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Original article

The relationships between an historic neighborhood classification grade and tree canopy and impervious surface in Washington, DC, USA

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ABSTRACT

Urban tree canopy provides benefits, but is not equitably distributed across neighborhoods, which is an environmental distributive injustice. Trees take time to grow, so historic neighborhood conditions explain, in part, present-day conditions and the inequitable distribution of tree canopy and associated benefits. In 1934, the Federal Housing Administration (FHA) was created to help develop new housing and promote homeownership by insuring home loans, and consequently helped shape urban development. In 1937, the FHA ranked neighborhoods in Washington, DC, and the greater metropolitan area based on various neighborhood characteristics, including the racial composition of inhabitants, using the letters A through H. A-E areas were associated with white residents. From 1934–1962, nearly all (98 %) of the loans the FHA insured went to white borrowers. We asked if tree canopy cover (which provides benefits) and impervious surface cover (which is deleterious) is associated with the rank-order of the FHA's neighborhood letter grades. High-resolution, high-accuracy land cover data from the Chesapeake Conservancy and FHA grade data from the Mapping Segregation Washington, DC project were used to examine and test these relationships with non-parametric Kruskal Wallis and Wilcoxon Rank Sum statistical tests. The percentage of tree canopy cover was significantly greater in high-ranked areas than lower, and impervious surface cover was more abundant in lower-ranked areas. The significant relationships persisted in sensitivity analyses using more encompassing definitions of tree canopy cover and impervious surface. The findings suggest that today's inequitably distributed tree canopy cover is related to historic inequality.

1. Introduction

In 1934, the United States Federal Housing Administration (FHA) was created to help develop new housing and promote homeownership by insuring home loans, as part of the New Deal created in response to the Great Depression of the 1930's (Library of Congress, n.d.). The FHA consequently helped shape urban development in the United States (Library of Congress, n.d.; U.S. Department of Housing and Urban Development, n.d.). The Great Depression was a period of extreme recession with extremely high unemployment and poverty rates (Goldston, 1968). Urban development created or precluded opportunities for tree canopy (the layer of leaves, branches, and stems when viewed from above), and the benefits it provides. In 1937, the FHA ranked neighborhoods in Washington, DC, and the greater metropolitan area based on several factors, including the racial composition of inhabitants (Shoenfeld, n.d.).

The ranking consisted of eight levels from "A" through "H", with A being the highest quality of property and H being the lowest (Shoenfeld, n.d.). Research suggests a racial bias in the construction of the FHA maps (Fishback et al., 2024); from 1934 to 1962 nearly all (98 %) of the loans insured by the FHA went to white borrowers (Shoenfeld, n.d.). In 1968, Congress passed the Fair Housing Act which outlawed race-based housing practices, like redlining (Locke et al., 2021), however, the effects are still observable today. For example, formerly redlined areas presently experience poverty, unemployment, low educational attainment, and poorer public health (Beyer et al., 2016; Gee, 2002; Krieger et al., 2020a, 2020b; Massey and Denton, 2018).

Present-day urban forest inequality is well-established. Meta-analyses indicate that higher-income areas (Gerrish and Watkins, 2018) and predominantly white communities (Watkins and Gerrish, 2018)have

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more tree canopy cover than their lower-income, community of color counterparts. Cross-site analyses of 31 Canadian cities also indicates that higher-income areas have more tree canopy cover (Quinton et al., 2022). A simulation and projection of urban sprawl from 2020 to 2050 in Sorocaba, state of São Paulo, Brazil suggests that agricultural lands and pastures are the most at risk of being urbanized despite their beneficial attributes (Ribeiro et al., 2024). Specifically in DC from 2006 to 2011, low-income areas lost more tree canopy in terms of area as a percentage of land area than higher income aeras, even though they had less in 2006 (Sanders et al., 2015). Moreover, areas that remained relatively wealthy had more tree canopy than areas that remained relatively impoverished, and the relatively impoverished areas lost more tree canopy than other types of neighborhoods (Chuang et al., 2017). The urban forest takes time to grow (Roman et al., 2018), and therefore historic socioeconomic and demographic conditions predict tree canopy cover today (Boone et al., 2010; Locke and Baine, 2014).

Like the FHA, the Home Owners' Loan Corporation (HOLC) created another system to encourage economic growth following the New Deal with the First Annual Report of the Federal Home Loan Bank Board (Federal Savings and Loan Insurance Corporation, 1933). The two systems differ in that the HOLC directly worked with individuals to provide loans while the FHA used banks as intermediaries to provide loan insurance (Dougherty, 2011). The FHA's and the HOLC's loans both encouraged home ownership and economic prosperity of Americans (Federal Savings and Loan Insurance Corporation, 1933; Library of Congress, n.d.). The HOLC ranked the quality of neighborhoods in major United States cities on an A to D scale. "A" was considered the best ranking and, and used to notate what HOLC described as noted as the highest quality neighborhoods. "A" was followed by "B", "C", and finally "D", which was considered the lowest quality ranking and used to identify neighborhoods deemed hazardous with homeowners most likely to default on home loans. Like the FHA classification, this ranking system was in part race-based.

Prior research suggests that formerly HOLC A-graded areas have more vegetation (Nardone et al., 2021), and greater tree canopy cover (Locke et al., 2021; Namin et al., 2020; Nowak et al., 2022). Because tree canopy cools urban areas via shading and evapotranspiration, while impervious surface like asphalt and buildings retain, and re-emits heat (Alonzo et al., 2021), formerly HOLC A-graded areas are likely cooler than formerly HOLC D-graded areas (Hoffman et al., 2020; Jung et al., 2024; Walker et al., 2024). They also often have less pollution (Estien et al., 2024) and noise pollution (Nelson-Olivieri et al., 2024).

There is no HOLC map for Washington, DC; however, an FHA map does exist. It remains an open question whether the historic FHA neighborhood classifications are reflected in the spatial distribution of the urban forest in Washington, DC today. The goal of this study was to determine the relationships between FHA grade and tree canopy and impervious surface coverage. Given the prior research above, we expected that neighborhoods with higher FHA grades would have more tree canopy coverage and less impervious surface coverage than neighborhoods that have lower FHA grades.

2. Methods

2.1. Study area and data sources

Washington, DC was chosen as the study area since prior research has largely ignored these neighborhood rankings (Fig. 1, top, left). An important counter example is that it was hypothesized that urban mammals vary by FHA grade, but there were no significant differences for 10 species (Collins and Gallo, 2024). The land cover varies substantially: the dense urban core is marked by an abundance of impervious surface, while the less-dense, leafy suburbs have less impervious surfaces and more tree canopy cover (Fig. 1, top, right). The metropolitan area contains neighborhoods with a range of land cover conditions, making Washington, DC well-suited to the study of historic neighborhood classifications and present-day land cover relationships.

The FHA neighborhoods containing 1937 letter grades were collected from Prologue DC and Mapping Segregation Washington, DC project (Shoenfeld, n.d.). Mapping Segregation Washington, DC contains several different types of maps regarding the segregation and housing quality rankings throughout the US capitol's history.

High-resolution (1 m^2), high-accuracy (>95 %) land cover data, including tree canopy and impervious surface classes were downloaded from the Chesapeake Conservancy (Chesapeake Bay Program, 2022; Pallai and Wesson, 2017). The Conservancy partners with U.S. Geological Survey and University of Vermont Spatial Analysis Lab, with funding from the Chesapeake Bay Program, to create freely-available land cover for all counties that intersect the Chesapeake Bay, which includes more than 200 jurisdictions across Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia, and Washington, DC (https://www.chesapeakeconservancy.org/projects/cbp-land-use-land-cover-data-project). The FHA neighborhoods cover most of present-day Washington, DC and extend into the neighboring jurisdictions in Maryland and Virginia (Fig. 1, top, left).

2.2. Land cover summaries

Land cover rasters were summarized into FHA polygons in R version 4.3.2 (R Core Team, 2023) via RStudio (Posit Team, 2024) using the sf (Pebesma, 2018) and terra packages (Hijmans, 2022). Land cover data per FHA neighborhood was calculated in four ways: Tree Canopy, Total Tree Canopy, Impervious Surfaces, and Total Impervious Surfaces (Table 1). These combinations were used because the land cover data contains a tree canopy class and three additional classes of tree canopy cover over impervious surfaces (tree canopy over buildings, roads, and other impervious surfaces). The three-dimensional world is mapped in two dimensions, and this land cover dataset contains three different classes where tree canopy hangs over other land covers (i.e. structures, roads, and other impervious surfaces like sidewalks). Two versions of each of the two land cover types (tree canopy and impervious surface) allow for sensitivity analyses to see if the results vary depending on how narrowly or broadly the tree canopy or impervious surfaces are defined. For example, a tree's canopy may cover an impervious surface like a sidewalk. As shown in Table 1, Total Tree Canopy contains trees that cover pervious and impervious surfaces and contains surfaces with Tree Canopy, Tree Canopy over Impervious Roads, Tree Canopy Over Structures, and Tree Canopy Over Other Impervious Surfaces. These four groupings allow for a main analysis of total tree canopy and total impervious surfaces, with sensitivity analyses of the more narrowly-defined tree and impervious surfaces. In this way, we can test the robustness of the results. For cartographic purposes, state boundaries were accessed via the tidycensus package (Walker and Herman, 2021).

2.3. Statistical analysis

Thirty percent of the neighborhoods ($n = 22$) were in the District of Columbia, 45 % ($n = 33$) in Maryland and the remaining 26 % ($n = 19$) in Virginia. With the exception of FHA Grade D ($n = 1$) and Grade F ($n = 4$), there are at least 7 neighborhoods per grade. Exploratory data analyses showed the outcomes were not normally distributed (not shown), so an Analysis of Variance (ANOVA) Test was deemed inappropriate. Instead, Kruskal-Wallis tests were used to identify the differences between each of the four land cover types and the eight FHA grades. After the Kruskal-Wallis tests determined significant differences, the Wilcoxon Rank Sum Test was used to test all pairwise differences containing grade A (A and B, A and C, etc.) to determine which pairs of neighborhood categories were significantly different or not. There was only one D-graded neighborhood so pairwise tests with a D-grade were omitted. An alpha threshold of 0.05 was used to determine significant differences.

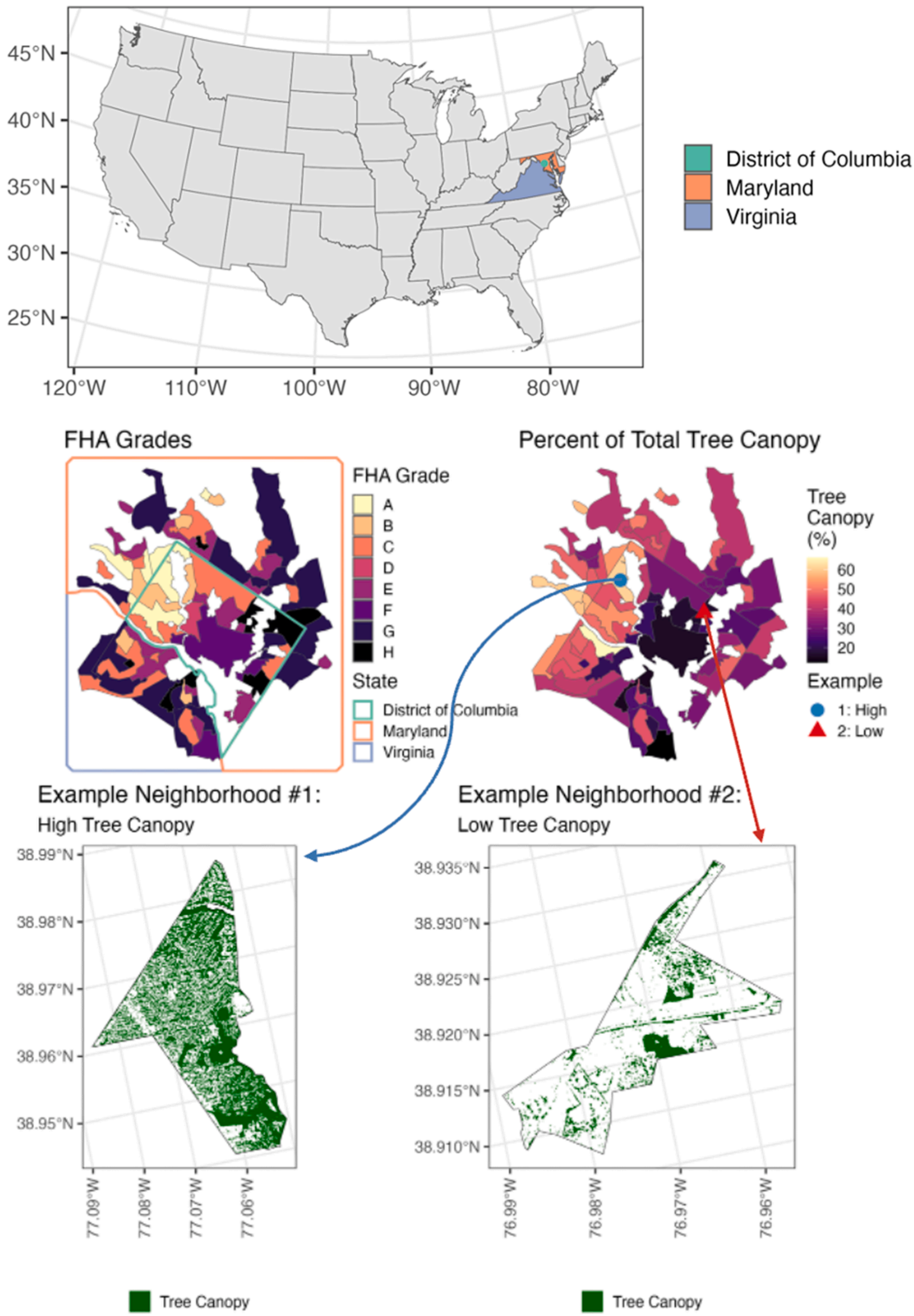

Fig. 1. Study area in national context (top). Federal Housing Administration (FHA) graded neighborhoods "A" through "H" in the Washington, DC metropolitan area in 1937, which spans the District and parts of Maryland and Virginia (middle, left). Today tree canopy varies across those FHA-graded neighborhoods (middle, right). An example A-graded neighborhood (bottom, left) has 61 % tree canopy, while an example H-graded neighborhood (bottom, right) has 14 % tree canopy cover.

Table 1
The Chesapeake Conservancy Land Cover contains 12 classes; this table shows how the various tree and impervious sub-types were combined into four dependent variables. The dependent variables in the analyses were Total Tree Canopy and Total Impervious Surface, the more narrowly-defined Tree Canopy and Impervious Surface definitions were used in sensitivity analyses.

Land Cover Type	Tree Canopy	Total Tree Canopy	Impervious Surface	Total Impervious Surface
Tree Canopy	X	X		
Tree Canopy Over Impervious Roads		X		X
Tree Canopy Over Structures		X		X
Tree Canopy Over Other Impervious		X		X
Impervious Roads			X	X
Impervious Structures			X	X
Other Impervious			X	X

3. Results

Median total neighborhood tree canopy cover was 41 % and median total impervious surface cover was 47 % (Table 2). Land cover varied across the FHA neighborhoods. For example, the difference between the first and third quartile for all four land cover categories was ~19 %, meaning that tree canopy and impervious coverage varies substantially between neighborhoods within the study area.

Total tree canopy in A-graded areas is significantly greater than other grades (Fig. 2I). Visually, the rank-order of the FHA grades generally matches the rank-order of the median total tree canopy, from highest to lowest, A to H. The reverse is true for total impervious surfaces where higher FHA grades are associated with lower total impervious surface cover (Fig. 2II). The same patterns hold when the more narrowly-defined tree canopy and impervious surface definitions are used (Figure S1), with more tree canopy and less impervious surface cover in high-graded neighborhoods.

Table 2
Distribution of Study Area Characteristics. Total Tree Canopy includes Tree Canopy and tree canopy overhanging classes (Tree Canopy Over Impervious Roads, Tree Canopy Over Structures, and Tree Canopy Over Other Impervious); Total Impervious Cover includes Impervious Cover and tree canopy overhanging classes. N (%); Median (Quartile 1, Quartile 3).

Characteristic	N = 74[1]
Tree Canopy (%)	31 (23, 39)
Total Tree Canopy (%)	40 (27, 47)
Impervious Cover (%)	41 (31, 50)
Total Impervious Cover (%)	47 (37, 57)
State	
District of Columbia	22 (30 %)
Maryland	33 (45 %)
Virginia	19 (26 %)
Federal Housing Administration (FHA) Grade	
A	8 (11 %)
B	7 (9.5 %)
C	14 (19 %)
D	1 (1.4 %)
E	15 (20 %)
F	4 (5.4 %)
G	17 (23 %)
H	8 (11 %)

4. Discussion

The statistical analyses showed significant differences between the tree canopy coverage and impervious surface cover across FHA grades. As shown in Fig. 2I, neighborhoods with higher FHA grades have greater tree canopy cover ($p < 0.05$). "A" has the most tree canopy cover and the subsequent FHA grades generally have less tree canopy cover (Figure S1) and less total tree canopy cover (Fig. 2). Neighborhoods with higher FHA grades also have less impervious surface cover ($p < 0.05$; Fig. 2II). The pattern is clear: after A-graded neighborhoods, the subsequent FHA grades generally have more total impervious Surface cover (Fig. 2II) and more impervious surface cover (Figure S1). In other words, neighborhoods with lower FHA grades have less tree canopy cover and more impervious surface coverage than higher-graded areas. This suggests that neighborhoods rated higher by the FHA in 1937 have more preferable environmental conditions today. Conversely, those living in what were deemed lower quality neighborhoods in the 1930s, experience lower environmental quality today. One implication is greater temperatures, since tree canopy and especially larger patches of tree canopy cover with soil and vegetation beneath the canopy, significantly cools Washington, DC (Alonzo et al., 2021).

This paper's findings align with similar research in other cities using the HOLC neighborhoods and grades, which were created at the same time for similar purposes. Higher-graded HOLC neighborhoods have more desirable environmental conditions today: they have lower temperatures on average (Hoffman et al., 2020; Jung et al., 2024; Walker et al., 2024), have more vegetation (Nardone et al., 2021), more tree canopy (Locke et al., 2021; Namin et al., 2020; Nowak et al., 2022), often have less pollution (Estien et al., 2024), and typically less noise pollution (Nelson-Olivieri et al., 2024). HOLC polygons are not available for Washington, DC, and therefore a similar historic neighborhood ranking system created by the FHA at the same time was used. The results here corroborate prior research.

This research suggests that today's tree cover distribution is associated with historic neighborhood conditions. Currently, there are many efforts taking place that are helping to maintain and increase tree canopy across the United States (Hauer and Peterson, 2016; Nguyen et al., 2017; Young and McPherson, 2013). Washington DC aims to increase its tree canopy to 40 % (Sanders et al., 2015), in part to combat rising heat (Bowser, 2012). Briefly, The District Department of Transportation (DDOT, https://ddot.dc.gov/) manages street trees, and The District Department of Energy & Environment (DOEE) administers the RiverSmart Homes to plant trees on residential lands, among other urban forestry programs (https://doee.dc.gov/service/trees-district). The National Park Service's National Capital Region manages dozens of Federally-owned parks and historic sites (https://www.nps.gov/orgs/1465/index.htm), while the DC Department of Parks and Recreation does the same for locally-owned properties (https://dpr.dc.gov/). Finally, the Casey Trees Foundation plants more than 6000 trees a year with a variety of volunteers and a myriad of cross-sector partners (https://caseytrees.org/). This study informs those efforts by identifying areas with low tree canopy cover and/or high impervious surface cover that were also subjected to race-based lending insurance practices of the past. This research also reinforces that trees are long-lived, and slow-growing, and the potential legacies of former government programs on present-day conditions (Boone et al., 2010; Grove et al., 2018; Roman et al., 2018). Additional research may investigate changes in infrastructure since the recording of the 1937 FHA grades.

4.1. Limitations and Strengths

Errors in the land cover data could challenge the validity of the findings. However, these land cover data represent the most detailed and accurate data created for this study area (Chesapeake Bay Program, 2022; Pallai and Wesson, 2017). Although median land cover varied significantly and meaningfully by FHA grade, there is within-letter

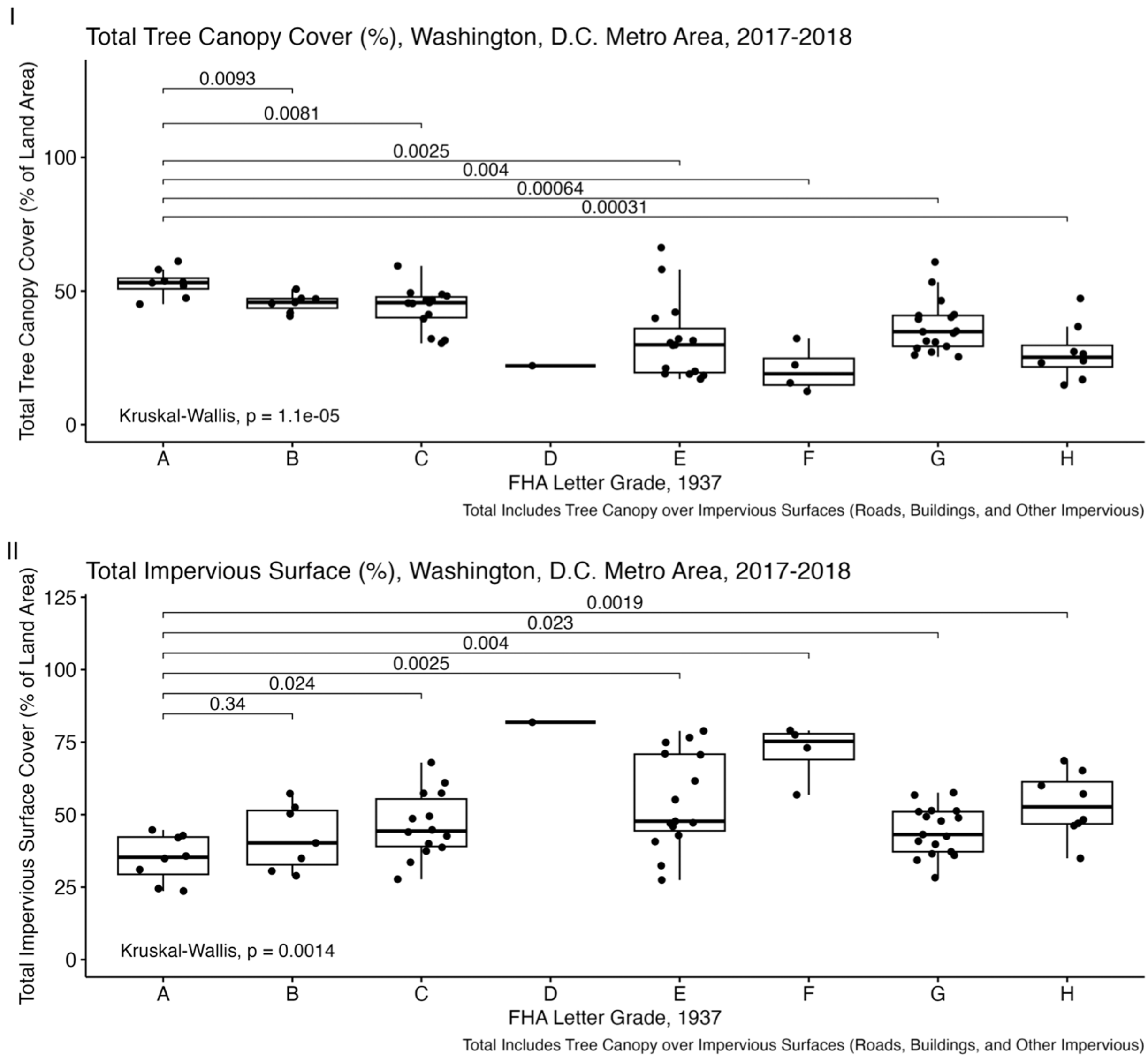

Fig. 2. Higher grade areas have more total tree canopy (I) and less total impervious surface (II). Total Tree Canopy which includes all tree canopy and canopy over classes; Total Impervious Surface which includes all tree over classes vary significantly By FHA letter grade. The numbers above the brackets are the p-values obtained from the Wilcoxon-Rank Sum tests.

grade variation, and some G- and H-graded neighborhoods have greater canopy cover than their A-, B-, or C-graded counterparts. The reverse is true for impervious surface cover. These medians show differences not attributable to chance, but not all neighborhoods follow the overall pattern. Additional research may explore the details of neighborhoods that do not corroborate those overall patterns. Finally, the world is more complicated than land cover and FHA-graded neighborhoods. Additional research could explore other temporally-lagged predictors of modern-day land cover, including large public works projects, development patterns, as well as tree planting initiatives. Current tree planting efforts, such as those coordinated and carried out by DDOT, DOEE, The National Park Service, DC Department of Parks and Recreation, Casey Trees and many partner organizations seek to maintain and increase the urban tree canopy.

5. Conclusion

The goal of this research was to examine the relationships between FHA grades that classified urban neighborhoods in the mid-1930s based, in part, on race, and land cover today. This work was motivated by prior similar research demonstrating the relationships between a similar historic neighborhood rating system by the HOLC and vegetation and tree canopy today. Higher-graded areas in that system contain more vegetation (Nardone et al., 2021), more tree canopy cover (Locke et al., 2021; Namin et al., 2020; Nowak et al., 2022), and are cooler (Hoffman et al., 2020; Jung et al., 2024; Walker et al., 2024). After standardizing, aggregating, and integrating high-resolution land cover data into FHA-graded neighborhood boundaries, all four types of land cover examined varied significantly: higher graded areas had more tree canopy and less impervious surface. The rank-order of the FHA system matches the rank-order of tree canopy and inversely impervious surface cover. The Chesapeake Conservancy's freely-available land cover data made these analyses possible. Tree canopy inequality today can be predicted, in part, by former inequality in the built environment. Neighborhoods that contained negative factors in the 1930's still experience negative environmental conditions almost 100 years later.

CRediT authorship contribution statement

Locke Dexter: Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Maney Jack:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2025.128836.

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