Equitable Distribution Report

Planning Studio 405/605

Executive summary:

The project goal for our senior studio class was to expand on Dr. Heckert and Dr. Rosan's 14 factors of their equity index. While also working closely with a West Philadelphia neighborhood, applying our findings to their community. Our team focused primarily on working with the index, researching and running various analyses to help aid in getting a better understanding. Our primary mission was with the use of a more developed and updated index; we could implement these with the use of Green Stormwater Infrastructure (GSI).

Working with the community members at the Overbrook Environmental Education Center (OEEC) we got great feedback for the community. In regards to what aspect of the index is most important and which type of green infrastructure they would like to see in their neighborhood.

Within our findings both with research and the community member meeting, we developed the needed and prioritized changes we would need to make to the index. Our team decided the areas of primary focus are, Land Surface Temperature (LST), Toxic Release Facilities (TRI), and finally an updated Tree Canopy Coverage.

Literature Review:

Green infrastructure (GI) is a term that's been around since the 1980's. Its original intent was to help find the best management practices to achieve better stormwater management, runoff reduction, erosion prevention, and aquifer recharge. Today, green infrastructure is defined as a range of measures that use plant/soil, permeable surfaces, stormwater harvest, or landscaping to reduce flows to sewer systems or surface waters. This project takes a focus on Green Stormwater Infrastructure (GSI) which has additional benefits over GI.

GSI is designed to mimic nature and capture stormwater where it falls. Examples of this include rain gardens, stormwater trenches, green roofs, and porous pavements. This means that GSI reduces and treats stormwater at its source while providing additional community benefits such as: reduced localized flooding, upping community aesthetics, improving local economic health by creating jobs, and reducing the economic impacts from flooding.

With GSI having many community and environmental benefits that go along with it, it is important to talk about where this infrastructure gets installed. In 2017, an article was released to discuss the equitable distribution of GSI. This study was after understanding the factors that influence the variability in distribution of public and private investments in green stormwater infrastructure. For this study, they used indicators of community context and capacity. These indicators were defined as context being the characteristics of disadvantaged communities and capacity as factors that facilitate individual and collective action. Through the use of GIS and statistical analysis, it was found that there is “an inequitable distribution of GSI within Philadelphia” (Mandarano & Meenar, 2017,p. 1340). At the end of the article it was said that prioritization of public sector investment in disadvantaged communities is necessary to provide a more equitable distribution of GSI projects and their associated benefits.

But why does it matter where GSI is installed? Distributional justice. This is the concept that there is a fairness in the distribution of goods in a community. Looking back at the Mandarano and Meener article they had found an inequitable distribution of GSI projects, meaning that the allocation of GSI projects throughout the community was uneven, or not fair. In an effort to combat the inequitable distribution a three step framework in order to prioritize areas for public sector investments in GSI was developed. This framework details identifying tracts based on level of disadvantage, identifying tracts based on level of capacity, and identifying priority census tracts based on high levels of disadvantage and high levels of capacity. Through this framework, it is believed that this will give disadvantaged communities a chance to be prioritized for public investments in GSI (Mandarano & Meener, 2017).

A few years years ago the Philadelphia water department committed to a green infrastructure approach in an attempt to reduce stormwater runoff and prevent combined sewer overflows. An article from 2016 talks about the benefits of a green infrastructure approach for stormwater management. It states that “Green stormwater management practices include a range of interventions that use greening either alone or in conjunction with highly engineered systems for the primary purpose of reducing stormwater runoff” (Heckert & Rosan, 2016,p. 1). They also talk about green infrastructure as an opportunity and a challenge for equitable green infrastructure planning. In their article they state that the Philadelphia Water Department plans to invest nearly $1.6 billion over twenty years for this project. While this is an astounding amount of money for green infrastructure, it provides a challenging opportunity for the Philadelphia Water Department in that they need to engage with the community more to figure out where to put the infrastructure and what types of projects they can complete. This ultimately presents an opportunity for equitable decision making about this project but provides a challenge in that there is a reliance on private property and private property owners to implement this infrastructure and that it may accidentally privilege residents with a higher socio-economic status. This again goes back to the idea of distributional justice and the need for equitable distribution.

While having everyone’s voices be heard on this topic can be a great thing, Heckert and Rosan noted that “this distributed nature of decision making also presents the very real possibility that GI investments might reinforce inequalities among communities” (Heckert & Rosan, 2016,p. 2). In order to help combat this, they talked about developing an equity index for green infrastructure. They talked about how a strategy used by planners is becoming increasingly popular. This index combines a series of indicators which are then used to calculate a measure of need, deprivation, or risk. They developed their own index for

Philadelphia. There are two parts of this index: The socioeconomic factors which cover percent of the population that is a minority, percent of the population that falls into low income, percent of the population of adults who have not completed high school, percent of the population under the age of five, percent of the population over the age of 64, and percent of the population that owns their home. The second part of the index is built environment measures which includes: proximity to traffic, ozone levels, particulate matter levels, park access, tree canopy cover, playground access, impervious surfaces, and amount of vacant land. Heckert and Rosan, through their equity index, were able to show that the development of an index provides a higher understanding of communities and their needs for green infrastructure.

An article from 2018 talks about how creating GIS-based planning tools can be used to promote equity through green infrastructure. The authors state that while current planning tools exist to assist in the development of green infrastructure projects, limitations have surfaced on the considerations of non-environmental concerns. They stated that "several new planning tools have been proposed that use indexes and other need-based approaches to account for a wider range of potential program impacts" (Heckert & Rosan, 2018,p. 1). Heckert and Rosan propose a planning workflow that can be used to incorporate the equity index in planning. This work flow begins with the prioritization of factors influencing community need, then assessment of GI practices, then weighting of desired GI outcomes in order to determine what the community wants out of the green infrastructure, and then optimization modeling where it determines the methods of achieving desired outcomes. The authors state that they "propose the inclusion of more interactive methods for incorporating community perspectives on the benefits of GI into GI planning methodologies to make them both more equitable and more responsive to community needs" (Heckert & Rosan, 2018,p. 1).

While distributional justice can ultimately be considered one of the more important parts of determining where GSI projects are installed, it is also important to keep in mind procedural justice. This is the idea that there is a level of fairness in the processes that resolves disputes and allocates resources. An article was written on distributional justice of green spaces between two European cities, and it was found that there was an uneven distribution around the cities. This caused some unintended consequences as some minority groups have less access to these spaces when compared with the rest of the population (Silva, Viegas, Panagopoulos, & Bell, 2018). This also applies to green infrastructure in that Mandarano and Meener found an inequitable distribution of GSI projects. They theorized that the prioritization of public sector investment in disadvantaged communities is necessary to provide a more equitable distribution of GSI projects and their associated benefits. In order to ensure procedural justice was used, Heckert and Rosan developed an index that includes socio-economic factors as well as environmental factors. This index helps to promote equity in picking areas for GSI projects.

In order to align with procedural justice, a Green Infrastructure Spatial Planning (GISP) model was developed. This GIS based model includes a multi criteria approach that includes six benefits: Stormwater management, Social Vulnerability, Green Space, Air Quality, Urban Heat Island amelioration, and landscape connectivity. Combined with this model, stakeholders then weight priorities in order to identify hotspots where green infrastructure benefits are severely needed. After a comparison of the GISP model to the current green infrastructure projects in Detroit, they found that there is a disconnect between the two. The analysis provided evidence to suggest that green infrastructure is not being placed in areas that are labeled as high priority. They state that their model “provides an inclusive, replicable approach for planning future green infrastructure so that it maximizes social and ecological resilience” (Meerow & Newell, 2017,p. 1).

Another article by Sara Meerow talks about using green infrastructure spatial planning models for evaluating ecosystem tradeoffs. They state that with a growing number of cities investing in green infrastructure to foster urban resilience and sustainability. They go on to state that while most solutions are often promoted on the basis of their multifunctionality, in practice most focus on a single benefit: “this represents a missed opportunity to strategically site green infrastructure” (Meerow, 2019, p. 1). In order to address this gap, Meerow builds on existing modeling approaches for green infrastructure planning to create a more generalizable tool for comparing spatial tradeoffs and synergistic hotspots for multiple desired benefits. Meerow applied the model to three different megacities: New York City, Los Angeles, and Manilla in the Philippines. This enabled the different cities to be compared. This model empirically illustrates the complexities of planning green infrastructure in different urban areas (Meerow, 2019).

Ultimately the decisions on how to approach these projects in Philadelphia comes down to the stakeholders. The tools to ensure an equitable distribution of GSI are out there and ready to be used and or replicated.

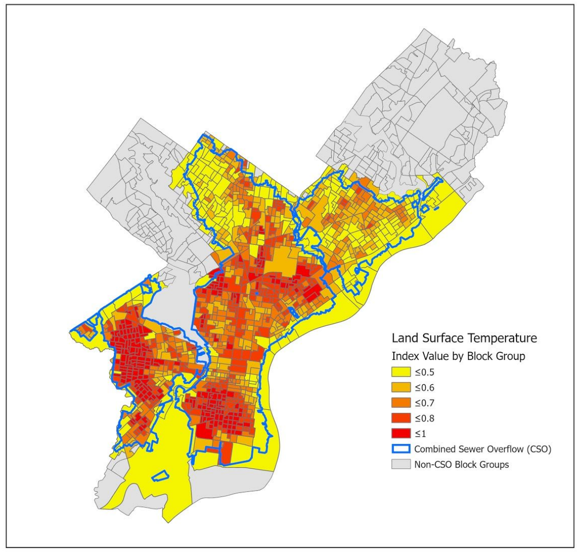
Updated Index:

This project goal was to expand more on the index of equity, established by Heckert and Rosan (2016). The pre-existing index included 14 factors, this project expanded in addition to two new factors, land surface temperature, Toxic release facilities and an updated pre-existing tree canopy. The index was designed to be consistently updated as areas change and time goes on. The importance of the index varies, but with the community members' input from the March 4th meeting, our team was able to narrow down which aspect was most important. This section dives deeper into why and how the index was expanded. Included are maps that illustrate how each of these features affected the Philadelphia region. These maps will also be including the combined sewer service and how it relates to these factors. This data is being shown using the census block group. This report explains the importance of these aspects and how the data can be transformed and shown.

The land surface temperature (LST):

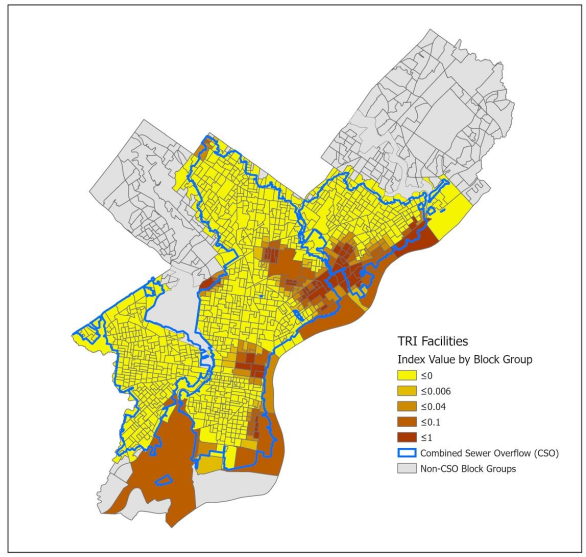
Land surface temperature is a key part when looking into effects of global warming issues. Understanding the heat island effect is important, providing focus on areas of higher population such as the Philadelphia region. The use of green infrastructure can help tremendously when mitigating higher land temperatures. Land surface temperature tends to be higher in the block groups with a lower income, high poverty, less education opportunity, elder community and areas of higher crime rate (Huang 2011). The included map uses a color coordinated system displaying areas in which are more prone to heat issues. The darker the red displays areas in which have a higher average land surface temperature. Creating the opportunity to focus on areas in which are high priority regarding heat mitigation.

Land Surface Temperature Map : The Land Surface Temperature (LST) data was obtained from USGS.gov Level-1 data, Landsat 8. The image was recorded on July 20, 2019 at 15:39:50. The USGS temperature calculation method was utilized. The method uses Bands 10 and 11 of Landsat 8 Thermal Infrared Sensors (TIRS). The calculations involve three conversions of the data, using constants, digital numbers and radiometric rescaling coefficients provided in the metadata file that is attached with the Landsat 8 download; 1. Conversion to Top Of Atmosphere (TOA) Radiance 2.Conversion to TOA Reflectance 3.Conversion to TOA Brightness Temperature. Each step uses a different formula (Landsat Missions. USGS). To ensure accuracy and the correct application of each equation, all computations were performed using R. Before applying the code, R was installed along with the “Raster” programming package. All conversion codes and steps were executed following the directions described in the article “*Calculations of Landsat Surface Temperature (LST) from landsat 8 using R.*” Two final raster layers were obtained from the conversion, band 10 and band 11. For our purpose we used band 10, as band 11 is more contaminated by stray light than band 10 (Martin 2016). A zonal statistics analysis was performed in ArcGIS Pro. The range was calculated. A new field “I-Temp” was added to the original index. The index score was calculated in the same manner as TRI facilities, the minimum temperature was subtracted from the block group temperature, and the difference was divided by the range. The analysis is represented on the map using quantile classification. The score of 0 indicates low need, and a score of 1 indicates high need.



TRI Facilities: Toxic Release Facilities (TRI), Is important because there has been a direct relation between the exposure of Toxic Release Facilities and urbanization (Ringquist 1997). Showing the specific census blocks that are prone to exposure of toxins that have been potentially released into the ground which can be found dangerous to these communities. It’s important to include this in our project because we want to ensure that we are pointing out areas in the city that need attention when it comes to cleaning these toxins up.

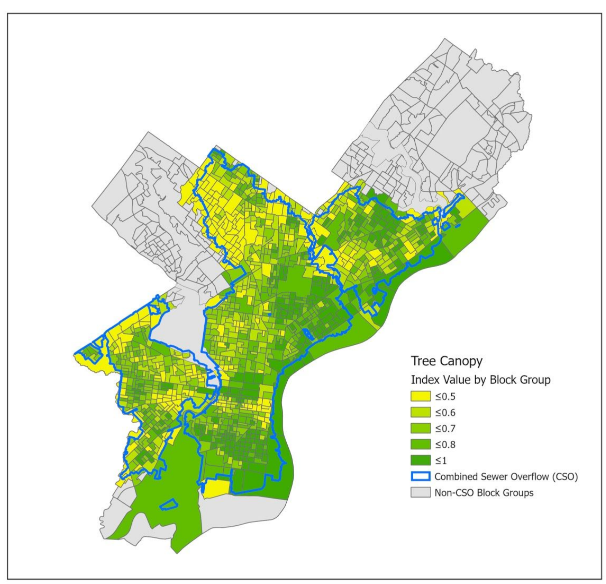
TRI Facilities Map: Toxic Release Inventory (TRI) data was obtained from EPA.Gov in a form of csv file. The file is a master list of all TRI facilities in Pennsylvania from 1987 to 2018. The facilities were geocoded in ArcGIS Pro, using the latitude and longitude information provided in the datafile. A selection by attribute and by location were performed to isolate the facilities within 1 mile of the Philadelphia County boundaries. A Kernel density analysis was applied to find the density of TRI facilities that are within 805 meters (½ mile) of the cells that cover the block groups. Extract values to points operation was performed. The range was calculated and a new field " I-TRI" was added to the original index. The Index score of I-TRI was calculated by subtracting the minimum value from the block group value and the difference was divided by the range of all the values. The analysis is represented on the map using quantile classification. A Score of 0 indicates low need and a score of 1 indicates high need .



Tree canopy 2018:

Tree canopy being one of the most cost effective and easiest ways to mitigate land surface temperature, while also creating green areas. Tree canopy coverage is important to include in this project because it shows the areas of Philadelphia that have coverage by tree, or areas that are being potentially exposed to the sun's rays. This is an important factor to look into due to the summer months, when the temperatures are rising. Resulting in a high urban heat island effect and a lack of community engagement between residents. This points out areas in the city that could use more tree cover. According to O'Neil Dunne's findings the tree canopy has dramatically declined in 2018 compared to the year of 2008. The importance of using updated data when looking at communities, makes decisions more accurate and clear. Within a short 10 year span Philadelphia has lost 1095 thousand acres of trees (O'Neil Dunne 2019).

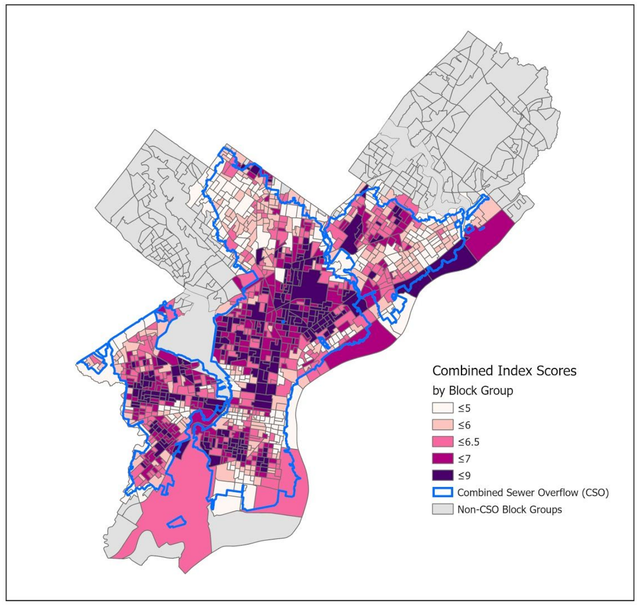
Tree Canopy Map : The raster layer of the tree canopy was retrieved from PASDA. The layer was reclassified in arcGIS Pro to 1 and 0, where 1 is tree canopy and 0 is all other land cover classes. A zonal statistics analysis with block groups as the feature layer was performed. The mean was calculated, and a select by attribute was performed to isolate the block groups with 30% or higher canopy coverage. A



new adjustment field was added to account for the 30% benchmark tree canopy coverage set by the city of Philadelphia. The range was calculated. A new field was added to the original index, “Canopy18”. The index score of Canopy 18 was calculated by subtracting the minimum value from the block group value and dividing the difference by the range. The result was subtracted from 1 to inverse the score . The analysis is represented on the map using quantile classification. A score of 0 indicates low need and a score of 1 indicates high need.

Combined indexes

The combined score was calculated by adding the scores of the original thirteen index values, the updated tree canopy values and the two new index values, TRI and LST. The combined score is represented on the map using quantile classification



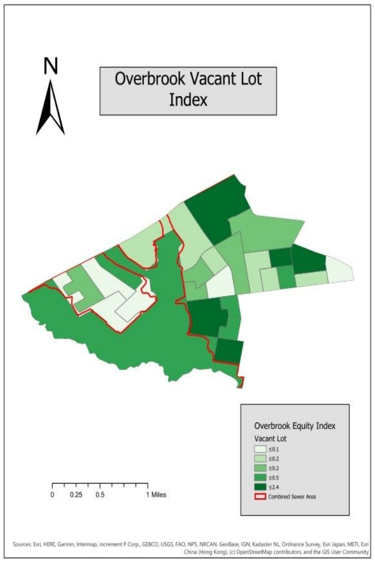
When these indexes are combined it gives up a new updated value. This is considered to be Philadelphia combined index score. According to this map the area of higher need can be found in central Philadelphia. These areas are in need of a mitigation method for high land surface temperature, exposure to toxic release raficilites and finally a low amount of tree canopy coverage.

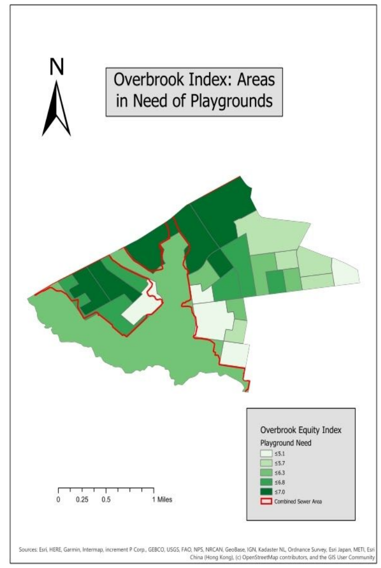
Recommendations for Overbrook:

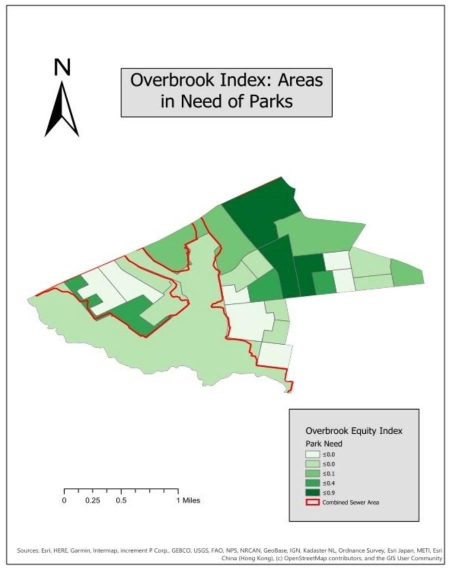
At the March 4th meeting at Overbrook Environmental Education Center, the Overbrook community showed much interest in implementing green stormwater infrastructure (GSI) within their community. During the processes of the meeting, we received great feedback from the community. West Chester University proposed nine elements to the community members, which represented areas where green stormwater infrastructure could potentially be installed. A voting system was set up where each community member was given five stickers to vote on the areas they would prioritise the installation of green stormwater infrastructure, with the option to place all stickers on one area or divide their votes on all 9 sections. Results of the votes are on the table below.

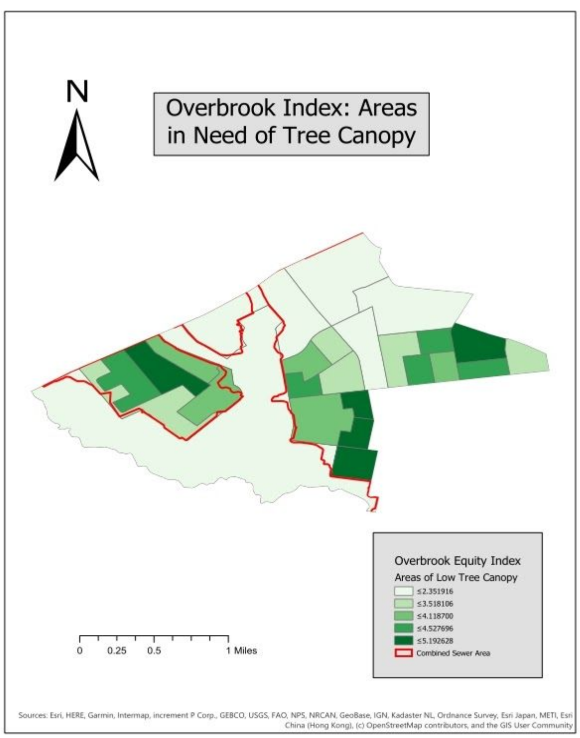
AREA	VOTES
65+ Population	13
Vacant Lots	11
Low Air Quality	10
High Summer Temperatures	8
Few Playgrounds	7
Low Property Values	7
Low Tree Canopy	6
High Traffic Area	6
Many Chemical Facilities	5

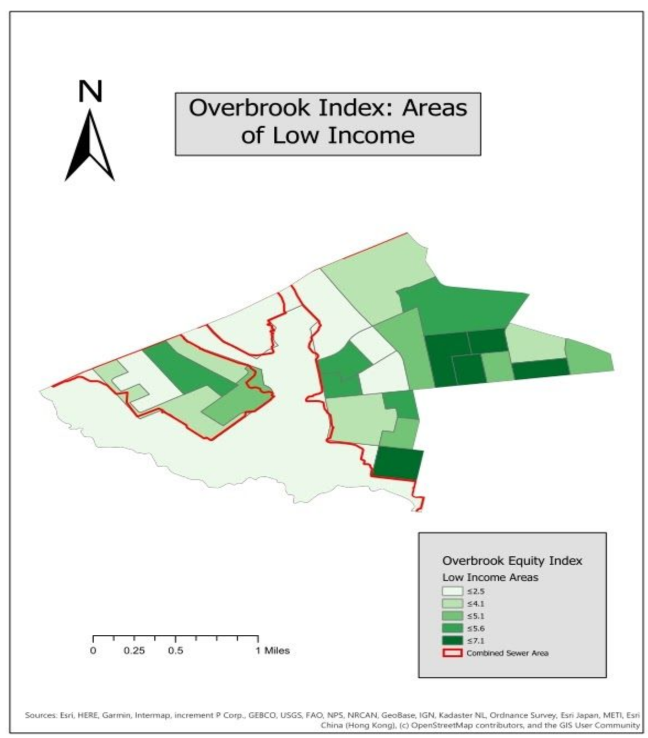
Once we tallied up the votes, they were then factored into Overbrook's Equity Index, to identify what parts of the community are in greatest need of GSI. Nine input layers were chosen for Overbrook: 65+ Population, Vacant Lots, Low Air Quality, Low Income, Land Surface Temperatures, Few Playgrounds, Low Tree Canopy, High Traffic Areas, and Many Chemical Facilities. Each of these input layers had existing scores, derived from those of Dr. Heckert and Dr. Rosan's city-wide green infrastructure equity index (Heckert & Rosan, 2016). These existing scores were then isolated to only the block groups within Overbrook, and multiplied by the amount of votes they received at the community meeting. Using quantile classification, we grouped the scores into five separate values for each input layerThe maps on pages 14-15 identify the block groups in which have greatest need for each value, with the highest numbers indicating highest need

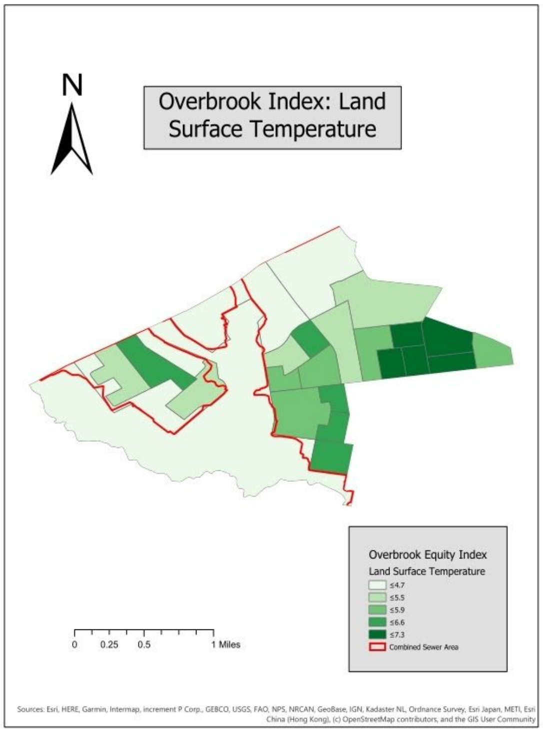

N
Overbrook Vacant Lot Index
Overbrook Equity Index
Vacant Lot
≤0.1
≤0.2
≤0.2
≤0.5
≤2.4
Combined Sewer Area
0 0.25 0.5 1 Miles

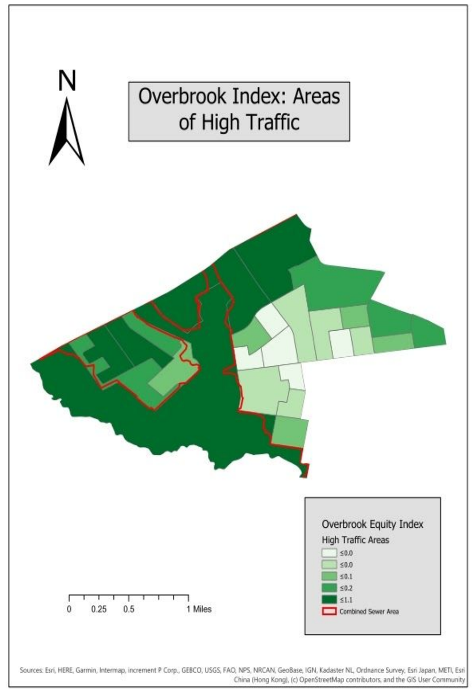

N
Overbrook Index: Areas in Need of Playgrounds
Overbrook Equity Index
Playground Need
≤5.1
≤5.7
≤6.3
≤6.8
≤7.0
Combined Sewer Area
0 0.25 0.5 1 Miles

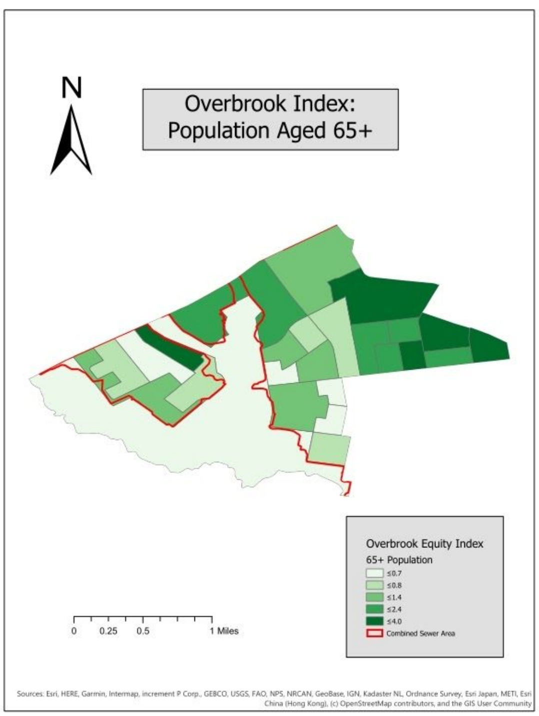

N
Overbrook Index: Areas in Need of Parks
Overbrook Equity Index
Park Need
≤0.0
≤0.0
≤0.1
≤0.4
≤0.9
Combined Sewer Area
0 0.25 0.5 1 Miles

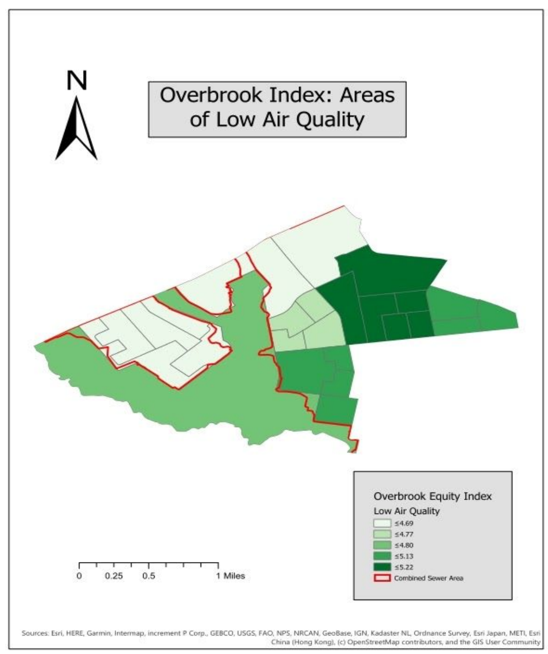

N
Overbrook Index: Areas in Need of Tree Canopy
Overbrook Equity Index
Areas of Low Tree Canopy
≤2.351916
≤3.518106
≤4.118700
≤4.527696
≤5.192628
Combined Sewer Area
0 0.25 0.5 1 Miles
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

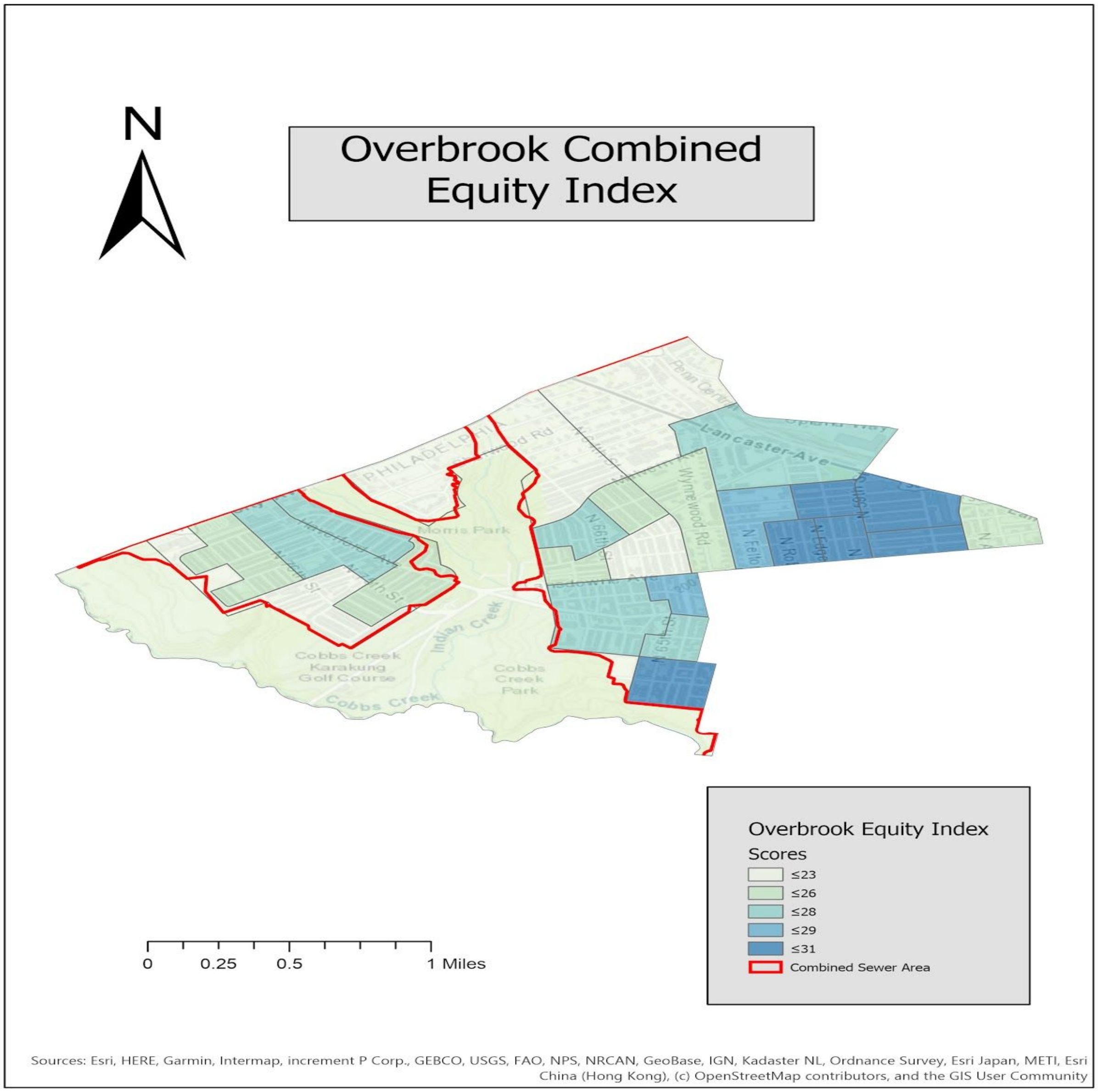

N
Overbrook Index: Areas of Low Income
Overbrook Equity Index
Low Income Areas
≤2.5
≤4.1
≤5.1
≤5.6
≤7.1
Combined Sewer Area
0 0.25 0.5 1 Miles
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community


N
Overbrook Index: Land Surface Temperature
Overbrook Equity Index
Land Surface Temperature
≤4.7
≤5.5
≤5.9
≤6.6
≤7.3
Combined Sewer Area
0 0.25 0.5 1 Miles
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community


N
Overbrook Index: Areas of High Traffic
Overbrook Equity Index
High Traffic Areas
≤0.0
≤0.0
≤0.1
≤0.2
≤1.1
Combined Sewer Area
0 0.25 0.5 1 Miles
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community


N
Overbrook Index: Population Aged 65+
Overbrook Equity Index
65+ Population
≤0.7
≤0.8
≤1.4
≤2.4
≤4.0
Combined Sewer Area
0 0.25 0.5 1 Miles
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community


N
Overbrook Index: Areas of Low Air Quality
Overbrook Equity Index
Low Air Quality
≤4.69
≤4.77
≤4.80
≤5.13
≤5.22
Combined Sewer Area
0 0.25 0.5 1 Miles
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community



Once these maps were created, the scores of each input value were tallied up by block group into a separate field, combining all index scores. The end result is our Overbrook Combined Equity Index. According to this map, the areas of Overbrook in greatest need are on the eastern and southeastern ends, which face low air quality, low tree canopy, high population over 65, high populations of low income, and high land surface temperature.Coincidentally, eastern and southeastern Overbrook also happen to have a large number of vacant lots that can be converted in green stormwater infrastructure.

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