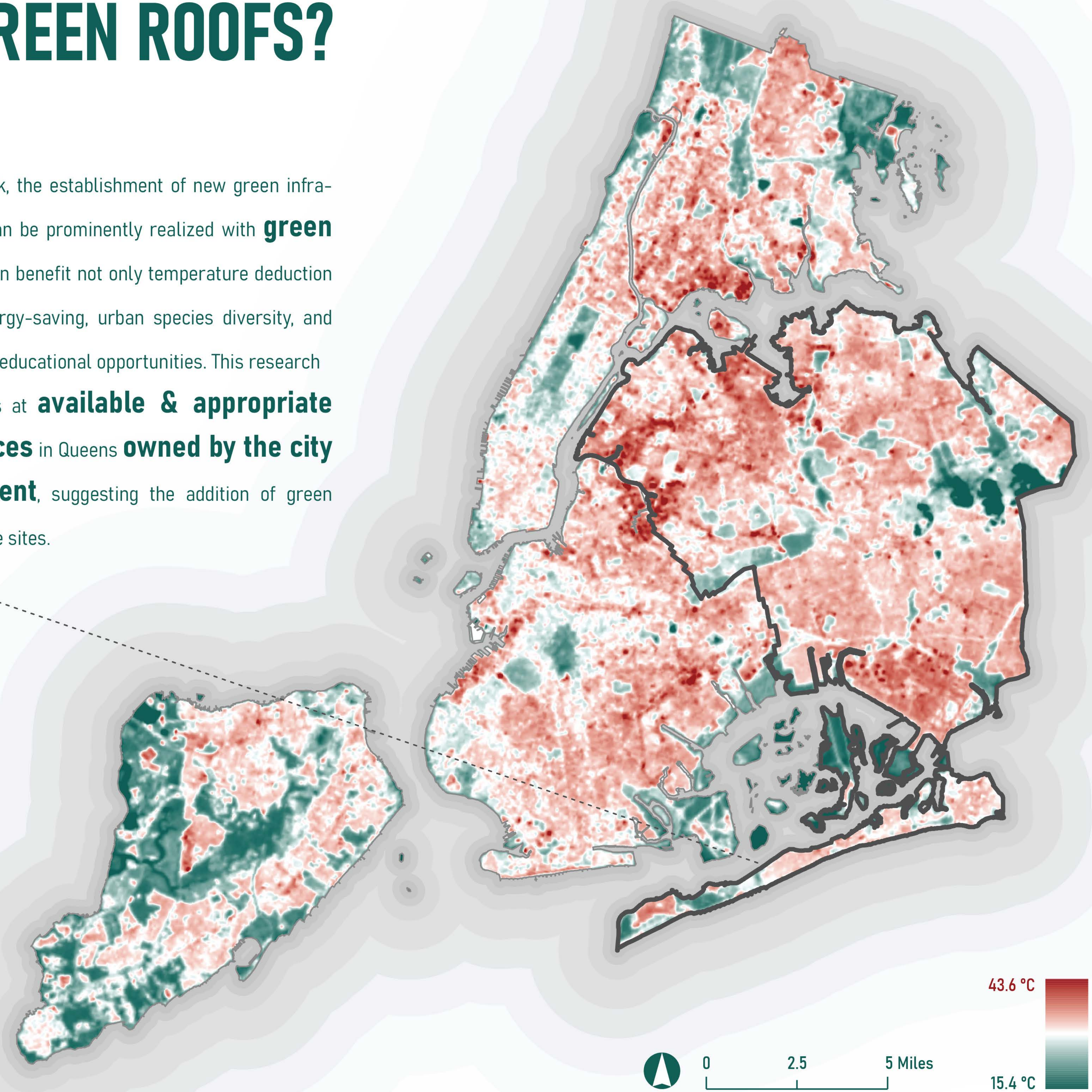
Introduction

# CAN WE HAVE MORE GREEN ROOFS?

## Queens, NYC, 2021

Metropolises like New York City have long been affected by the **Heat Island phenonmenon**. As indicated in the **Land Surface Temperature** measured during Aug 26th to Sept 1st 2021, the urban temperatures various widely ranging from 15.4°C to 43.6°C, suggesting a significant pattern of urban heat island effect accross the city. Among all five boroughs, **Queens** had experienced the most drastic pattern of urban heat island effect among all boroughs in the city with a LST ranging from **15.4°C to 41.3°C**.

**Green infrastructure** is an effective and practical approach contributing to temperature reduction in urban areas. For dense cities like New York, the establishment of new green infrastructures can be prominently realized with **green roofs**. It can benefit not only temperature deduction but also energy-saving, urban species diversity, and even job and educational opportunities. This research project looks at **available & appropriate roof spaces** in Queens **owned by the city government**, suggesting the addition of green roofs to those sites.




**Data Resources:**

1. USGS Earth Explorer (2021)
2. Department of Environmental Protection (2020&2021)
3. Treglia, Michael L., McPhearson, Timon, Sanderson, Eric W., Yetman, Greg, & Maxwell, Emily Nobel. (2018)
4. New York Department of City Planning (2021)
5. Department of City Planning (2021)

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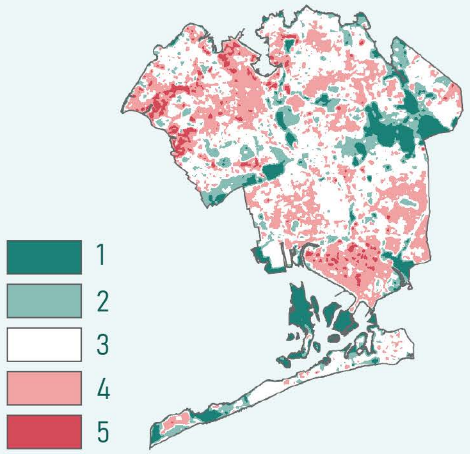
# WHAT DO WE BASED ON?

The decision was made based on a weighten decision map that evaluates multiple characterics of the site which lead to to urban heat island effect, including both meteorological and topographical parameters. Each set of parameter was arranged and reclassified based on their unique feature classes considering contributions to urban heat island effect. **(Note _ the reclassification for land cover type reference a scholar article:** Zhao, Jiacheng, Xiang Zhao, Shun-lin Liang, Tao Zhou, Xiaozheng Du, Peipei Xu, and Donghai Wu. “Assessing the Thermal Contributions of Urban Land Cover Types.” Landscape and Urban Planning 204 (2020): 103927. https://doi.org/10.1016/j.landurbplan.2020.103927. **)**

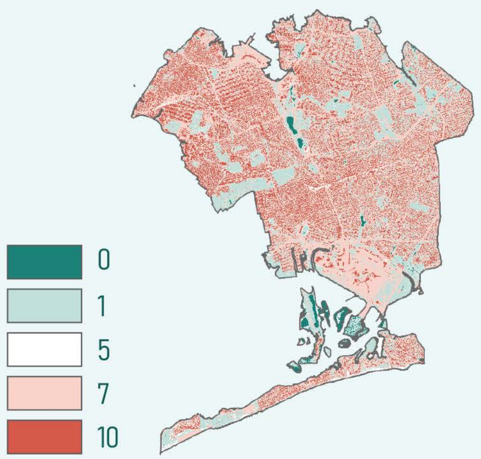
## Land Surface Temperature (Degree)

| Full Temperature Range | Temperature Range | Reclassified Score |
|---|---|---|
| 15.4- 43.6°C | 15-28 °C | 1 |
| | 28-30 °C | 2 |
| | 30-32 °C | 3 |
| | 32-34 °C | 4 |
| | 34-44 °C | 5 |



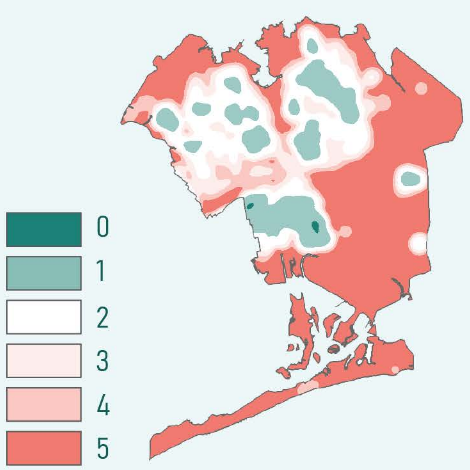

## Categorized Land Cover Type (Per Type)

| Classification | Land Cover Types | Reclassified Score |
|---|---|---|
| Water Body | Water | 0 |
| | Open Water | |
| | Pool | |
| Natural Landscape | Tree | 1 |
| | Bush | |
| | Grass | |
| Bareland | Bare Soil | 5 |
| | Gravel | |
| | Rock | |
| | Sand | |
| | Wood | |
| Impervious Surface | Asphalt | 7 |
| | Concrete | |
| | Metal | |
| | Brick Paver | |
| Building | Roof | 10 |
| | Solar Panel | |
| | Sythetic Turf | |



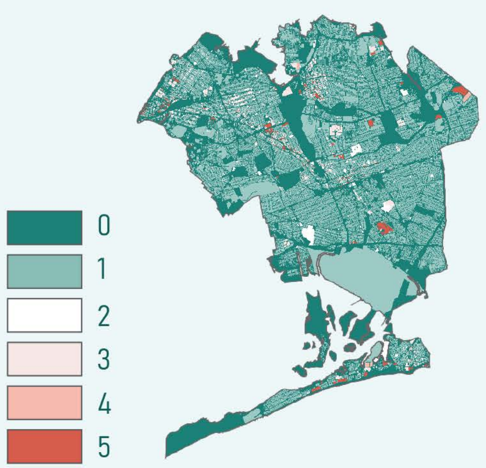

## Need for Green Infrastructure (Kernenl Density)

| Full Kernel Density Range | Kernel Density Range | Reclassified Score |
|---|---|---|
| 0-1117.07 | 0-13 | 5 |
| | 13-39 | 4 |
| | 39-87 | 3 |
| | 87-196 | 2 |
| | 196-558 | 1 |
| | 558-1118 | 0 |




## Level of Urbanization (Number of Floor per Lot)

| Full Num. of Floor Range | Num. of Floor Range | Reclassified Score |
|---|---|---|
| 0-104 | 0-1 | 0 |
| | 1-3 | 1 |
| | 3-5 | 2 |
| | 5-8 | 3 |
| | 8-11 | 4 |
| | 11-104 | 5 |




**Data Resources:**

1. USGS Earth Explorer (2021)
2. Department of Environmental Protection (2020&2021)
3. Treglia, Michael L., McPhearson, Timon, Sanderson, Eric W., Yetman, Greg, & Maxwell, Emily Nobel. (2018)
4. New York Department of City Planning (2021)
5. Department of City Planning (2021)

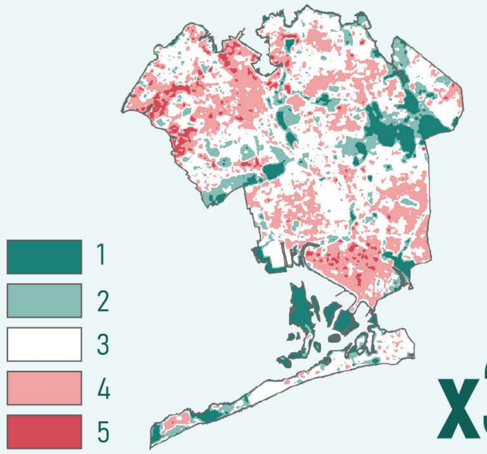
# WHERE TO HAVE MORE GREEN ROOFS?

Among all existing but not utilized property roofs in Queens, NYC, three were selected for green roof sites to mediate the heat island effect across the borough. The final selection was made based on a weighted decision map that evaluates the site's four identified characteristics that contribute to the urban heat island generation, with a score ranging from 7-49. The higher the score is, the more suitable the site is for the green roof proposal.

1. Long Island City High School, City Council District 22
2. Q7A Sanitation Garage, City Council District 19
3. MTA New York City Transit - Queens, City Council District 27

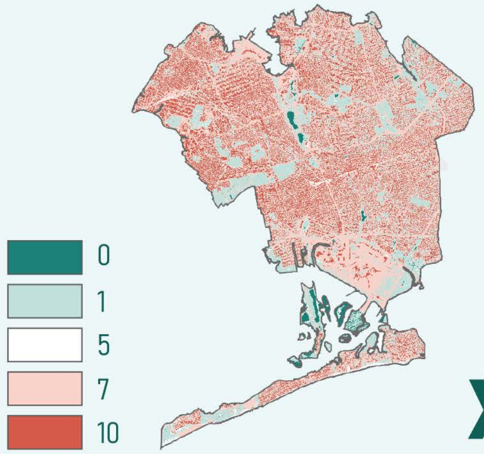
## Evaluation Criteria:

Land Surface Temperature (Degree)



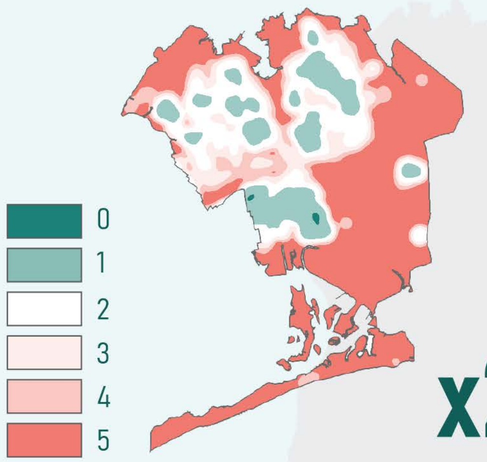

x3 +

Categorized Land Cover Type (Per Type)



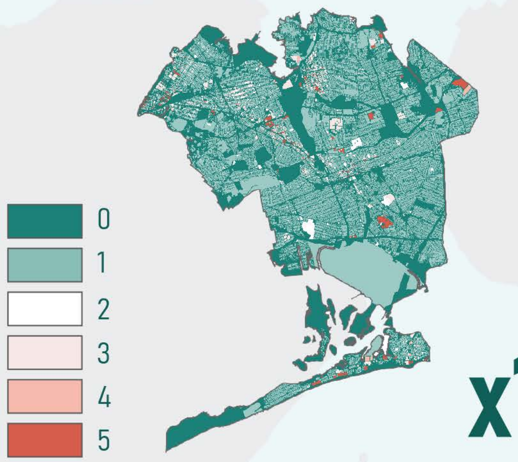

x2 +

Need for Green Infrastructure (Kernenl Density)

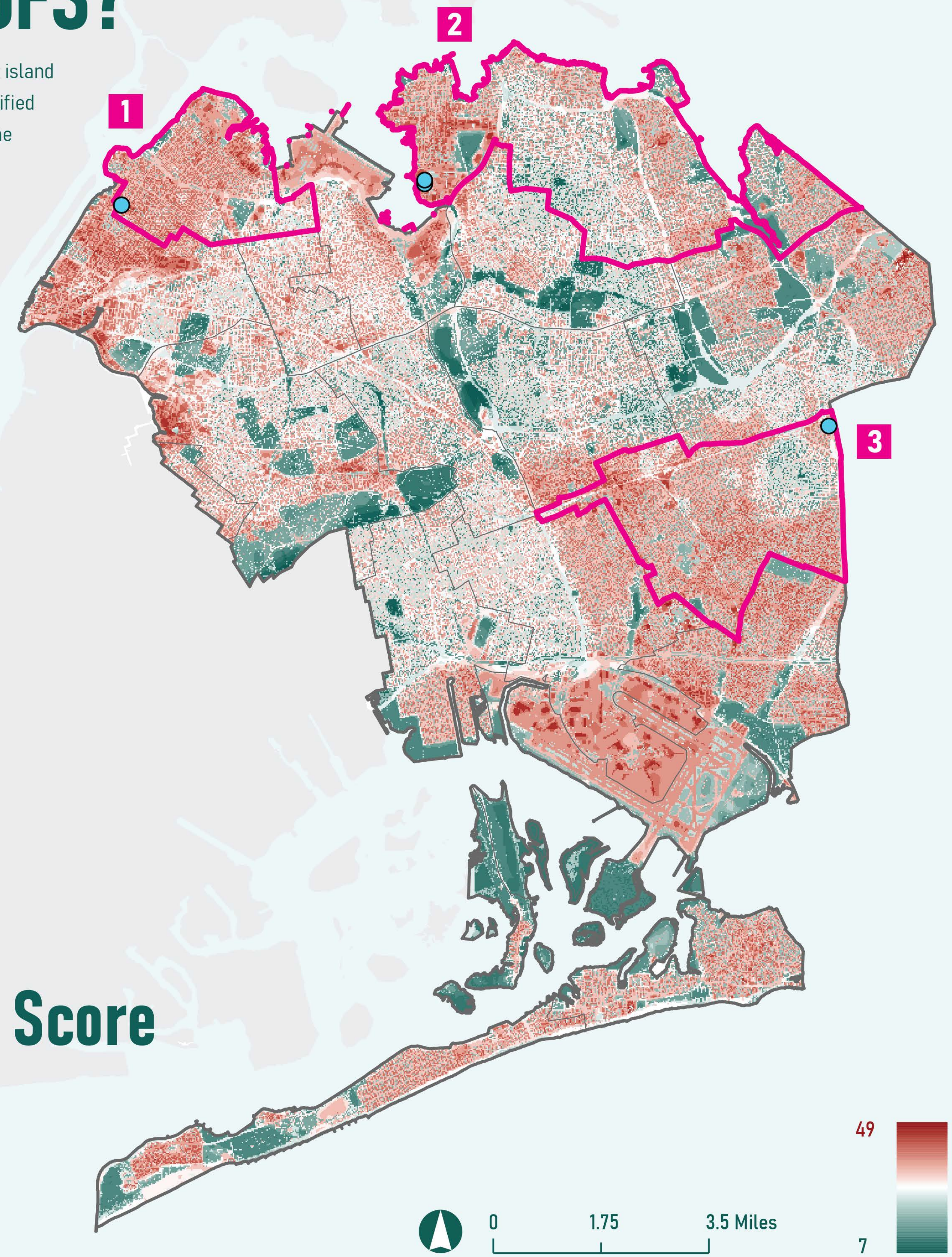



x2 +

Level of Urbanization (Number of Floor per Lot)




x1 = Final Score




**Data Resources:**

1. USGS Earth Explorer (2021)
2. Department of Environmental Protection (2020&2021)
3. Treglia, Michael L., McPhearson, Timon, Sanderson, Eric W., Yetman, Greg, & Maxwell, Emily Nobel. (2018)
4. New York Department of City Planning (2021)
5. Department of City Planning (2021)

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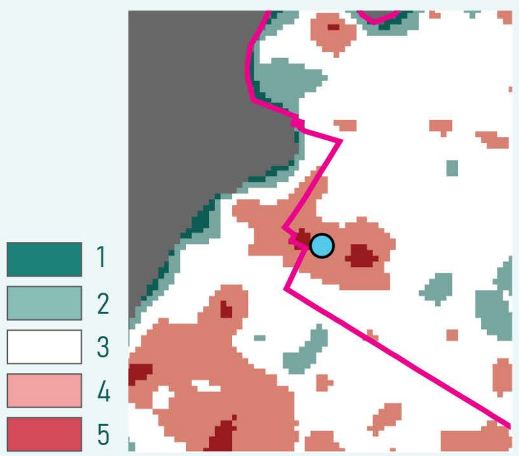
# LONG ISLAND CITY HIGH SCHOOL

## 1 Building Footprint: 61,450 sqft

Among all existing but not utilized city-owned property roofs in Queens, Long Island City High School in City Council District 22 ranks among the top choices with a score of 44. The school is located in an area with the highest temperature score and land cover score due to the high concentration of materials contributing to the urban heat island effect while significantly lacking green infrastructure. In addition, the green roof addition to a school will contribute to the educational purposes of this program. Thus, this building is a strong candidate for the green roof addition.

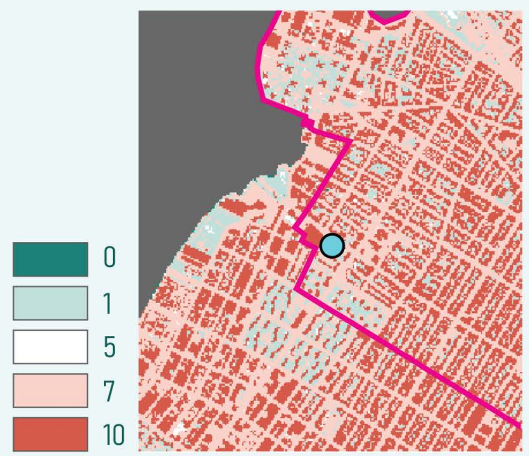
## Evaluation Criteria:

Land Surface Temperature (Degree)



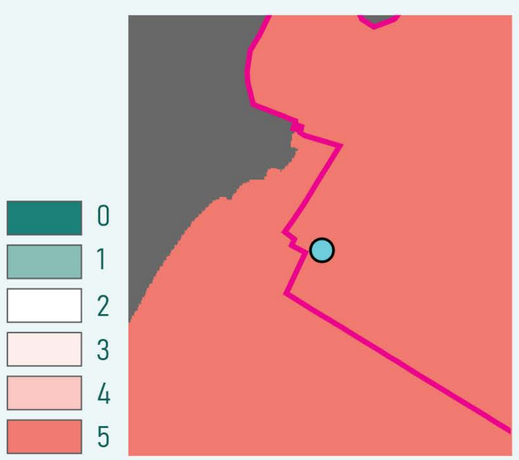

x3 +

Categorized Land Cover Type (Per Type)




x2 +

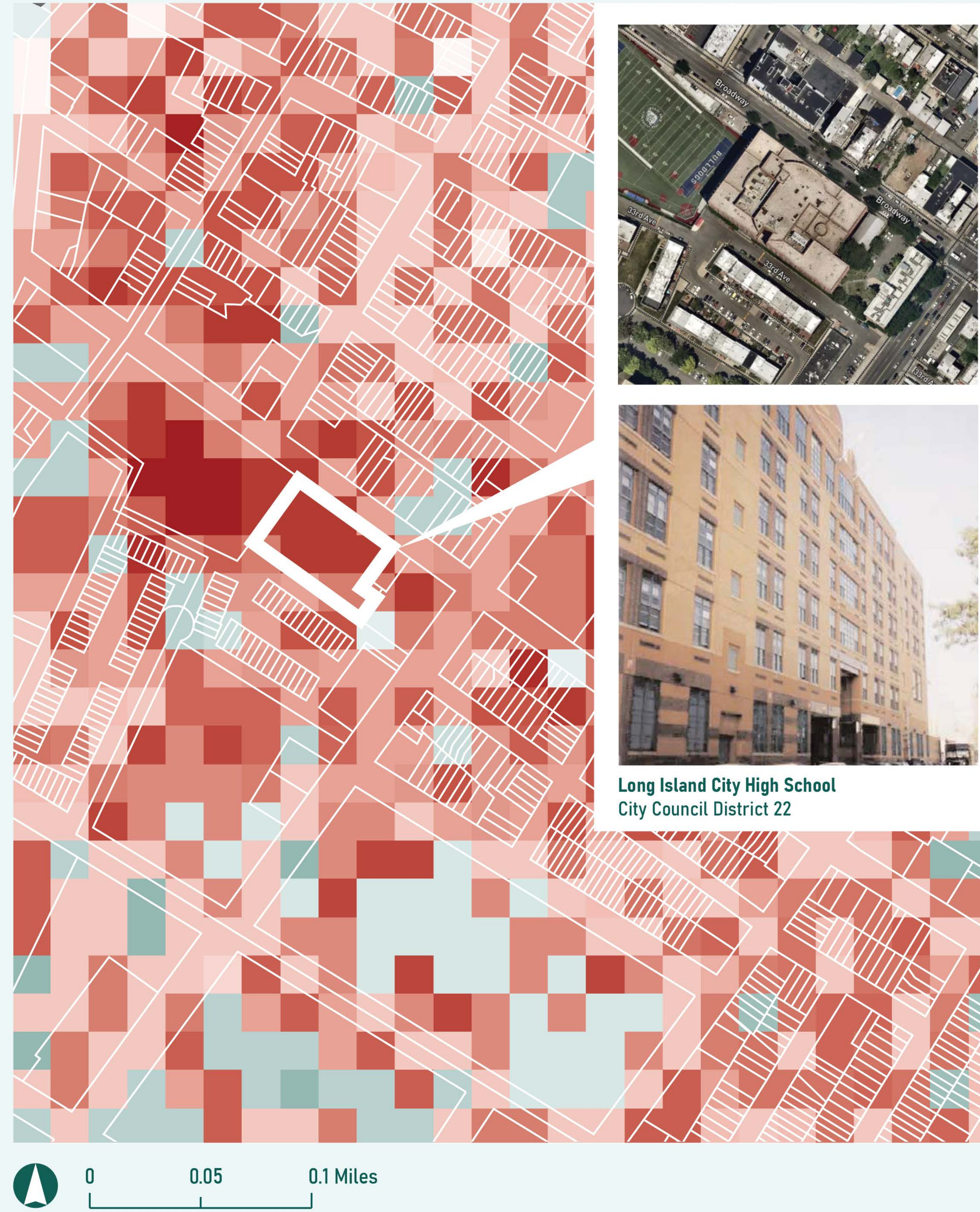
Need for Green Infrastructure (Kernenl Density)




x2 +

Level of Urbanization (Number of Floor per Lot)


x1 =




**Long Island City High School**
City Council District 22

# Final Score: 44

Data Resources:

1. USGS Earth Explorer (2021)
2. Department of Environmental Protection (2020&2021)
3. Treglia, Michael L., McPhearson, Timon, Sanderson, Eric W., Yetman, Greg, & Maxwell, Emily Nobel. (2018)
4. New York Department of City Planning (2021)
5. Department of City Planning (2021)

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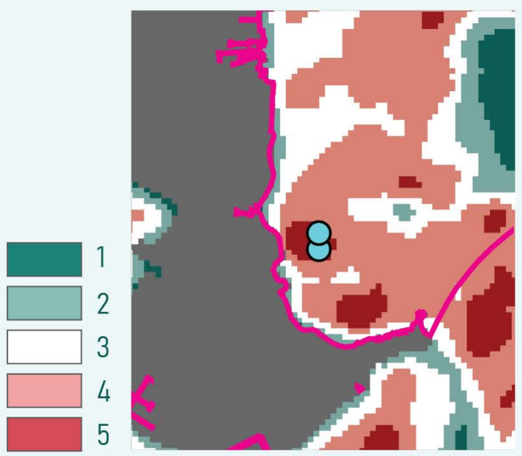
# Q7A SANITATION GARAGE

## 2 Building Footprint: 85,189 sqft

Q7A Sanitation Garage in City Council District 19 also ranks among the top choices with a score of 44.5. The garage is located in an area with the highest temperature score and land cover score due to the high concentration of materials contributing to thermal change while significantly lacking green infrastructure similar to Long Island City High School. In addition, as a sanitation garage, the green roof addition will also bring awareness of environmental concerns for the citizens. Thus, this is a strong candidate for green roof addition.

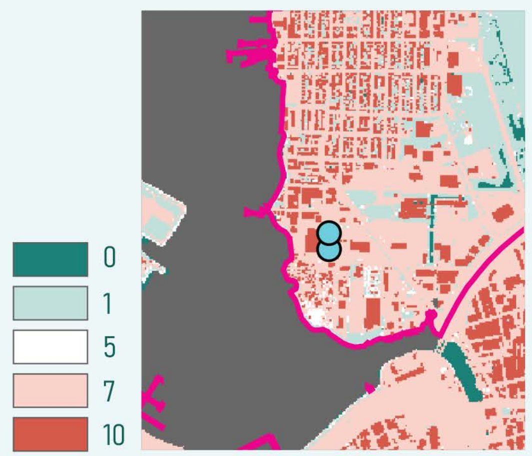
## Evaluation Criteria:

Land Surface Temperature (Degree)



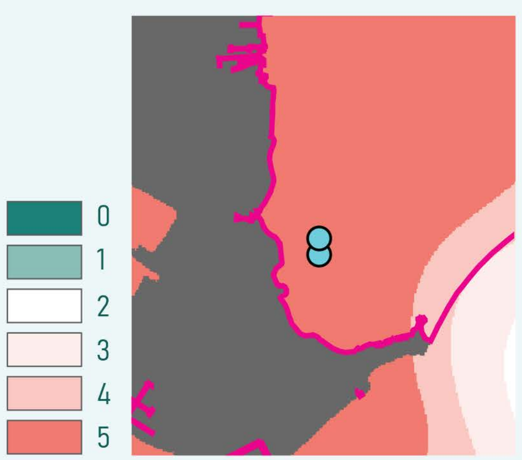

x3 +

Categorized Land Cover Type (Per Type)



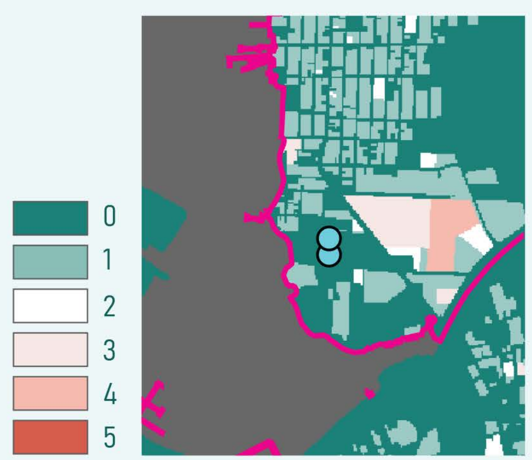

x2 +

Need for Green Infrastructure (Kernenl Density)

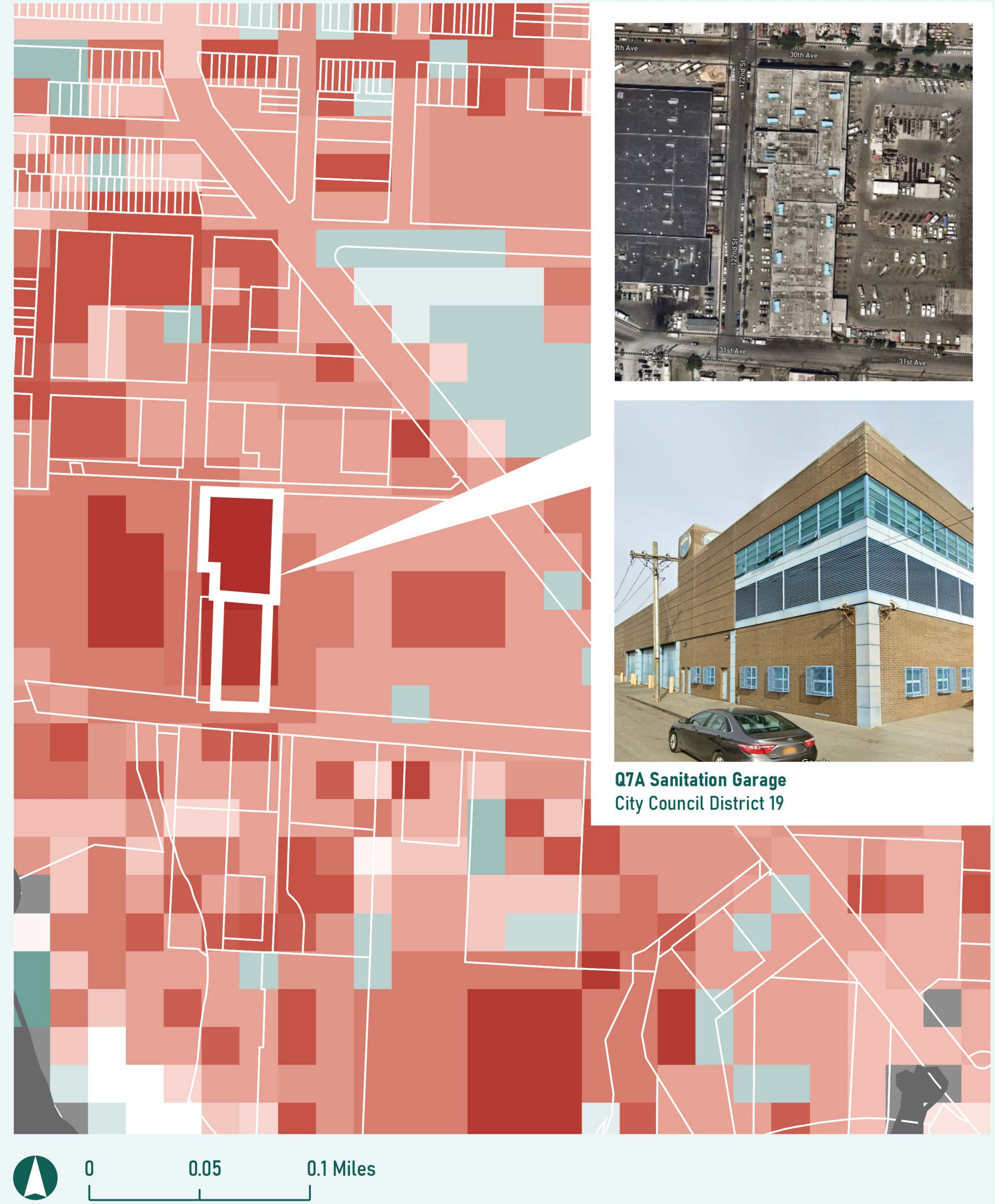



x2 +

Level of Urbanization (Number of Floor per Lot)




x1 =




**Q7A Sanitation Garage**
City Council District 19

**Final Score: 44.5**

**Data Resources:**

1. USGS Earth Explorer (2021)
2. Department of Environmental Protection (2020&2021)
3. Treglia, Michael L., McPhearson, Timon, Sanderson, Eric W., Yetman, Greg, & Maxwell, Emily Nobel. (2018)
4. New York Department of City Planning (2021)
5. Department of City Planning (2021)

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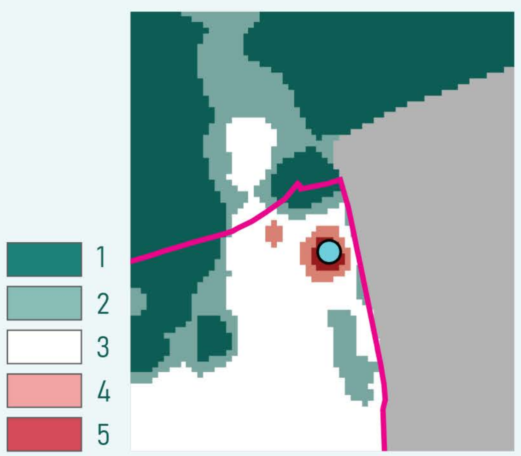
# MTA NEW YORK CITY TRANSIT

## 3 Building Footprint: 189,598 sqft

MTA New York City Transit - Queens in City Council District 27 also ranks among the top choices with a score of 45.7. With a building footprint of 189,598 SQFT, it is located in an area with similar meteorological and topographical parameters to the first two selected sites. In addition, as a public transportation infrastructure, the green roof addition will also bring awareness of environmental concerns for citizens.

## Evaluation Criteria:

Land Surface Temperature (Degree)

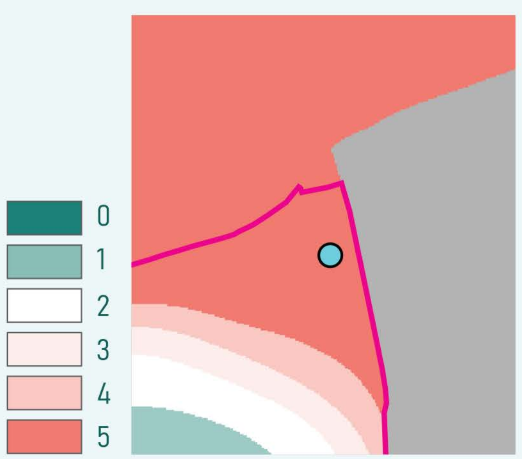



x3 +

Categorized Land Cover Type (Per Type)

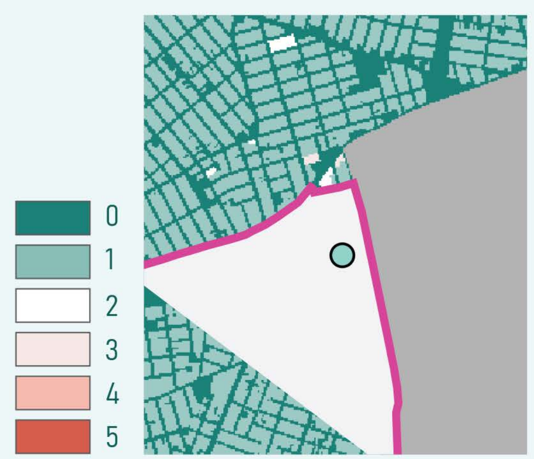

x2 +

Need for Green Infrastructure (Kernenl Density)

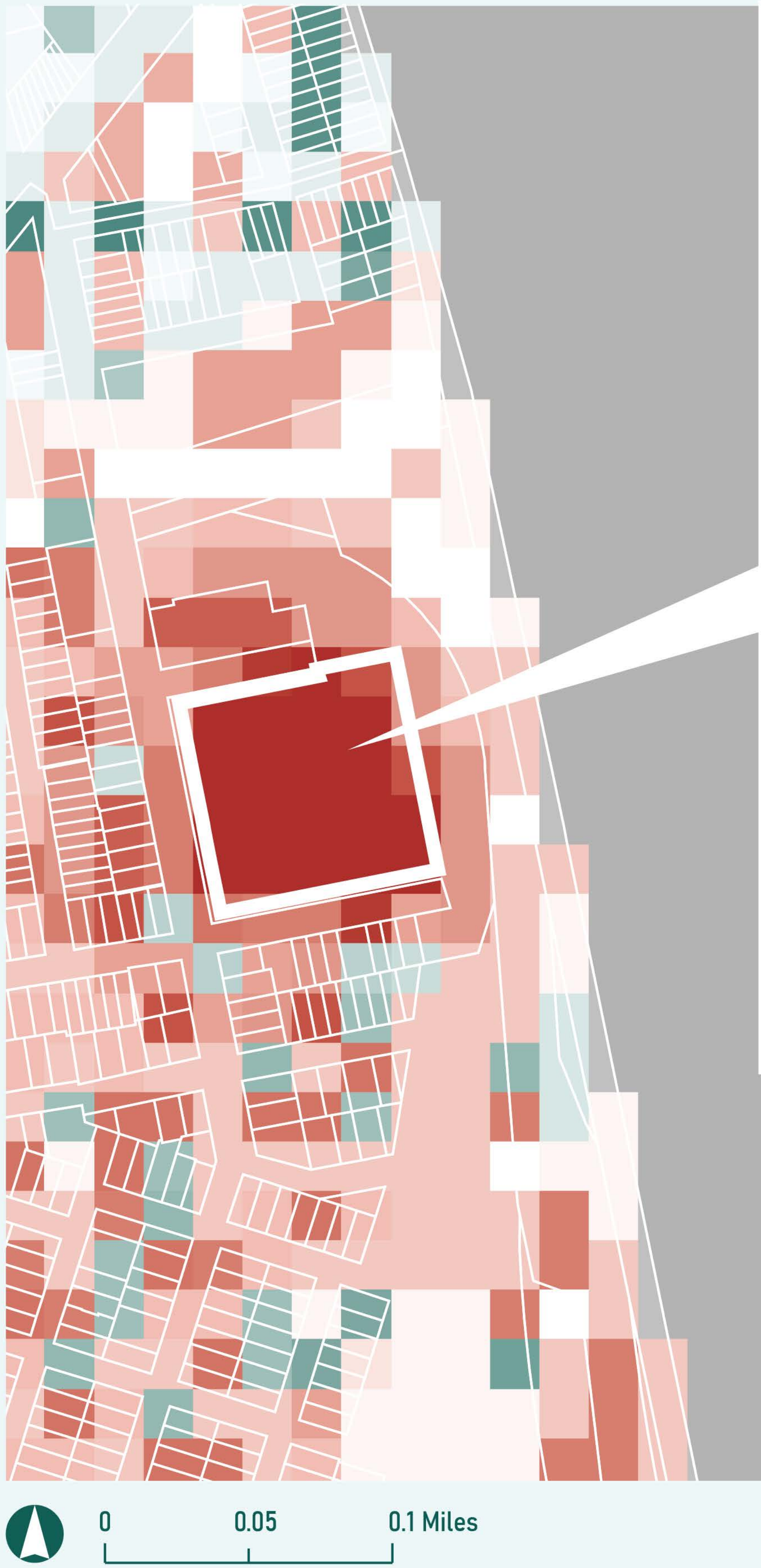



x2 +

Level of Urbanization (Number of Floor per Lot)




x1 =




MTA New York City Transit - Queens
City Council District 27

**Data Resources:**

1. USGS Earth Explorer (2021)
2. Department of Environmental Protection (2020&2021)
3. Treglia, Michael L., McPhearson, Timon, Sanderson, Eric W., Yetman, Greg, & Maxwell, Emily Nobel. (2018)
4. New York Department of City Planning (2021)
5. Department of City Planning (2021)

# Final Score: 45.7

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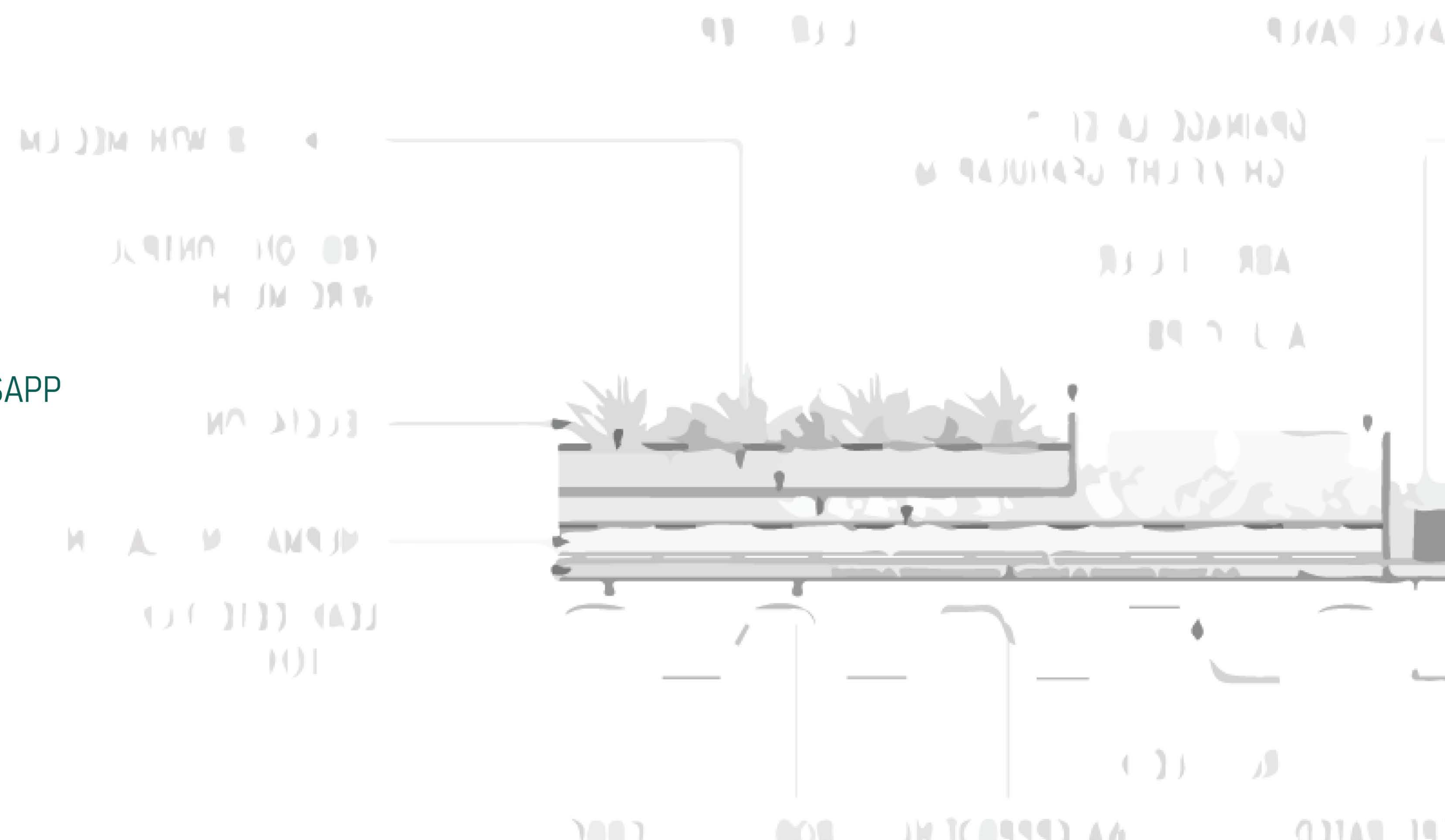
The End

# THANK YOU!

**Special thanks to:**

Professor Leah Meisterlin, Columbia GSAPP
Lab Instructor Daniel Froehlich, Columbia GSAPP
TA Moses Narayan Levich, Columbia GSAPP



# Can We Have More Green Roofs?

**Fall 2021, Geographical Information System Final Report**

Name: Wei Xiao (wx2245), Fang Wan (fw2379)

Professor: Leah Meisterlin

Lab Instructor: Daniel Froehlich

Date: 12/14/2021

## 1.0 Introduction: Project Background

Along with rapid urbanization, metropolises like New York City have long been affected by the heat island phenomenon. Its cause of formation is dynamic and complex, often hard to conceptualize due to the heterogeneous nature of all factors. For the purpose of understanding the nature of the heat island phenomenon across New York City and its further implication to the built environment, our project aims to investigate areas in the city that can be utilized to mediate such an environmental crisis.

In order to implement a thorough investigation and promote a final optimizing proposal, there is some critical background information that needs to be explored and understood. First, it is crucial to know the basic facts about the heat island effect. Artificial structures such as roads, buildings, and other infrastructures absorb and re-emit much more heat radiating from the sun than water bodies, forests, and other natural landscapes, which correlates to their specific heat capacity - one inherent physical attribute of matter. Natural coverings, including water and vegetation, have significantly higher heat capacity than metal or concrete materials. In other words, the temperature of one unit ground surface covered by artificial materials will increase more dramatically than that shielded by natural landscapes when absorbing the same amount of heat. As a result, urban areas, where these low heat capacity materials from manufactured structures are highly concentrated, become the "islands" with higher temperatures than the surrounding suburban areas with larger natural surfaces. Therefore, a well-developed metropolis like the City of New York will experience much dramatic heat island effect due to the highly densified urban constructions and the lack of open green spaces.

Based on these factors, the construction of green infrastructure, consisting of rain gardens, green roofs, and other natural retention systems, is an effective and practical approach to reducing the temperature in urban areas. For megacities, especially in New York, considering the limited availability of spaces, the establishment of new green infrastructures can be prominently realized with green roofs. There are about 730 buildings with green roofs in New York City, which merely represents "60 acres of the total 40,000 acres of rooftop space available (or less than 0.1% of NYC's 1 million buildings)"[1]. It indicates a great possibility for adding more green roofs that can benefit not only temperature deduction but also food production, stormwater mitigation, air pollution, energy-saving, urban species diversity, and even job and educational opportunities.

(*Figure 01: Urban Green Roof.*

Image Source: Michael Hardman, Senior Lecturer in Urban Geography, and Nick Davies, Research Fellow. "Green Roofs Improve the Urban Environment – so Why Don't All Buildings Have Them?" *The Conversation*, March 31, 2021.)

Among all potential agencies that can bring such a project to life, the city government had the greatest power and resources to construct additional green roofs across the city. Therefore, our project aims to examine the qualification of currently available and appropriate empty roof spaces owned by the city government that can be converted to green roofs to mediate the negative impact of the urban heat island effect. Towards the end, the project will be finalized into a visual presentation with great potential to be shared with the city government.

[1] Frazer, Kate. "Green Roofs in New York City." Superheroes in the City. Accessed November 7, 2021. https://www.nature.org/en-us/about-us/where-we-work/united-states/new-york/stories-in-new-york/green-roofs-new-york-city/.

## 2.0 Project Scope

### 2.0.0 Summary of Scope

The scope of this research project intends to cover the geographical area of a selected borough in New York suffering the most from the heat island effect. Due to the nature of the research question, which is indicated in the below section, our project looks at a time range from the date when most recently updated information that the city agencies could provide to inform our future provision.

### 2.0.1 Research Question

Where are the three city-owned, currently empty roof spaces that we can convert to green roofs to alleviate the heat island effect across the region?

### 2.0.2 Hypothesis

By examining the research outcome through GIS analysis, our hypothesis is that the city government can add additional green roofs to the building in the selected borough where the heat island effect is more severe while a lack of green infrastructure is presented.

## 3.0 Project Methodology

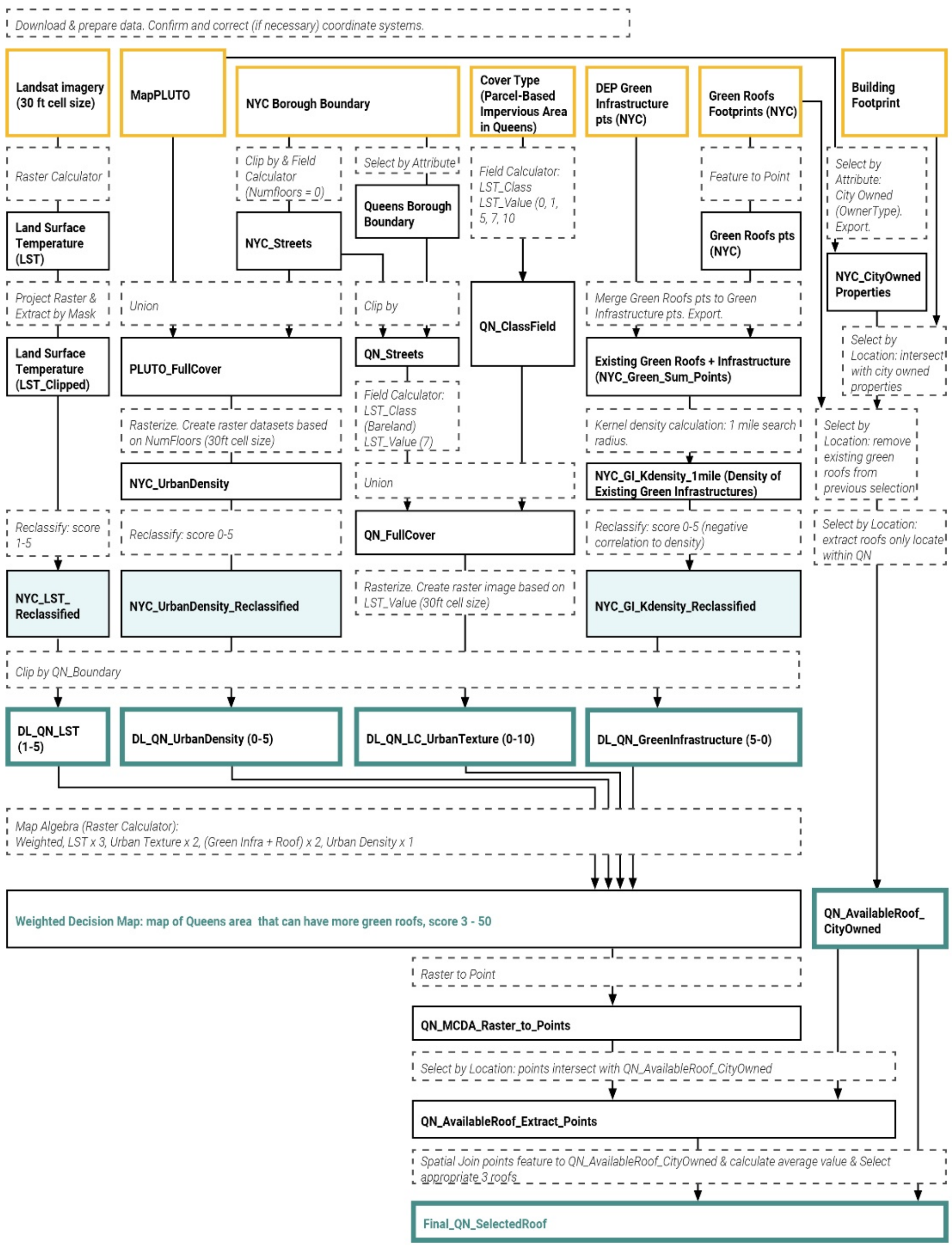
### 3.0.0 Methodology Summary

The project aims to identify geographical units from an aggregated spatial analysis model. Therefore, the employed methodology derives from logical thinking of how each layer of information should be appropriately aggregated to inform our decision-making. The scheme of our process begins from identifying the pattern of the heat island effect across the City of New York, then investigating how it corresponds to the built environment and what the city has done to mediate its impact upon our living environment. The investigation further informs us what we can do more to alleviate its influence from areas that can be identified and extracted - in our case, three building roofs that can be converted to green roofs.

### 3.0.1 Methodology Diagram

The below figure 02 shows a detailed step-by-step methodology of our research project. In summary, after the first step of visualizing the land surface temperature across the City of New York, the intended borough for further investigation was selected. Then all other layers of factors contributing to the current pattern of heat island effect: land cover type, existing green infrastructure across the area, and the level of urbanization, each was processed to match the same unit for the combined, weighted decision layer considering all the related factors listed above, from which our selection was made and finalized.

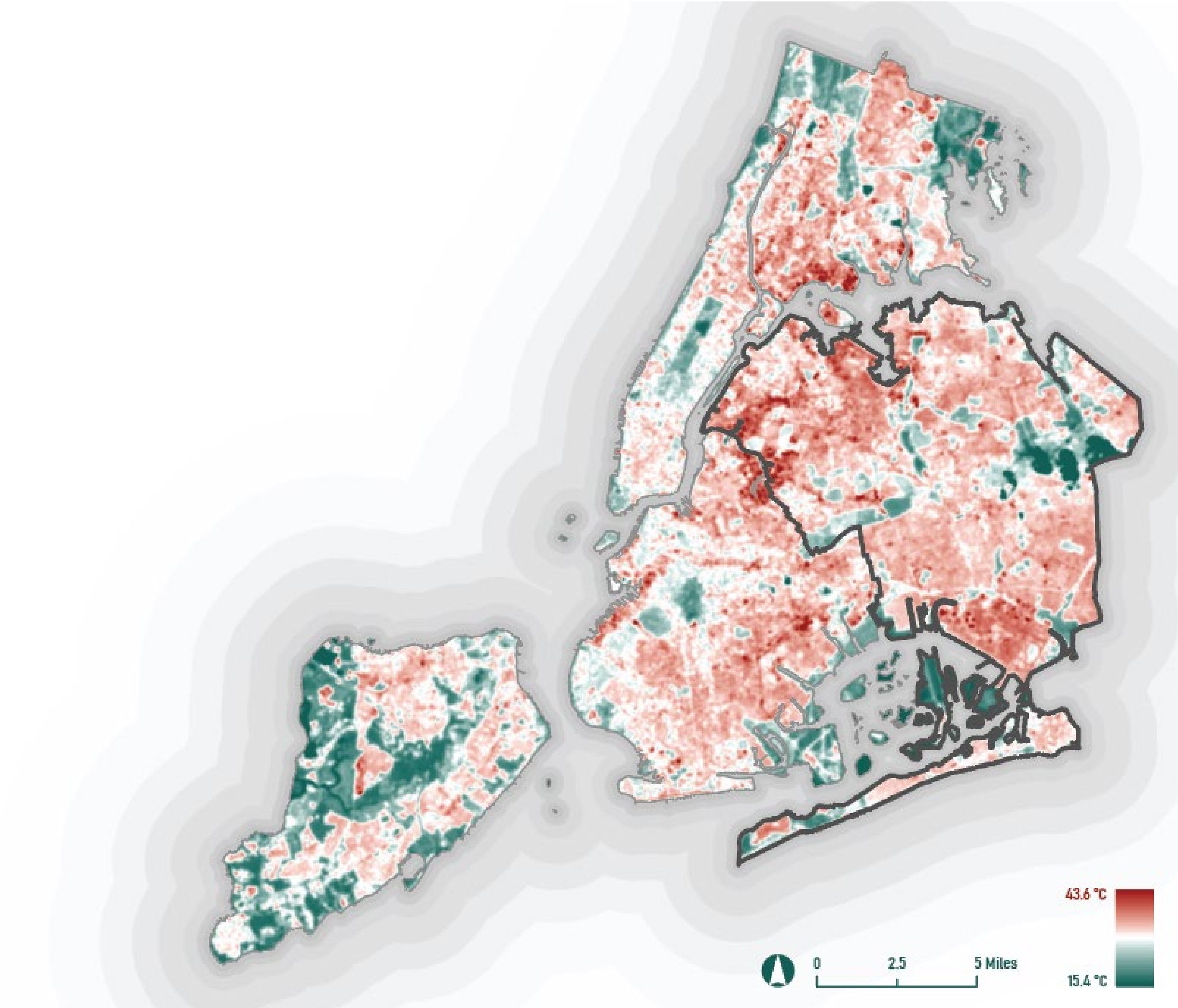
The below section 3.0.3 Methodology Breakdown guides you through each layer as well as its reclassification and weighted criteria for the final decision layer.




*(Figure 02: Methodology Diagram)*

### 3.0.2 Methodology Breakdown

Layer 1: Which borough should have more green roofs?

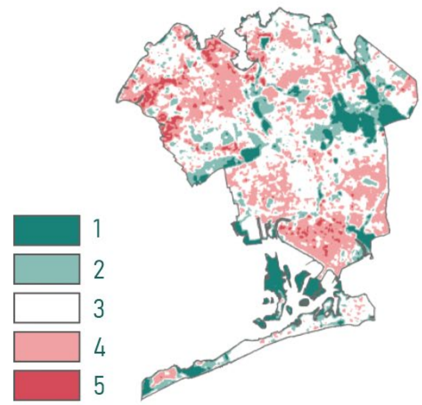



*(Figure 03: Land Surface Temperature Visualization)*

As indicated in the Land Surface Temperature Visualization with data measured from August 26th to September 1st, 2021, the urban surface temperatures vary widely, ranging from 15.4°C to 43.6°C, suggesting a significant pattern of urban heat island effect across the city. Among all five boroughs, Queens experienced the most drastic urban heat island effect among all boroughs in the city, with an LST ranging from 15.4°C to 41.3°C. Therefore, Queens is selected as the targeted borough for further investigation. In addition, to maintain the granularity and specificity of this project's analysis, the raster cell size of 30 by 30 feet is made as to the baseline unit for all other layers. (Data source: USGS Earth Explorer)

Layer 1.a: Reclassify Queens land surface temperature (degree)

| Full Temperature Range | Temperature Range | Reclassified Score |
|---|---|---|
| 15.7- 43.9°C | 15-28 °C | 1 |
| | 28-30 °C | 2 |
| | 30-32 °C | 3 |
| | 32-34 °C | 4 |
| | 34-44 °C | 5 |

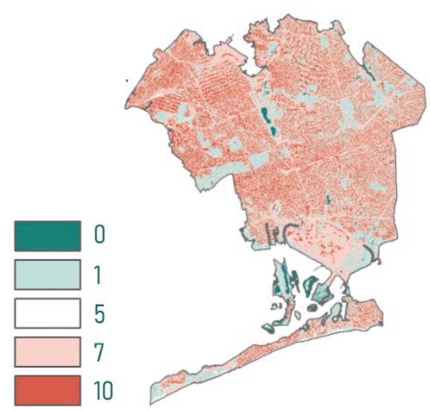



*(Figure 04: Queens' Land Surface Temperature Reclassification)*

Based on the thermal comfort temperature criteria, the full LST range between 15.7°C to 43.9°C was subdivided into five categories and reclassified with a value range of 1-5. Since the land surface temperature is the most crucial factor in generating urban heat island effects, this layer is weighed by 3 for the final decision layer.

Layer 2: Reclassify Queens Land Cover Type (per Type)

| Classification | Land Cover Types | Reclassified Score |
|---|---|---|
| Water Body | Water | 0 |
| | Open Water | |
| | Pool | |
| Natural Landscape | Tree | 1 |
| | Bush | |
| | Grass | |
| Bareland | Bare Soil | 5 |
| | Gravel | |
| | Sand | |
| | Sand | |
| | Wood | |
| Impervious Surface | Asphalt | 7 |
| | Concrete | |
| | Metal | |
| | Brick Payer | |
| Building | Roof | 10 |
| | Solar Panel | |
| | Sythetic Turf | |



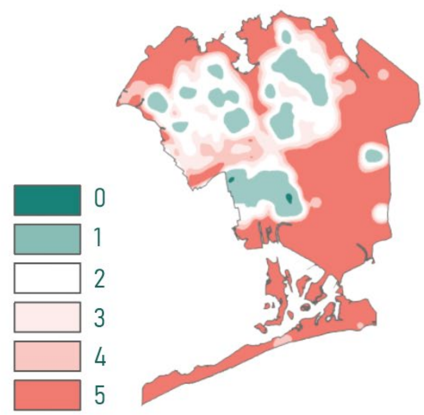

*(Figure 05: Queens' Land Cover Type Reclassification)*

As indicated in the introduction section, land cover type contributes significantly to the formation of urban heat islands, specifically those materials with low heat capacity. The original dataset from the study of the Department of Environmental Protection's Citywide Parcel-Based

Impervious Area[2] had detailed 18 material types that together formed New York City's built environment. Based on scholars Jiacheng Zhao, Xiang Zhao, Shunlin Liang, Tao Zhou, Xiaozheng Du, Peipei Xu, and Donghai Wu's research[3] assessing thermal contributions from different urban land cover types, our project divided the 18 identified land cover materials into 5 categories. With water as the baseline, all classes of land cover type were reassigned with new classified scores ranging from 0-10, valuing their thermal contribution to the heat island effect. Due to the importance of land cover type, this reclassified layer is weighted by 2 for the final decision layer.

Layer 3: Reclassify the Need for Green Infrastructure (Kernel Density)

| Full Kernel Density Range | Kernel Density Range | Reclassified Score |
|---|---|---|
| 0-1117.07 | 0-13 | 5 |
| | 13-39 | 4 |
| | 39-87 | 3 |
| | 87-196 | 2 |
| | 196-558 | 1 |
| | 558-1118 | 0 |




*(Figure 06: Queens' Existing Green Infrastructure Density)*

To avoid redundancy in the construction of green infrastructure and to identify areas lacking their presence, the existing green infrastructures across the borough were mapped, including existing green roofs and other types of infrastructure such as rain gardens. A kernel density map used a search distance of 1 mile for the visualization, then reclassified with a score range of 0-5. It is important to point out here that the highest score refers to the areas that lack green infrastructures, while the lowest score means that the site doesn't need additional

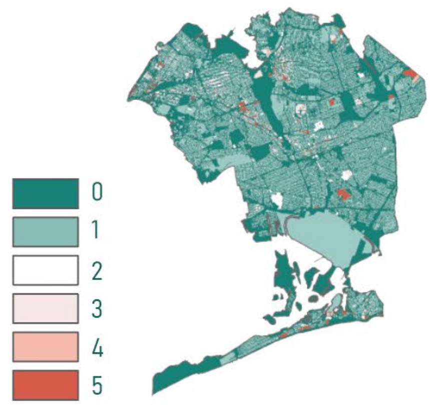
[2] Department of Environmental Protection (DEP), "DEP's Citywide Parcel-Based Impervious Area GIS Study", [shapefile]. Created July 13, 2020, updated August 6, 2020.

[3] Note _ the reclassification for land cover type reference a scholar article: Zhao, Jiacheng, Xiang Zhao, Shunlin Liang, Tao Zhou, Xiaozheng Du, Peipei Xu, and Donghai Wu. "Assessing the Thermal Contributions of Urban Land Cover Types." *Landscape and Urban Planning 204* (2020): 103927.

infrastructures. In other words, the need to add green roofs is negatively correlated to the density of existing infrastructures. This layer is weighted by 2 for the final decision layer.

Layer 4: Reclassify the Level of Urbanization (Number of Floors per Lot)

| Full Num. of Floor Range | Num. of Floor Range | Reclassified Score |
|---|---|---|
| 0-104 | 0-1 | 0 |
| | 1-3 | 1 |
| | 3-5 | 2 |
| | 5-8 | 3 |
| | 8-11 | 4 |
| | 11-104 | 5 |



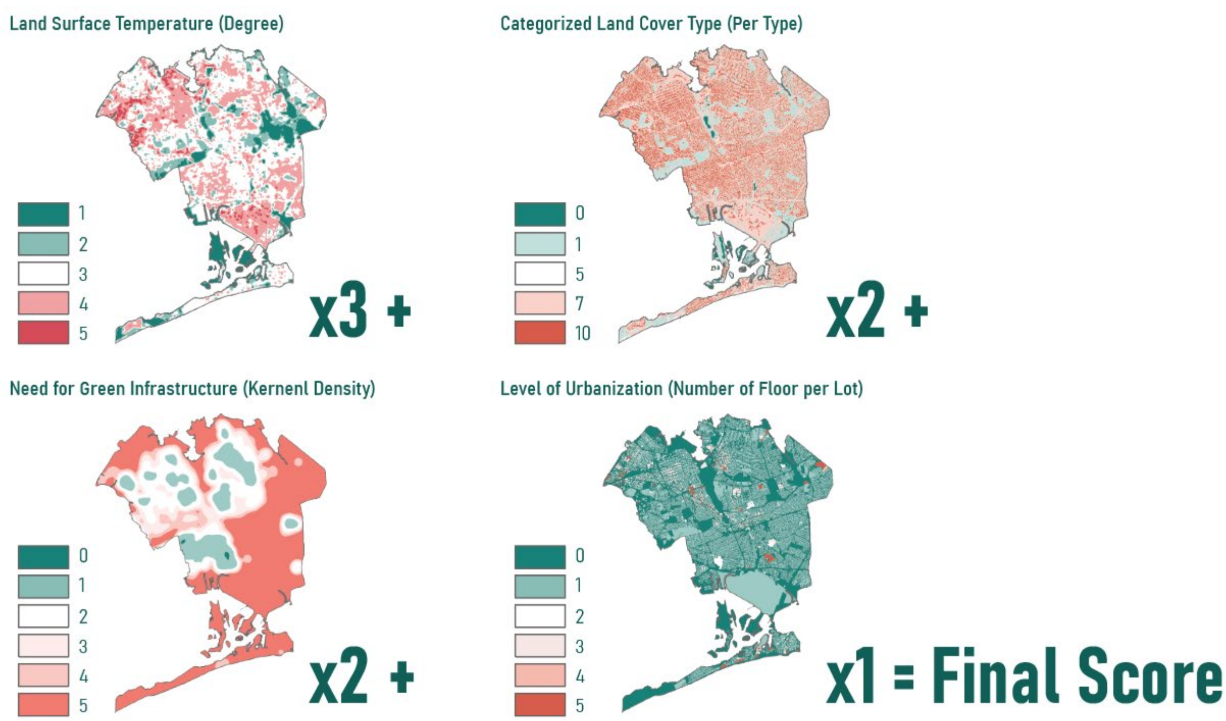

*(Figure 07: Queens' Level of Urbanization)*

As a direct indicator of the level of urbanization, the number of floors reflects the extent to which a city expands vertically. Our proposal identifies areas with a high urbanization rate as potentially lacking enough open spaces for environmental interventions. Therefore, the number of floors across the city was categorized based on the common standard for development: 1-3 floors as low-rise, 3-5 floors as low to mid-rise, 5-8 as mid-rise, 8-11 floors as high-rise, and above 11 floors as skyscrapers. Correspondingly, a score range of 0-5 was assigned to this layer and weighted by 1 for the final decision map.

Layer 5: Weighted final decision layer

To conclude, with each layer's thermal contribution to the urban heat island effect determined, the final decision layer was calculated based on the blow formula (which is also shown in Figure 08):

**"Final Decision Layer = Reclassify Queens land surface temperature*3 + Reclassify Queens Land Cover Type*2 + Need for Green Infrastructure*2 + Level of Urbanization*1"**




*(Figure 08: MCDA Guide)*

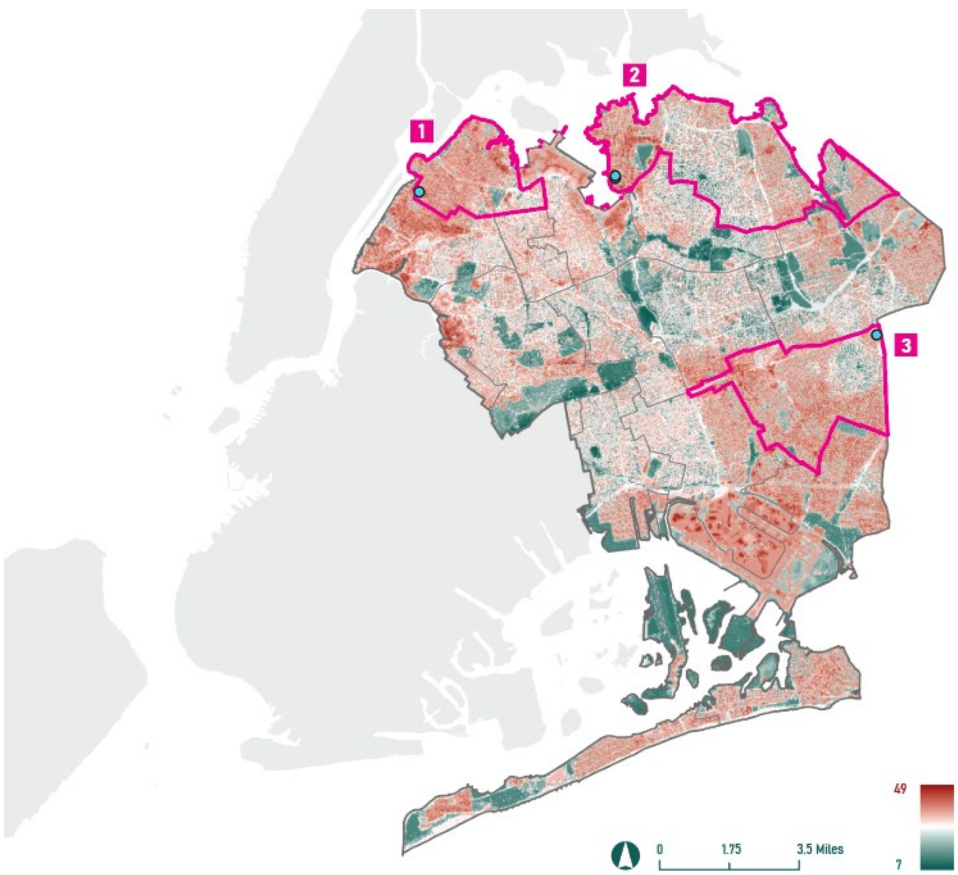
### 3.0.3 Assumptions and Potential Constrains

This research project is based on the assumption that the identified roof is suitable for green roof conversion. However, the practicality of green roof construction depends on each building's existing structure type and load-bearing capacity, which is hard to identify from a data-oriented perspective but should be done through further on-site investigation.

## 4.0 Analysis Outcome

### 4.0.1 Summary

Among all existing but not utilized property roofs in Queens, NYC, three were selected for green roof sites to mediate the heat island effect across the region. As described in the above section 3.0 Project Methodology, the final selection was made based on a weighted decision map that evaluates the site's four identified characteristics that contribute to the urban heat island generation, with a score ranging from 7-49. The higher the score is, the more suitable the site is for the green roof proposal. This research had strategically chosen three sites (figure 10) with different public programs: Long Island City High School, Q7A Sanitation Garage, and MTA New York City Transit - Queens, aiming to bring back the awareness of environmental concerns and further educate people about the possibility of green infrastructures that can be employed throughout the city.

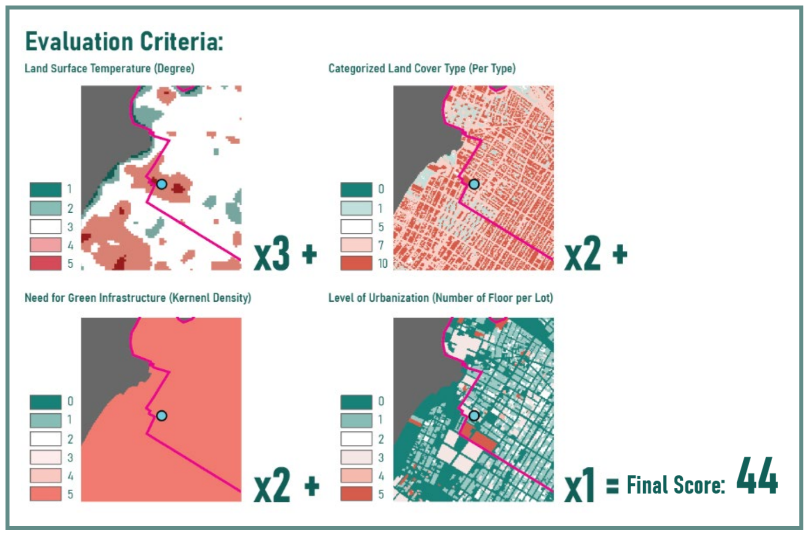



*(Figure 09: Final Weighted Decision Map with Selected Locations)*

### 4.0.2 Three Selected Sites

<u>Site 01: Long Island City High School in City Council District 22</u>

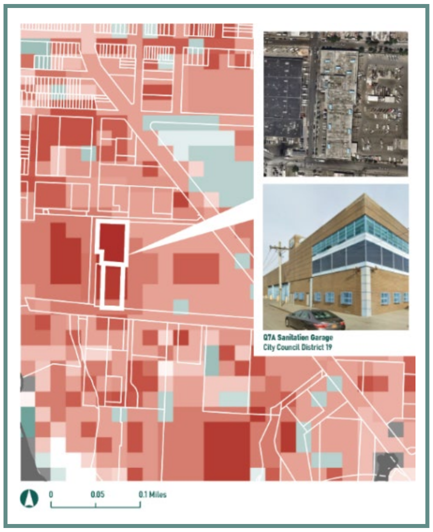
Among all existing but not utilized city-owned property roofs in Queens, Long Island City High School in City Council District 22 (Figure 10) ranks among the top choices with a score of 44. With a building footprint of 61,450 SQFT, the school is located in an area with the highest temperature score and land cover score due to the high concentration of materials contributing to the urban heat island effect while significantly lacking green infrastructure (figure 11). In addition, the green roof addition to a school will contribute to the educational purposes of this program. Thus, this building is a strong candidate for the green roof addition.

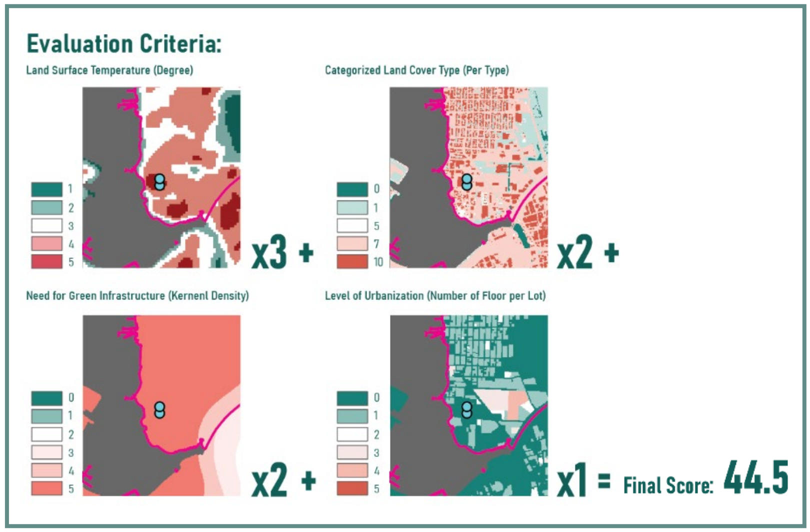




*(Left: Figure 10; Right: Figure 11)*

<u>Site 02: Q7A Sanitation Garage in City Council District 19</u>

Q7A Sanitation Garage in City Council District 19 (Figure 12) also ranks among the top choices with a score of 44.5. With a building footprint of 85,189 SQFT, the garage is located in an area with the highest temperature score and land cover score due to the high concentration of materials contributing to thermal change while significantly lacking green infrastructure (Figure 13) similar to Long Island City High School. In addition, as a sanitation garage, the green roof addition will also bring awareness of environmental concerns for the citizens. Thus, this is a strong candidate for green roof addition.

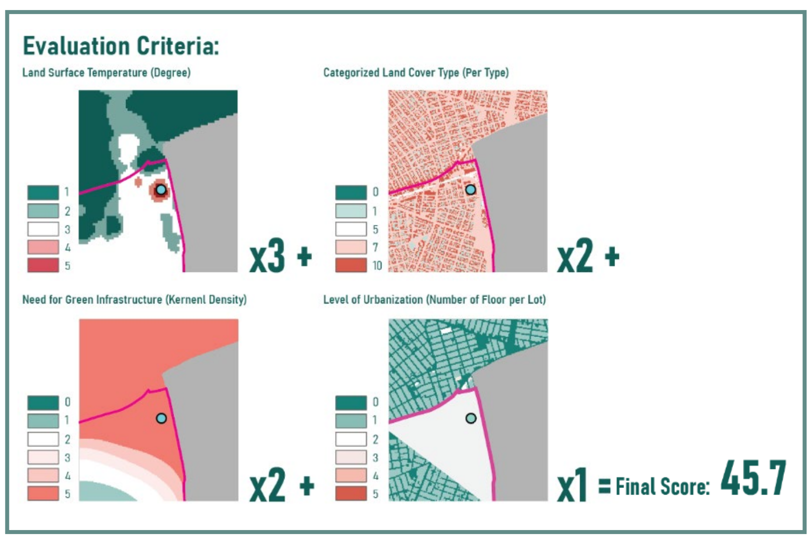



(Left: Figure 12; Right: Figure 13)

Site 03: MTA New York City Transit-Queens

MTA New York City Transit - Queens in City Council District 27 (Figure 14) also ranks among the top choices with a score of 45.7. With a building footprint of 189,598 SQFT, it is located in an area with similar meteorological and topographical parameters (Figure 15) to the first two. In addition, as a public transportation infrastructure, the green roof addition will also bring awareness of environmental concerns for citizens.


(Left: Figure 14; Right: Figure 15)

## 5.0 Conclusion and Reflection

### 5.0.1 Conclusion

Throughout this project, our team had completed the research question and identified three available and appropriate roofs in Queens owned by the city government that can be converted to green roofs to mediate the urban heat island effect. While those are only three among the 2,491 available spaces for intervention, this project had laid out a thorough methodology to analyze and value those roofs for continuing works. The three identified roofs are starting points for the city to consider existing opportunities in the built environment to fight against the environmental crisis. Therefore, it can be (or should be) taken as a long-term program for the city government to create a more sustainable future for citizens.

However, we've also identified constraints that this project embodied based on the assumption that all roofs can be evaluated under this framework. As stated in the methodology section, the practicality of green roof establishment remains unclear with pure data interpretation. The city government should work closely with construction companies and agencies to further determine each roof's appropriateness considering its existing structure and load bear capacity for the addition of green roofs through a pragmatic lens.

### 5.0.2 Reflection

The project had also challenged our conventional understanding of environmental patterns across the city. We initiated with the hypothesis that the borough of Manhattan would suffer the most from urban heat island effects due to its level of urbanization and change regarding city surface materials. However, the visualization of summer land surface temperature had proved that instead of Manhattan, the borough of Queens suffers the most. One lesson from this is that we should be cautious about applying common sense while doing research projects.

## 6.0 Bibliography: Datasets and Other references

### 6.0.1 Datasets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### 6.0.2 Other references:


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2. Zhao, Jiacheng, Xiang Zhao, Shunlin Liang, Tao Zhou, Xiaozheng Du, Peipei Xu, and Donghai Wu. "Assessing the Thermal Contributions of Urban Land Cover Types."

*Landscape and Urban Planning 204* (2020): 103927.
<https://doi.org/10.1016/j.landurbplan.2020.103927.>

# 7.0 Appendix

## 7.0.1 Detailed methodology notes

| STEP-BY-STEP METHODOLOGY | | | | |
|---|---|---|---|---|
| Major Steps | Step Break-Down | | Created Layer | Layer Type |
| **Step 1:** Start a new, empty ArcMap Project | | | | mxd File |
| **Step 2:** Prepare for Land Surface Temperature (LST) raster file for entire New York. Reference: [(https://giscrack.com/how-to-calculate-land-surface-temperature-with-landsat-8-images/)](https://giscrack.com/how-to-calculate-land-surface-temperature-with-landsat-8-images/) | **1.** Download Landsat Imagery from USGS Earth Explorer | | | |
| | **2.** Import required bands (Band 4, 5, 10) into ArcMap, check coordinate system | | | |
| | **3.** Use **Raster Calculator** to calculate LST values | **1.1** TOA_Radiance= 0.0003342 * “Band 10” + 0.1 | TOA | Raster File |
| | | **1.2** TOA_BT = (1321.0789 / Ln ((774.8853 / “%TOA%”) + 1)) – 273.15 | BT | Raster File |
| | | **1.3** NDVI = (Band 5 – Band 4) / (Band 5 + Band 4) | NDVI | Raster File |
| | | **1.4** PV = Square ((NDVI – NDVImin) / (NDVImax – NDVImin)) | PV | Raster File |
| | | **1.5** E = 0.004 * PV + 0.986 | E | Raster File |
| | | **1.6** LST = (BT / (1 + (0.00115 * BT / 1.4388) * Ln(ε))) | LST | Raster File |
| | **4.** Reproject LST layer to State Plan projected coordinate system using **Project Raster** | | LST_Reproject | Raster File |
| | **5.** Import New York borough boundary | | NYC_Boroughs | Vector File |
| | **6.** Clip the reprojected LST raster layer with NYC borough boundary using **Extract by Mask** | | LST_Clipped | Raster File |
| **Step 3:** Reclassify LST raster file | **7.** Reclassify LST raster file using **Reclassify (Spatial Analyst)** with a 30*30 feet cell size | **Note:** Choose manual classification with 5 bands. (15-28°C, 28-30°C, 30-32°C, 32-34°C, 34-44°C) and assign new value as (1,2,3,4,5) | NYC_LST_Reclassified | Raster File |

| | | | | |
|---|---|---|---|---|
| | **8.** Import NYC MapPluto data | | MapPluto | Vector File |
| | **9.** Use NYC MapPluto layer to clip NYC borough boundary with **Clip(Analysis)** tool to get street polygons | | NYC_Streets | Vector File |
| **Step 4:** Prepare PLUTO data for urban density analysis | **10.** Add new field named "NumFloors" with value 0 | | | |
| | **11.** Join MapPluto layer and NYC_Streets layer using **Union** function | | PLUTO_FullCover | Vector File |
| | **12.** Rasterized PLUTO_FullCover layer using **Feature to Raster** function, based on NumFloors. | | NYC_UrbanDensity | Raster File |
| **Step 5:** Reclassify NYC_UrbanDensity raster file | 13. Reclassify NYC_UrbanDensity raster file using **Reclassify (Spatial Analyst)** with a 30*30 feet cell size | **Note:** Choose manual classification with 6 bands.<br>(0-1, 1-3, 3-5, 5-8, 8-11, 11-104) and assign new value as (0,1,2,3,4,5) | NYC_Urban Density_Reclassified | Raster File |

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| | | | | |
|---|---|---|---|---|
| **Step 6:** Prepare Land Cover data for land cover analysis.<br>(Note: Due to file size concerns, only import Queens data | **14.** Using <u>Select by Attribute function</u>, select Queen's boundary data and export as a new layer | | QN_Boundary | Vector File |
| | **15.** Prepare Queens' full land cover data | **15.1** Use QN_Boundary file to clip NYC_Street File with <u>Clip(Analysis)</u> function, get Queens' street data | QN_Streets | Vector File |
| | | **15.2** Add two fields - LST_Class, LST_Value in QN_Streets' attribute table, use <u>Field Calculator</u> to assign "Bareland" to LST_Class, assign "7" to LST_Value | | |
| | | **15.3** Import Queens' land cover data (QN_LCpp) | QN_LCpp | Vector File |
| | | **15.4** Add two fields - LST_Class, LST_Value to QN_LCpp's attribute table | | |
| | | **15.5** Use <u>Field Calculator</u>, assign 18 land cover types into 5 categories.<br>Water, Open Water, Pool - Water Body;<br>Trees, Bush, Grass - Natural Landscape;<br>Bare Soil, Gravel, Sand, Rock, Wood - Bareland;<br>Asphalt, Concrete, Metal, Brick Paver - Impervious Surface;<br>Roof, Solar Panel, Synthetic Turf - Building. | | |
| | | **15.6** Use <u>Field Calculator</u>, assign unique values to the 5 categories:<br>Waterbody -0<br>Natural Landscape - 1<br>Bareland - 5<br>Impervious Surface - 7<br>Building - 10 | | |
| | | **15.7** Select all data and export as a new layer named QN_ClassField | QN_ClassField | Vector File |
| | | **15.8** Join QN_ClassField and QN_Streets layer using <u>Union</u> function | QN_FullCover | Vector File |
| **Step 7:** Rasterize QN_FullCover vector file based on values | **16.** Rasterized PLUTO_FullCover layer using <u>Feature to Raster</u> function, based on LST_Value with a 30*30 feet cell size | | DL_QN_LC_UrbanTexture | Raster File |

| | | | | |
|---|---|---|---|---|
| **Step 8:** Prepare Green Infrastructure Data for existing green infrastructure density analysis | **17.** Prepare Existing Green Roof Data | **17.1** Import existing green roof data GreenRoofData2016-2018 | GreenRoofData 2016-2018 | Vector File |
| | | **17.2** Extract centroid points of existing green roofs using **Feature to Points** function and export as new point feature. | NYC_GreenRoof_Points | Point Feature |
| | **18.** Import existing green infrastructure data and immediately export as new point feature named NYC_GreenInfrastructure_Points | | NYC_GreenInfrastructure_Points | Point Feature |
| | **19. Merge** NYC_GreenRoof_Points and NYC_GreenInfrastructure_Points | | NYC_Green_Sum_Points | Point Feature |
| | **20.** Run **Kernel Density** for NYC_Green_Sum_Points using a 1 mile search radiance | | NYC_GI_Kdensity_1mile | Raster File |
| **Step 9:** Reclassify NYC_GI_Kdensity_1mile raster file | **21.** Reclassify NYC_GI_Kdensity_1mile using **Reclassify (Spatial Analyst)** with a 30*30 feet cell size | **Note:** reclassify with 6 bands based on quantile classification but with minor adjustment to round up the value (0-13, 13-39, 39-87, 87-196, 196-588, 588-1118) and assign new value as (5,4,3,2,1,0) | NYC_GI_Kdensity_Reclassified | Raster File |
| **Step 10:** Prepare Final MCDA layer by clipping NYC level reclassified raster files to Queen's regional level | **23.** Clip the NYC_LST_Reclassified raster layer with QN_Boundary using **Extract by Mask** | | DL_QN_LST | Raster File |
| | **24.** Clip the NYC_UrbanDensity raster layer with QN_Boundary using **Extract by Mask** | | DL_QN_UrbanDevensity | Raster File |
| | **25.** Clip the NYC_GI_Kdensity_Reclassified raster layer with QN_Boundary using **Extract by Mask** | | DL_QN_GreenInfrastructure | Raster File |
| | **26.** Maintain DL_QN_LC_UrbanTexture as what it is | | DL_QN_LC_UrbanTexture | Raster File |
| ***Step 11:** create MCDA layer | **27.** Use Raster Calculator to calculate the final weighted decision layer | **Note:** MCDA formula DL_QN_LST*3 + DL_QN_LC_UrbanTexture*2 + DL_QN_GreenInfrastructure*2+ DL_QN_UrbanDevensity*1 = QN_MCDA | QN_MCDA | Raster File |

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|---|---|---|---|---|
| **Step 12:** Prepare for appropriate roof selection | **28.** Import NYC Building Footprints file | | BuildingFootprint | Vector File |
| | **29.** Use **Select by Attribute** feature to filter lots from Plutomap that are owned by city government based on field "OwnerType", export as a new dataset | | NYC_CItyOwnedProperties | Vector File |
| | **30.** Use **Select by Location** feature to sort BuildingFootprint that intersect with NYC_CityOwnedProperties | | | |
| | **31**. Use **Select by Location** function, to remove from previous selection which intersects with NYC_GreenRoof_Points | | | |
| | **32.** Use **Select by Location** function, to select from the previous selection that intersects with QN_Boundary | | | |
| | **33.** Export final selection as a new dataset | | QN_AvailableRoof_CityOwned | Vector File |
| **Step 13:** Covert MCDA grid cells to pints and spatial join to QN_AvailableRoof_CityOwned to find mean score of each roof | **34.**convert MCDA grid cells to points using **Raster to Point** function | | QN_MCDA_Raster_to_Points | Point Feature |
| | **35.** Use **Select by Location** function to select point features that intersect with QN_AvailableRoof_CityOwned | | QN_AvailableRoof_Extract_Point | Point Feature |
| | **36.** **Spatial Join** QN_AvailableRoof_Extract_Point to QN_AvailableRoof_CityOwned and calculate average/mean score of each roof | | Final_QN_AvailableRoof | Vector File |
| **Step 14:** Finalize selection | **37.** Finalize three roof selection and export as a new dataset | | Final_QN_SelectedRoof | Vector File |

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| | | | | |
|---|---|---|---|---|
| **Step 15 (optional):** For visualization | **38.** Inmport City Council District shapefile and use <u>**Select by Location**</u> function to fileter City Council District within Queens, then export to a new dataset named QN_CCD | | QN_CCD | Vector File |
| | **39.** Use <u>**Select by Location**</u> function to select features from QN_CCD that intersect with Final_QN_SelectedRoof and export as a new dataset named as QN_FinalSelection_CCD | | QN_FinalSelection_CCD | Vector File |
| | **40.** Use <u>**Feature to Point**</u> function to convert Final_QN_SelectedRoof to point features, named as QN_FinalSelection_Points | | QN_FinalSelection_Points | Point Feature |