Fall 2020

Canopy Cover, Impermeability, and Green Space in Pennsylvania Redlined Neighborhoods

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Abstract

Previous studies have explored the relationship between redlining and canopy cover by using percent canopy cover. This data type can miss low-density trees that are common in urban areas, differences between parks and street trees, and differences in the size of the green space. With a distinction between parks and street trees, we are able to determine what types of green space redlined communities have access to, since different types of green space have different kinds of impacts on the community. This study aims to analyze the relationship between previously redlined Pennsylvania neighborhoods and their current canopy impermeability, using high resolution tree canopy cover data. As was hypothesized, both York and Philadelphia grade D neighborhoods had less green space, smaller areas of contiguous green space, and were farther from green space. This perpetuates the cycle of systemic racism in urban communities and reinforces environmental injustices.

Keywords

Redlining, Land Cover, Green Space, Geospatial Analysis, LIDAR, Environmental Justice, Geographic Information Systems

Disciplines

Environmental Studies | Race, Ethnicity and Post-Colonial Studies | Urban Studies and Planning

Comments

Written for ES 450: Independent Study in Environmental Studies

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ES450: Individualized Study

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1. Introduction

Research has shown that green space in communities is beneficial to its citizens, increasing the quality of life, impacting health and well-being, especially of those living in urban communities (Zhang et al. 2017). Urban communities with limited green space are quickly becoming "urban heat islands", meaning that with more concrete and fewer green space, temperatures will continue to rise (Howard Center for Investigative Journalism 2017). These residents tend to have more medical issues relating to their heart, kidney, and lung health, in addition to prescription drugs for mental illness and diabetes being less effective, and pregnant women giving birth to children with more medical problems (Howard Center for Investigative Journalism 2017). Numerous studies have linked these communities that are suffering from extreme temperatures and related health issues, with historically redlined neighborhoods (Plumer and Popovich 2020).

1.1. Redlining and Access to Green Space

Redlining was a practice beginning in the 1930s that marked areas that were mainly inhabited by Black residents, as areas for mortgage lenders to avoid (Perry and Harshbarger 2019). Between 1935 and 1940, the Home Owners Loan Corporation assigned grades to residential neighborhoods, which were determined to reflect mortgage security (Nelson et al. 2020). Highest ranked neighborhoods were given an A grade, while those receiving the lowest ranking were given a D grade, with the D ranked neighborhoods being considered "hazardous" for loans and investments and would therefore not be given loans (Nelson et al. 2020). Redlining appears to have a lasting impact today by playing a role in de facto segregation and discrimination, and strong correlations in access to green space. A 2013 published study explored the relationship between land cover, classification as heat risk related land cover or HRRLC, and residential segregation (Jesdale et al. 2013). Using 2001 data from the National Land Cover Dataset and 2000 census data, they were able to compare land cover with demographic data (Jesdale et al. 2013). Groups were classified as living in a HRRLC area, if half of the population or more experienced lack of tree canopies and if more than half of the ground was covered by impermeable surfaces (Jesdale et al. 2013). This study determined that non-Hispanic Blacks, non-Hispanic Asians, and Hispanics, were 52%, 32%, and 21% more likely than non-Hispanic whites to live in a HRRLC classified area, respectively (Jesdale et al. 2013). In a more recent study, they compared previously redlined neighborhoods to estimates of land surface temperature using satellite imagery (Wilson 2020). The study focused on three cities: Baltimore, MD, Dallas, TX, and Kansas City, MO (Wilson 2020). Wilson noted that most studies focused on the relationship between heat exposure and human health, but using air temperature data, which is not the same as land surface temperature (Wilson 2020). They found that marginalized groups and lower socioeconomic groups made up the majority of the residents within these areas that were previously redlined, and that those areas have higher average land surface temperatures (Wilson 2020).

A final study analyzed the relationship between historical redlining and current canopy cover in neighborhoods (Locke et al. 2020). This study compared previously redlined neighborhoods with neighborhoods which were not previously redlined. In 37 urban areas that were previously redlined and are currently inhabited by marginalized groups, they found that there is approximately 23% tree canopy cover (Locke et al. 2020). This differs greatly from neighborhoods which were not redlined, classified as "Grade A", and inhabited by mainly white citizens born in the United States (Locke et al. 2020). These areas had approximately 43% tree canopy cover, which is almost twice as much as the tree canopy cover in the previously redlined neighborhoods (Locke et al. 2020). It was also determined that these results were consistent across small and large urban areas, and that it allowed for the conclusion to be made that there is a statistically significant relationship between historical redlining and canopy cover (Locke et al. 2020).

Extensive research has been done to explore the different impacts of this issue. One study focused on redlined neighborhoods and human health in Atlanta, Chicago, Cleveland, Los Angeles, Miami, New York, Oakland, San Francisco, and St. Louis (Nardone et al. 2020). Their hypothesis was that redlining impacted racial and ethnic inequalities relating to health, which they investigated using census data, data from the Centers for Disease Control, and health data from the 500 Cities Project (Nardone et al. 2020). It was determined that there are strong relationships between redlined neighborhoods and higher rates of health problems including cancer, asthma, poor mental health, and lack of health insurance, especially compared to areas which were not redlined (Nardone et al. 2020). Another study looked specifically at the relationship between redlining and preterm birth, which is classified as being less than 37 weeks gestation (Krieger et al. 2020). This study looked at all single births in New York City from 2013 to 2017, and analyzed the maternal residence at time of birth to census data and redlined neighborhood data (Krieger et al. 2020). In not redlined neighborhoods that were classified "Grade A", or the "best" classification in the redlining data, 5% of births were preterm (Krieger et al. 2020). This contrasts to redlined neighborhoods, which were classified as "Grade D" or "hazardous" neighborhoods, where 7.3% of births were preterm (Krieger et al. 2020). These results were determined to be statistically significant, indicating that historic redlining could be a factor in current preterm birth risks (Krieger et al. 2020).

1.2. Objectives

Previous studies have investigated connections between redlined neighborhoods and canopy impermeability, by calculating percent canopy cover using the Landsat-based NLCD tree canopy data set. This type of data can miss low-density tree canopies that are common in urban areas, which is especially important as redlined neighborhoods tend to be in urban areas. Percent canopy cover can also miss the differences between parks and street trees, often excluding street trees, and the differences in the size of the green space. With a distinction between parks and street trees, we are able to determine what types of green space redlined communities have access to, since different types of green space have different kinds of impacts on the community.

This study aims to analyze the relationship between previously redlined Pennsylvania neighborhoods and their current canopy impermeability, using high resolution tree canopy cover data. There are three main research questions which this study will address.

1. How does percent green space in redlined neighborhoods differ to that of non-redlined neighborhoods?
2. How does the average distance from green space differ between redlined neighborhoods and non-redlined neighborhoods?
3. How does the average size of contiguous green space differ between redlined neighborhoods and non-redlined neighborhoods?

It is hypothesized that previously redlined neighborhoods have significantly less canopy and permeable surfaces, less areas of contiguous canopy and permeable surfaces, and be farther from those areas on average.

2. Methods

2.1. Study Area

Two cities, York and Philadelphia, were selected based on the fact that the two cities are in a similar location, as both are located in South Eastern Pennsylvania, but are vastly different in size (Figure 1).

York has an estimated population of 43,932 people as of 2019 and had 43,807 people in 2010 (United States Census Bureau 2020). The city is 59.6% white, 33.3% Hispanic or Latino, 25.8% Black or African American, and about 15.9% of other races combined (United States Census Bureau 2020). In 2010, York was 5.29 square miles with a population density of 8,259.6 people per square mile (United States Census Bureau 2020).

Philadelphia has an estimated population of 1,584,064 people as of 2019 and had 1,526,012 people in 2010. The city is 41.2% white, 42.3% Black or African American, 14.5% Hispanic or Latino, and 10.6% of other races combined (United States Census Bureau 2020). In 2010, Philadelphia was 134.1 square miles with a population density of 11,379.5 people per square mile (United States Census Bureau 2020).

2.2. Redlining Data

In ArcGIS, a redlining shapefile was downloaded from Mapping Inequality's data on redlined neighborhoods (Nelson et al. 2020). The University of Richmond's Digital Scholarship Lab as well as Virginia Tech and University of Maryland students and professors, georeferenced historical HOLC maps, created polygons, and transcribed area transcriptions in order to create this dataset (Nelson et al. 2020).

Redlining was formed to continue to perpetuate racist systems, which is evident in the redlining official descriptions, which outline each neighborhood's grade as well as the reasoning behind it. Grade A descriptions for both cities included statements such as "well restricted residential area" and "section is desirable, but danger of Jewish encroachment is imminent. (Nelson et al. 2020). Grade D neighborhood descriptions for both cities included statements such as "Negro concentration-heavy adolescence" and "concentration of undesirables, low class whites and negro" (Nelson et al. 2020). While redlining itself is no longer around, the impact it creates is still in motion and continues to contribute to the cycle of racism.

2.3. Canopy and Impermeable Surface Data

A one-meter resolution tree canopy raster layer which was derived from LIDAR, was downloaded from the Spatial Analysis Laboratory at the University of Vermont (O'Neil-Dunne 2015). A 2011 30 meter resolution raster of Pennsylvania impermeable surfaces was downloaded from the National Land Cover Database. The analysis was conducted in a 30 meter resolution.

To analyze the different types of green spaces, four classes were determined.

1. Tree canopy and permeable surfaces
2. Tree canopy and impermeable surfaces
3. No tree canopy and permeable surfaces
4. No tree canopy and impermeable surfaces

Each 30 meter pixel was defined as tree canopy if the pixel met or exceeded the determined threshold of 25% canopy. Each 30 meter pixel was defined as impermeable surfaces if it met or exceeded a threshold of 85% impermeable. The four classes were created using the raster calculator to determine regions which met the criteria of the four classes.

2.4 Analysis

In order to determine the percent area of each of the four classes in each HOLC grade, the zonal statistics tool was utilized. To determine the average distance to green space from each HOLC grade, the layers of each of the four classes were combined, converted into polygons, and analyzed with the euclidean distance and zonal statistics tools. To determine the average patch size of each of the four classes, the redlining and polygon layers were intersected, and then the table was summarized by average area for each class. A more detailed method is included in Appendix A.

3. Results

3.1. How does percent green space in redlined neighborhoods differ to that of non-redlined neighborhoods?

The results indicate that on average, grade A neighborhoods will have more canopy and permeable surfaces, while grade D neighborhoods will have more areas with no canopy and impermeable surfaces (Figure 2). This trend is present in both York and Philadelphia.

It was determined that the average percent of no canopy and impermeable surfaces was 25% for grade A neighborhoods and 50% for grade D neighborhoods (Figure 2). This makes it evident that in York, grade A neighborhoods on average have nearly four times as much canopy and permeable surfaces while grade D neighborhoods have twice as much area with no canopy and or permeable surfaces (Figure 3). In Philadelphia, it was determined that the average percent of canopy and permeable surfaces was 78% for grade A neighborhoods and 20% for grade D neighborhoods (Table 1). In Philadelphia, it was determined that the average percent of no canopy and impermeable surfaces was 3.2% for grade A neighborhoods and 31% for grade D neighborhoods (Table 1). Philadelphia grade A neighborhoods have nearly four times as much canopy and permeable surfaces, while grade D neighborhoods have nearly ten times as much area with no canopy of permeable surfaces (Figure 3). Overall, grade A neighborhoods have a much higher percentage of area with canopy and permeable surfaces, while grade D neighborhoods have a much higher percentage of areas with no canopy and impermeable surfaces

3.2. How does the average distance from canopy and permeable surfaces differ between redlined neighborhoods and non-redlined neighborhoods?

In both Philadelphia and York, grade A neighborhoods were on average much closer to green space, while grade D neighborhoods were on average much farther from green space, with grade

B and C neighborhoods falling in between (Figure 4). In York, it was an average distance of 13.83 meters from HOLC grade A neighborhoods to green space, while it was an average distance of 82.3 meters from HOLC grade D neighborhoods (Table 2). York grade D neighborhoods were on average, nearly six times farther from green spaces (Figure 5). In Philadelphia, it was an average distance of 21.33 meters from HOLC grade A neighborhoods to green space, while it was an average distance of 143.28 meters from HOLC grade D neighborhoods (Table 2). Philadelphia grade D neighborhoods were on average, nearly seven times farther from areas with canopy and permeable surfaces (Figure 5).

3.3. How does the average size of contiguous green space differ between redlined neighborhoods and non-redlined neighborhoods?

In both Philadelphia and York, grade A neighborhoods have much more areas of canopy and permeable surfaces. Grade D neighborhoods have more areas with no canopy and impermeable surfaces, but the difference is much smaller than in areas of canopy and permeable surfaces (Figure 4). In York, the average patch size of class 1 areas with canopy and permeable surfaces was 32,044.8 meters for HOLC grade A neighborhoods and 2,489.39 meters for HOLC grade D neighborhoods (Table 3). The average patch size of class 4 areas with no canopy and impermeable surfaces was 1,646.94 meters for HOLC grade A neighborhoods and 6,648.7 meters for HOLC grade D neighborhoods. In York, the average patch size of areas with canopy and permeable surfaces was nearly 13 times larger in grade A neighborhoods than in grade D neighborhoods (Figure 6). The average patch size of areas with no canopy and impermeable surfaces was nearly four times higher in grade D neighborhoods than in grade A neighborhoods. In Philadelphia, the average patch size of class 1 areas with canopy and permeable surfaces was

95,048.88 meters for HOLC grade A neighborhoods and 3,626.29 meters for HOLC grade D neighborhoods (Table 3). The average patch size of class 4 areas with no canopy and impermeable surfaces was 1,646.94 meters for HOLC grade A neighborhoods and 10,216.95 meters for HOLC grade D neighborhoods. In Philadelphia, the average patch size of areas with canopy and permeable surfaces was roughly 26 times larger in grade A neighborhoods than in grade D neighborhoods (Figure 6). The average patch size of areas with no canopy and impermeable surfaces was roughly 6 times higher in grade D neighborhoods than in grade A neighborhoods.

4. Discussion

This study found that formerly redlined neighborhoods have less green space, are farther from green space, and have fewer areas of contiguous green space. Our study had similar results to many similar studies. In the study on residential housing segregation and urban tree canopy, they looked at 37 formerly redlined urban areas and found that grade D neighborhoods have about 23% canopy, as opposed to grade A neighborhoods which had 43% canopy (Locke et al. 2020). This is nearly twice as much canopy. In our study, it was determined that in York, 17% of areas in grade D neighborhoods had canopy and permeable surfaces, while 67% of areas in grade A neighborhoods had canopy and permeable surfaces. In Philadelphia, 20% of areas in grade D neighborhoods had canopy and permeable surfaces, while 78% of areas in grade A neighborhoods had canopy and permeable surfaces. In both York and Philadelphia, there was nearly four times as much canopy and permeable surface in grade A neighborhoods, which is quite similar to the previous study done. Our study builds on the previous research which only addressed canopy, by also focusing on impermeability, as well as other measures of accessibility.

Other research focuses on the idea of access to green space, but most of it does not explore other ways of analyzing this access other than simply percent canopy. Average size of contiguous green space gives a lot of information about the distribution of canopy and permeable surfaces. This differentiates between parks, backyards, and other large green spaces, as opposed to a small square of grass with a tree in the sidewalk. Having access to green space for recreational use is important to health, as well as important for keeping overall community temperatures low. Grade A neighborhoods had 13 times larger areas of contiguous canopy and permeable surfaces in York, and 26 times larger in Philadelphia. Grade D neighborhoods in these cities had much smaller average patch size of contiguous canopy and permeable surfaces on average. Grade D neighborhoods additionally had larger patch size of areas that had no canopy and impermeable surfaces, with these areas being nearly four times larger in York and roughly 6 times larger in Philadelphia. The rest of the areas were composed of classes that either had canopy and impermeable surfaces or no canopy and permeable surfaces. Differentiating between four separate classes of canopy impermeability is important due to the different impacts that they have on the community. Canopy and permeable surfaces will have a much larger overall beneficial effect than just either canopy or permeable surfaces. These larger areas of contiguous canopy and permeable surfaces, specifically over 300 square meters, was what was determined to be green space. In furthering the analysis of green space accessibility, distance gave a lot of information regarding true accessibility. In historically redlined areas that may still be areas in poverty today, the ability to be in walking distance of green space is more critical. While what is considered walking distance may be subjective, in York grade D neighborhoods are nearly 6 times farther from areas with canopy and permeable surfaces, while in Philadelphia they were nearly 7 times farther, indicating less access than grade A neighborhoods.

Previous studies named limitations including using 2001 NLCD impervious data, which did not differentiate between type of material and how impermeable the surface is (Jesdale et al. 2013). Our study improved on this by using the more recent NLCD imperviousness data from 2011, which has percent imperviousness and differentiates between material type. The main limitation of this study is the fact that average distance was calculated using Euclidean distance, which is in a straight line. In reality, people cannot walk in a straight line or as the crow flies, and Euclidean distance may not be as accurate if there are highways, train tracks, buildings, etc. in the way.

5. Conclusions

Historical redlining classified neighborhoods into four classifications, with grade A being the highest and theoretically best investment opportunity, while grade D was the lowest and theoretically worst investment. There is ample research indicating that there is a relationship between redlining and canopy impermeability, as well as the resulting health impacts. It was hypothesized that grade A neighborhoods would have more access to green spaces, or areas with canopy and permeable surfaces, which was supported by the findings in both cities. In both York and Philadelphia, grade D neighborhoods had less green space, smaller areas of contiguous green space, and were farther from green space. This perpetuates the cycle of systemic racism in urban communities and reinforces environmental injustices.

Tables

Table 1: The percent of each of the four classes, for each of the four HOLC grades in York, Pennsylvania and Philadelphia, Pennsylvania.

York			**Philadelphia**		
Class 1: Canopy/permeable			**Class 1: Canopy/permeable**		
HOLC Grade	**Average**	**Standard Deviation**	**HOLC Grade**	**Average**	**Standard Deviation**
A	0.67	0.47	A	0.78	0.41
B	0.32	0.47	B	0.49	0.50
C	0.12	0.32	C	0.32	0.47
D	0.17	0.38	D	0.20	0.40
Class 2: Canopy/impermeable			**Class 2: Canopy/impermeable**		
HOLC Grade	**Average**	**Standard Deviation**	**HOLC Grade**	**Average**	**Standard Deviation**
A	0.06	0.23	A	0.0012	0.034
B	0.16	0.37	B	0.0014	0.037
C	0.24	0.43	C	0.0045	0.067
D	0.23	0.42	D	0.009	0.094
Class 3: No canopy/permeable			**Class 3: No canopy/permeable**		
HOLC Grade	**Average**	**Standard Deviation**	**HOLC Grade**	**Average**	**Standard Deviation**
A	0.21	0.40	A	0.19	0.39
B	0.18	0.39	B	0.43	0.49
C	0.10	0.30	C	0.47	0.50
D	0.13	0.34	D	0.48	0.50
Class 4: No Canopy/impermeable			**Class 4: No Canopy/impermeable**		
HOLC Grade	**Average**	**Standard Deviation**	**HOLC Grade**	**Average**	**Standard Deviation**
A	0.07	0.25	A	0.032	0.17
B	0.33	0.47	B	0.082	0.27
C	0.54	0.50	C	0.21	0.41
D	0.47	0.50	D	0.31	0.46

Table 2: The average distance in meters from each of the four HOLC grades to areas of canopy and permeable surfaces over 300 square meters in York, Pennsylvania and Philadelphia, Pennsylvania.

York			Philadelphia		
HOLC Grade	**Average**	**Standard Deviation**	**HOLC Grade**	**Average**	**Standard Deviation**
A	13.83	25.60	A	21.33	44.75
B	39.74	43.29	B	63.97	76.36
C	73.12	53.64	C	98.64	89.19
D	82.30	88.61	D	143.28	125.06

Table 3: Average patch size in meters of the four determined classes for each of the four HOLC grades, for York, Pennsylvania and Philadelphia, Pennsylvania.

York		Philadelphia	
Class 1: Canopy/permeable		**Class 1: Canopy/permeable**	
HOLC Grade	**Average**	**HOLC Grade**	**Average**
A	32044.80	A	95048.88
B	6020.92	B	12911.84
C	2013.37	C	6203.77
D	2489.39	D	3626.29
Class 2: Canopy/impermeable		**Class 2: Canopy/impermeable**	
HOLC Grade	**Average**	**HOLC Grade**	**Average**
A	1033.24	A	829.49
B	1647.75	B	823.26
C	2156.39	C	800.48
D	1866.60	D	845.84
Class 3: No canopy/permeable		**Class 3: No canopy/permeable**	
HOLC Grade	**Average**	**HOLC Grade**	**Average**
A	1866.67	A	3868.91
B	1644.88	B	10045.57
C	1228.02	C	9283.40
D	1342.04	D	12418.86
Class 4: No Canopy/impermeable		**Class 4: No Canopy/impermeable**	
HOLC Grade	**Average**	**HOLC Grade**	**Average**
A	1646.94	A	4311.33
B	5398.53	B	4958.52
C	14273.05	C	7463.09
D	6648.70	D	10216.95

7. Figures

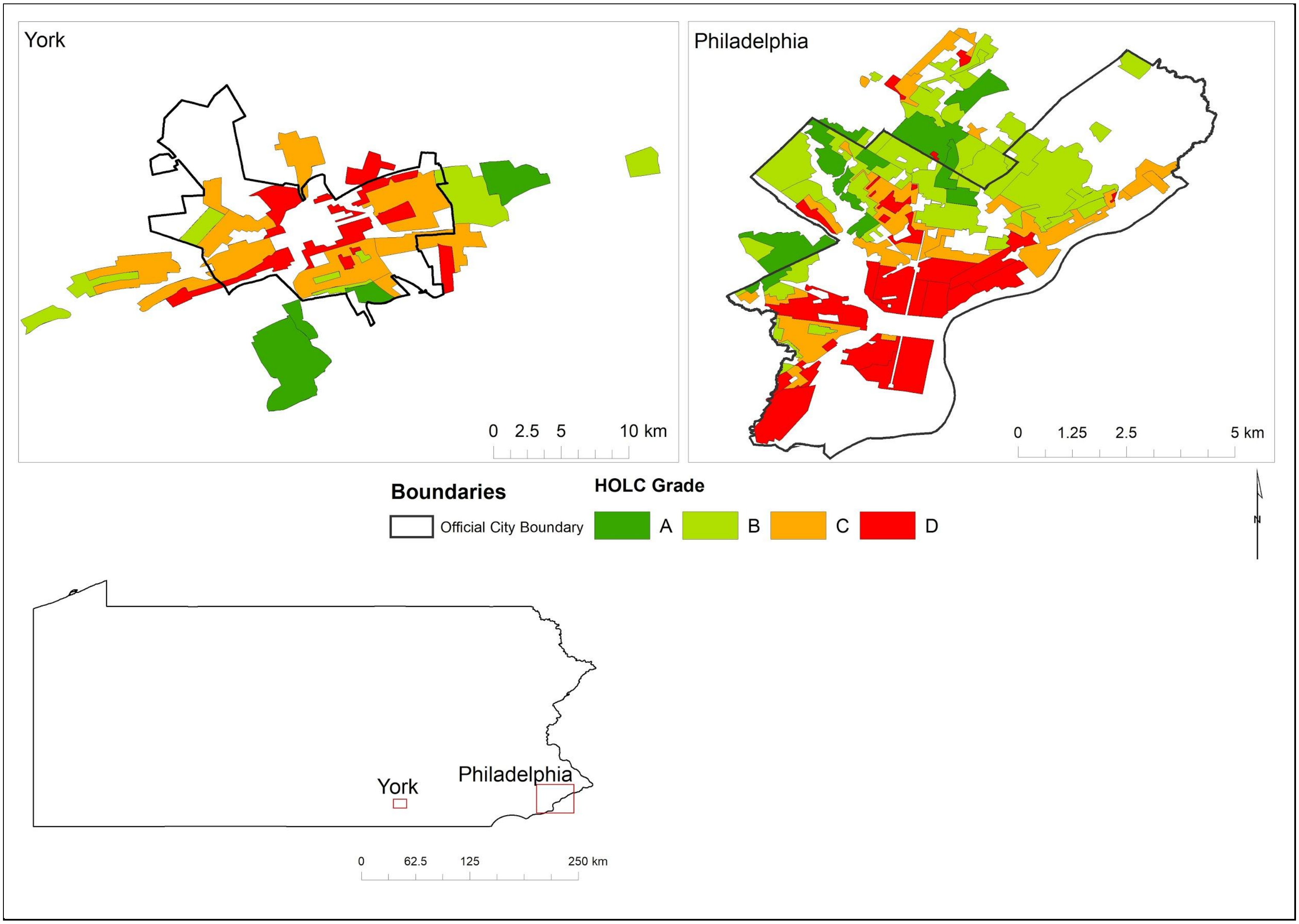

Figure 1: Map of study areas: York and Philadelphia, Pennsylvania, with York located West of Philadelphia. Redlined neighborhoods are marked in the insets.

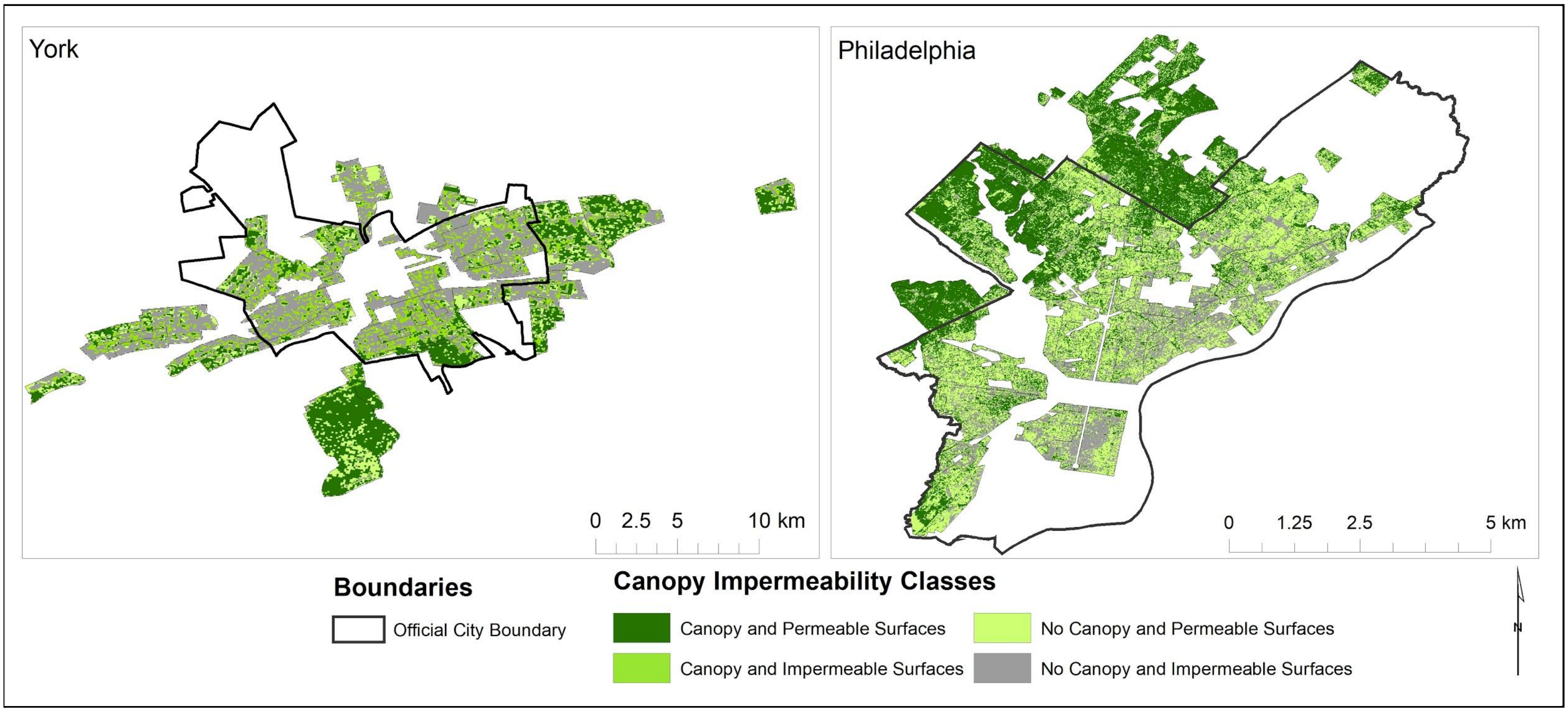

Figure 2: The land cover classes in York and Philadelphia, Pennsylvania. Grade A neighborhoods (shown in Figure 1), have more areas that are canopy and permeable surfaces than areas that were classified as grade D neighborhoods.

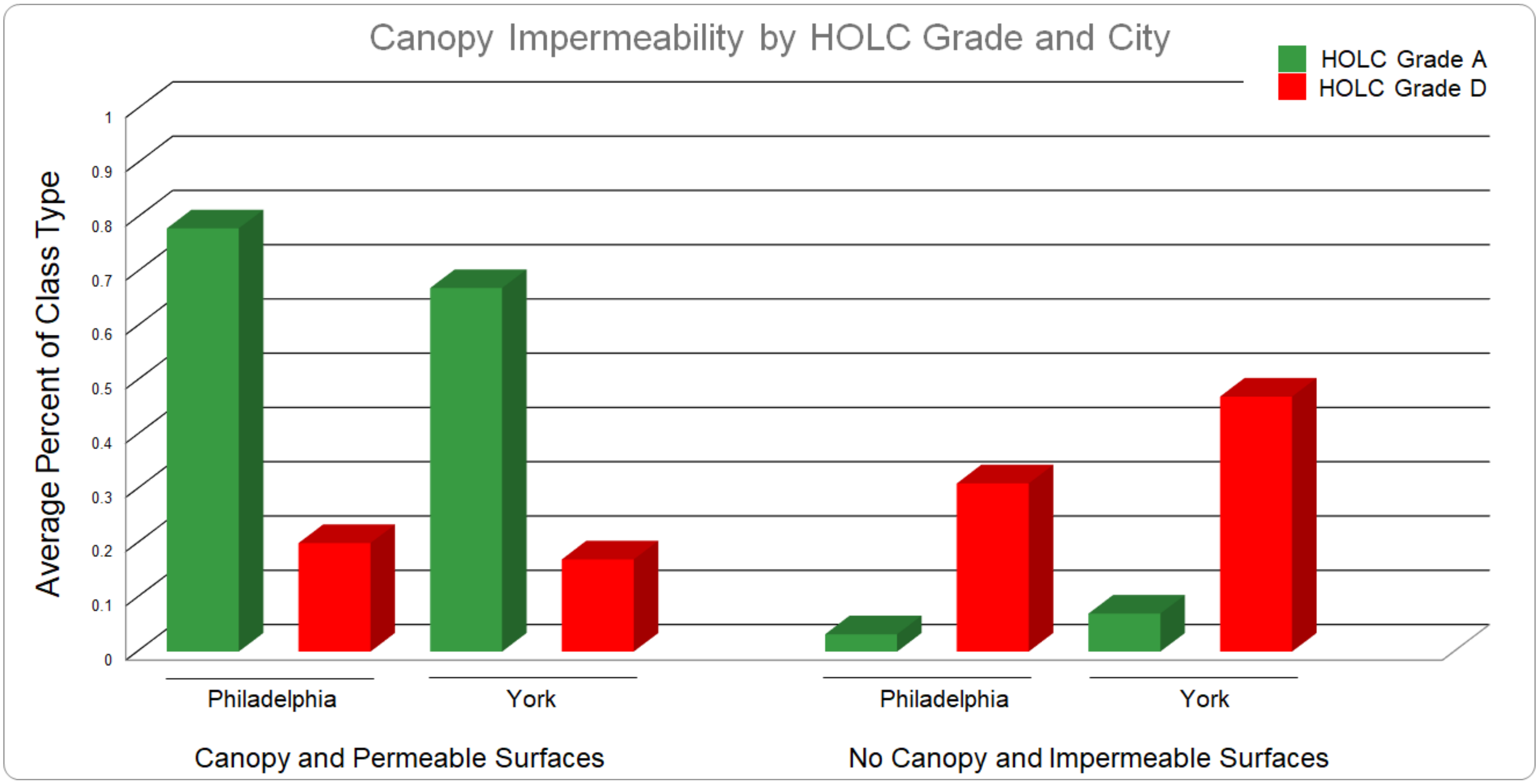

Figure 3: The percent cover of class type for Philadelphia and York, Pennsylvania. HOLC grade A neighborhoods have significantly more areas with canopy and permeable surfaces, where grade D neighborhoods have significantly more areas with no canopy and impermeable surfaces.

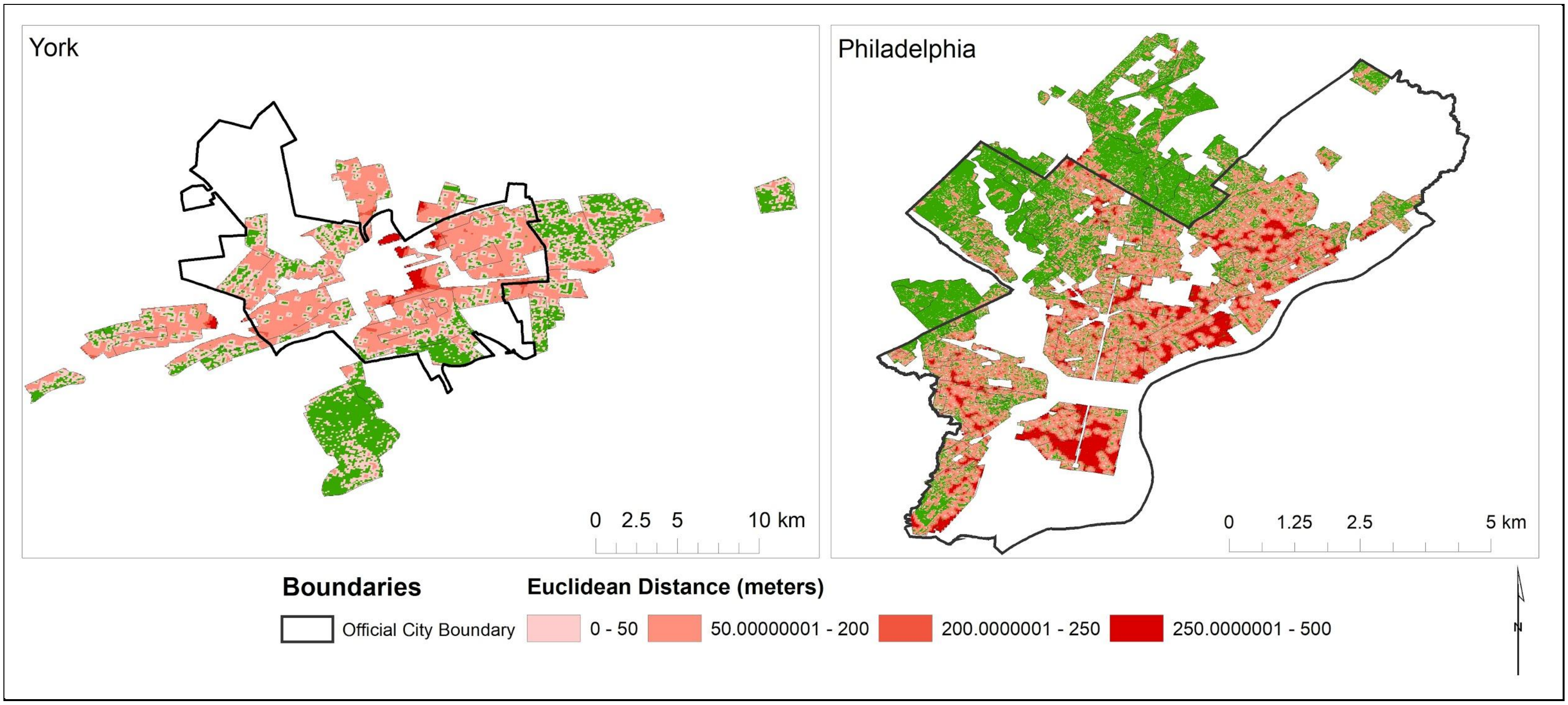

Figure 4: Map of green spaces, or areas of canopy and permeable surfaces, and the distance from green spaces indicated in red. Grade D neighborhoods tend to be farther on average from green spaces than grade A neighborhoods are.

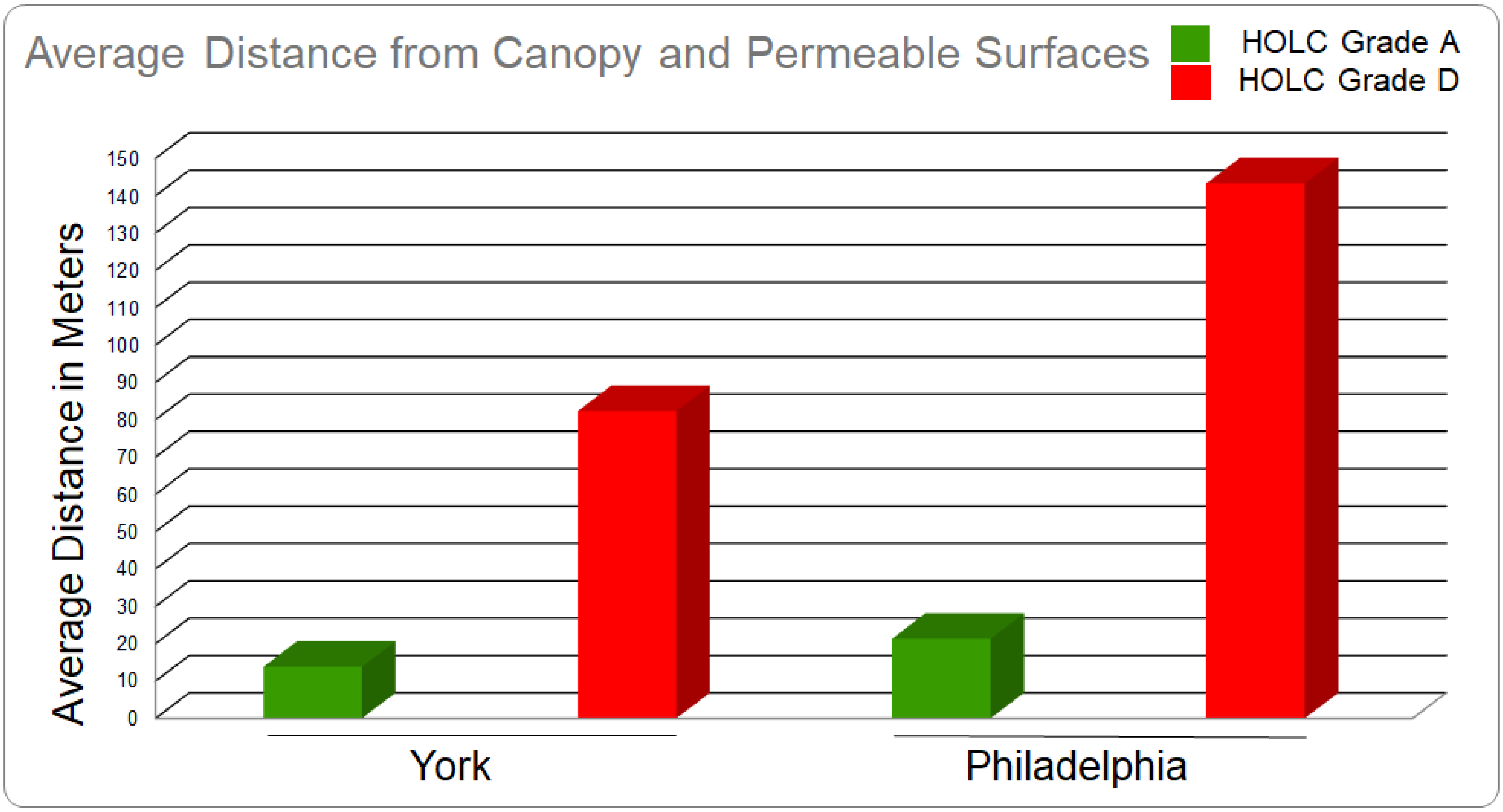

Figure 5: The average distance to green spaces from each of the four HOLC grades for Philadelphia and York, Pennsylvania. Grade D neighborhoods in both cities were significantly farther from canopy and permeable surfaces.

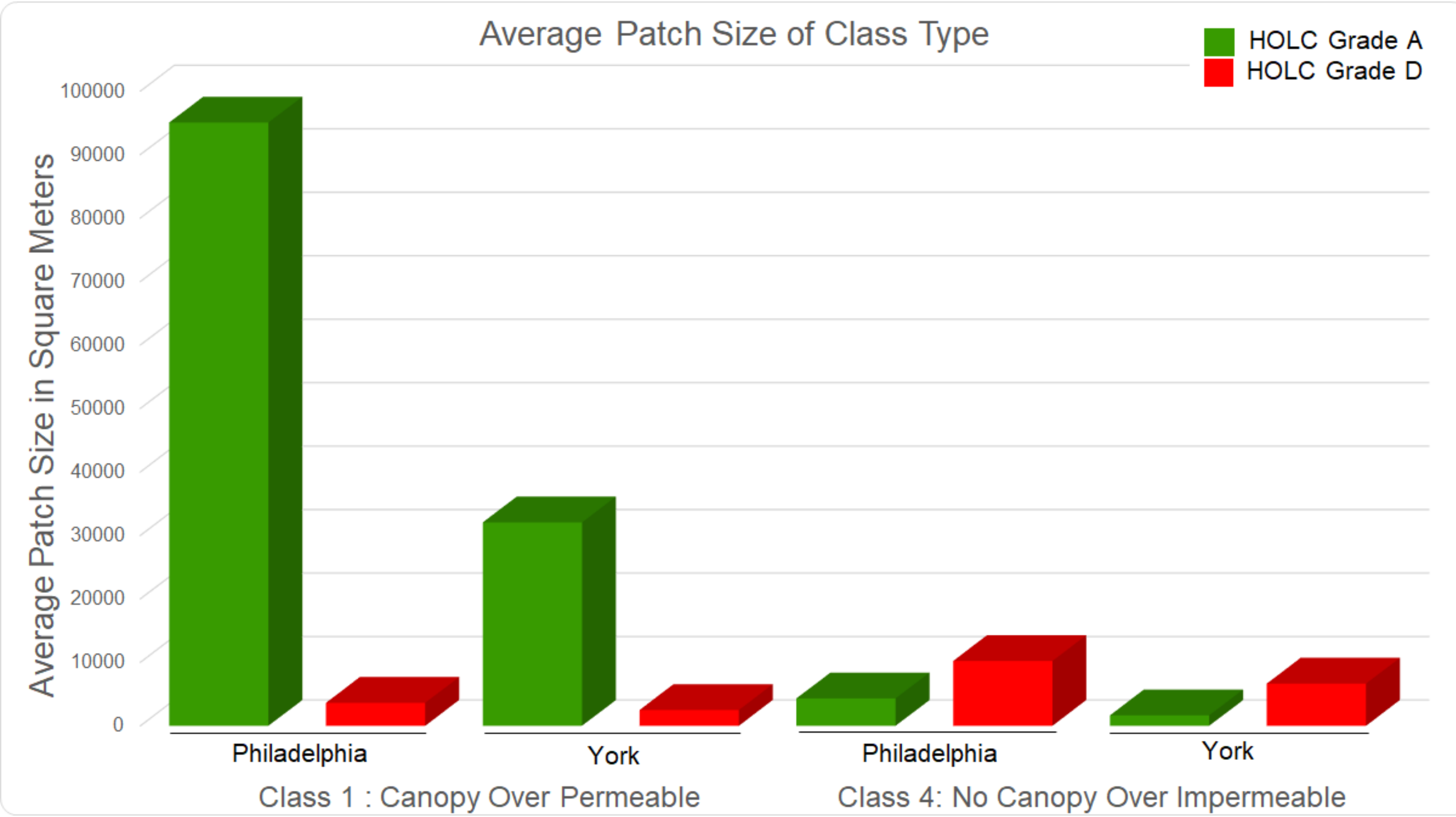

Figure 6: The average patch size in square meters, by class type for HOLC grades A and D in Philadelphia and York, Pennsylvania. In both Philadelphia and York, grade A neighborhoods have much larger areas of contiguous canopy and permeable surfaces.

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9. Appendix A

Percent for Each Class

A raster clip was performed on the tree canopy layer, impermeable surface layer, and redlining layer in order to clip it to the city limits. The aggregate tool was used on the tree canopy layer to convert it to the same resolution as the impermeable layer. Raster calculator was used to divide the tree canopy layer by 9 to make the raster a percent. Raster calculator was then used to create a binary raster of the aggregate tree canopy layer, to determine areas that were above 25% tree canopy. The raster calculator was used to create a binary raster impermeable surfaces layers, differentiating areas that were above 85%. The raster calculator was then used on the tree canopy raster and the impermeable surface raster, in order to create each of the previously determined four classes. For example, the first layer (tree canopy and impermeable surfaces) included the areas that were labeled as "1" in both rasters, which indicated they contained both tree canopy and impermeable surfaces. This was repeated for each of the remaining three layers. The zonal statistics tool was used on each of the four classes, with the HOLC redlining zones as the zone field, to create a table that determined the area and percent of the city which made up each of the four classes for each of the four HOLC grades.

Average Distance

The combine tool was used to combine all four of these classes, and the reclassify tool was used to reassign raster values to the corresponding numbers of these layers. The raster to polygon tool was used on the combined class layer. The layer was then selected for polygons with a shape area greater than 300 meters, and a new layer was created from the selection. The Euclidean distance tool was used on the new polygon layer to calculate the distance to other polygons, and this resulting layer was extracted by mask with the redlining layer as the input raster. Finally, a zonal statistics table was created with the redlining layer as the feature mask data, HOLC grade as the zone field, and the extract layer as the input value field, to determine the average distance to each of the four classes, from each of the four redlining grades.

Average Patch Size

The intersect tool was used on the redlining and polygon layers. In the resulting table, the grid code “1”, which corresponds to class 1, was selected, and summarized by the average area. This was repeated for each of the three remaining grid codes.