Theoretical Framework of the Geographic Information Study Guide Online Lesson Plan

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Abstract

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Geographic Information Study Guide (GISG) is the name of a high school level, online lesson plan I created using data, visualization and analysis tools available through Esri. For the purposes of this publication, GISG refers to the first published lesson using the format. The aim of the lesson is to provide students with an engaging and empowering introduction to applications of Geographic Information Systems (GIS) and current environmental and sociological research topics by exploring concrete, personally relevant data gathered from their local geography.

The website functions not as a piece of scientific or theoretical research, but as a working piece of science communication designed primarily for a target audience of Seattle high school students. The main text of this thesis explains the rationale behind the conceptual and design choices behind the GISG online learning tool, as well as GISG's applications, limitations, and potential avenues for future development. GISG can be accessed at: https://storymaps.arcgis.com/stories/dbbf0f36d5fc4d6db7cbb18c4700524c

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Chapter 1: Introduction

Geographic Information Study Guide (GISG) is the name of a high school level, online lesson plan I created using Esri StoryMaps and ArcGIS Pro. The aim of the lesson is to introduce Seattle-area high school students to tangible, personally relevant examples of environmental justice (EJ) principles and research topics in science and sociology, using Geographic Information Systems (GIS). The website functions not as a piece of scientific or theoretical research, but as a working piece of science communication designed primarily for a target audience of Seattle high school students. The main text of this thesis explains the rationale behind the conceptual and design choices behind the GISG online learning tool, as well as GISG's applications, limitations, and potential avenues for future development as a tool for qualitative analysis and visualization of abstract concepts in local settings.

1.1: Acknowledgement

This project was written in and about the lands of the dxʷdəwʔabš (anglicized form: Duwamish) people.

Specifically, Geographic Information Study Guide was written in and about the place usually referred to by its American name of Seattle. The reality of ongoing Duwamish and other Indigenous Peoples' influence here, however, is absent from much of the available quantitative historic data. Consequently, many of the maps in the online lesson plan mirror the pattern of Indigenous erasure. To be clear: Indigenous people have lived here since time immemorial, and they still do. Their omission from historic documents is evidence of erasure, not of absence.

1.2: Project goals

Throughout human history, geographic information has been used to shape our world. Imagined boundaries depicted in maps dictate the national and other jurisdictions under which we spend our lives. Spatial boundaries determine what schools we attend as children, and our political representatives as adults. They are used as deliberate tools of oppression, for example the Home Owners Loan Corporation (HOLC) redlining maps used to deny Black Americans access to home loans from 1935 until the Fair Housing Act was enacted in 1968 (Rothstein, 2017, p. 65, 177-8). Spatial data can also be revolutionary, as in abolitionist thought, where "freedom is a place" (Gilmore, 2017, p.227). The array of spatial data publicly available online provides novel opportunities for users to explore these complex concepts and relationships.

Despite the unprecedented potential to generate innovative connections and foster inquiry, information overload, unconsolidated data and technological barriers create obstacles to engagement with the available wealth of data (Luker, 2008, p. 11-12; Bawden & Robinson, 2008). To our great collective detriment, these hurdles stand in the way of new insights and untold opportunities for professional and political growth at individual and societal scales (Bawden & Robinson, 2008, p. 185; Eppler & Mengis, 2004). Students are uniquely underserved by the related tendency to silo the powerful information and technical skills inherent to GIS in professional and other technical spheres. Failure to make GIS accessible to youth delays their exposure to valuable research and professional tools. Furthermore, it deprives them of opportunities to refine their worldview, and focus their political will (i.e. local or larger scale citizen science and information campaigns, political organizing).

Inspired by my coursework at the University of Washington School of Marine and Environmental Affairs and Gapminder's seminal Trendalyzer tool for user generated bubble

charts of global data, I set out to create a friendly, interactive GIS tool for Seattle high school level users who do not wish to delve into raw data and code. In designing GISG, I sought to incorporate Esri StoryMaps's interactive mapping capabilities into interdisciplinary, locally focused lesson plans. My goal underscoring all this is to offer the completed lesson plan to the teachers at the Nova Project, the alternative high school I attended, to use in their classrooms. Now published online, GISG: Lesson 1 illustrates concepts in Seattle history and ecology by allowing users to explore a curation of publicly available data layers inspired by the EJ literature review paper, *The ecological and evolutionary consequences of systemic racism in urban environments*.

The article indicates that present and historic racial demographics of neighborhoods can be predictive of current environmental quality (Schell et al., 2020, p. 4). Government-sanctioned redlining and racially restrictive covenants are among the best documented formal policies of racial discrimination in U.S. history. Restrictive covenants, widespread in Seattle in the first half of the 20th century, were formal neighborhood agreements to maintain racial segregation (Gregory et al., 2022). They were often taken favorably into account in determinations of redlining grade (Rothstein, 2017, p. 86). The documents were legally enforced until the *Shelley v. Kraemer* federal ruling of 1948 and remained legal to observe as nonbinding agreements between private parties until the Fair Housing Act (Rothstein, 2017, p. 85).

Dr. Schell and his colleagues go on to overview several environmental and ecological variables studied in EJ literature, including greenspace, air quality, residential plant diversity, animal species distribution, and more. To craft a grade-level appropriate lesson plan, I chose to focus on the relationship between Seattle's redlining history and greenspace distribution. To offer an intuitive metric of greenspace, I used the authoritative National Land Cover Database

canopy cover raster data available through Esri. Seattle's redlining map, like most major U.S. cities', was also available in an authoritative digitized form through Esri. Finally, I connected these layers to overall ecological health by overlaying canopy and redlining grade with Washington Department of Fish and Wildlife Priority Habitat Species data.

The online lesson does not conclude with a declaration of whether greenspace or environmental quality are equitably distributed in Seattle. Instead, it asks users to determine whether they found the data provided consistent with a pattern of environmental racism, and to consider what environmental racism and equity look like to them. My overarching goal with the project is to offer a tool that learners can use to generate reference materials to explore their own questions or depict their own observations regarding our shared local geography and history. Beyond research considerations, I hope that students are able to use GISG to share their newfound insights outside of the classroom, perhaps with family and friends, fostering collaboration, idea exchange, and greater engagement with their immediate surroundings.

Chapter 2: Influences and methods

2.1: Pedagogy

GISG heavily utilizes the "Triple E" (engage, enhance, extend) pedagogical framework (Kolb, 2020, p. 12). This approach seeks to improve learning outcomes for technology-heavy lessons by mindfully incorporating technology as a tool to support the process of learning, without allowing it to overshadow core concepts. The linear but open-ended and interactive narrative progression of GISG: Lesson 1 keeps the user *engaged*. Their learning is *enhanced* by the novel technology's ability to show them information that is not otherwise readily accessible. Finally, GISG reinforces learning by very literally *extending* the lesson beyond the classroom, grounding potentially abstract concepts like environmental justice in familiar places. Thus,

GISG's specifically local framing is a key factor in establishing personal relevance to the target user. The fundamental goal that defines GISG's perspective as a teaching material is to connect academic concepts to our daily lives. Its relatively narrow geographic scope has the added benefit of helping ensure that the written lesson plan engages with the broader context of the embedded maps' data in a nuanced, accurate manner.

Consistent with "Triple E," GISG: Lesson 1 is adapted from the "Connect, Extend, Challenge" format, as well as the "Save the Last Word for Me" discussion template. "Connect, Extend, Challenge" directly overlaps with "Triple E" in its aim of extending new material to students' prior knowledge and lived experiences. It does this in the form of a reading response prompting students to ask how the new material connects with, builds from and challenges their existing knowledge (Facing History and Ourselves, n.d.). I adapted this format in my recommended reading guide for *The ecological and evolutionary consequences of systemic racism in urban environments*. Given the advanced level of the article, I suggest classes further synthesize their learning though a group discussion before moving onto the lesson itself. I recommend the collaborative "Save the Last Word for Me" format, which I feel is conducive to comfortable communication between students at varying levels of confidence with the article. In this discussion structure, students break into small groups to share their favorite sections of a reading assignment and take turns responding to their classmates' selections. The exercise's stated purpose is "to clarify and deepen our thinking about articles we read" (Averette, n.d.). This goal is highly compatible with the "Triple E" method of teaching with technology. Specifically, it was chosen to improve the initial level of engagement with the article and allow students to brainstorm ways in which it extends to their daily lives or existing knowledge.

In light of the innately emotionally challenging nature of the material itself, I do specifically advocate an active discussion moderation style from instructors. On the main lesson plan, I link to a separate web page on which I recommend teachers consider reading and adapting "Discussion Guidelines," published by the MIT Teaching and Learning Lab, "Making the Most of Hot Moments in the Classroom," published by the University of Michigan Center for Research on Learning and Teaching, "Responding to Microaggressions in the Classroom," by Dr. Tasha Souza, and "Can We Talk? Tips for Respectful Conversations in Schools, Workplaces and Communities," published by the Anti-Defamation League.

2.2: Theoretical framework

During my literature review, I was deeply moved by Dr. Eve Tuck's distinction between desire- and damage-centered inquiry (2009). Explaining the concept of damage-centered inquiry, Tuck notes, "It looks to historical exploitation, domination, and colonization to explain contemporary brokenness, such as poverty, poor health, and low literacy. Common sense tells us this is a good thing, but the danger in damage-centered research is that it is a pathologizing approach in which the oppression singularly defines a community" (p. 413). I understand Tuck's work to indicate that the academic tendency to conduct research from this perspective can be disempowering, objectifying, and ultimately counterproductive. Borrowing from the Ladder of Citizen Participation metric of community engagement in political action, I would estimate that damage-centered research generally relegates researched communities to levels of "nonparticipation" wherein the "real objective is not to enable people to participate in planning or conducting programs, but to enable powerholders to 'educate' or 'cure' the participants" (Arnstein, 1969, p. 217). This dynamic has been prevalent in, even characteristic of, Western institutions' interactions with Black and Indigenous communities. Dr. Tuck states that, "Desire-

based research frameworks, by contrast, can yield analyses that upend commonly held assumptions of responsibility, cohesiveness, ignorance, and paralysis within dispossessed and disenfranchised communities. Desire, yes, accounts for the loss and despair, but also the hope, the visions, the wisdom of lived lives and communities" (p. 417). It is not the opposite of damage-centered inquiry or a denial of past or present violence (p. 419), but a separate framework built upon premises of self-determination and full humanity.

Dr. Tuck's work made me mindful of presumption of damage and of the risk of objectification, particularly discussing environmental racism within the controlled narrative of the StoryMap platform. In order to reduce the imposition of objectifying characterizations of community damage, I built GISG: Lesson 1 on key scholarship approached from a perspective grounded in the self-defense tradition of EJ. Dr. Christopher Schell's work on ecological ramifications of redlining is grounded firmly in this framework. Furthermore, its goals are compatible with the liberatory aims of abolition ecology, which "seeks to build intuitions and processes that are explicitly focused on the political ecological imperatives of access to fresh air, clean water, sufficient land, amelioration of toxic chemicals, and beyond" (Heynen & Ybarra, 2021). GISG's narrative, therefore, attempts to explore the legacy of redlining as an ongoing instance of environmental racism without engaging in objectifying characterizations of community damage. It is intended to allow Seattle students and teachers to begin to engage with desire-centered thinking through the example of Dr. Schell's desire-centered EJ inquiry.

To realize this vision, GISG uses research methods established in qualitative geography, a discipline associated with critical geography and critical GIS. "Instead of making sweeping generalizations of an entire study area or population, these methods were developed to reveal the effect of local context on social processes and their spatial outcomes" (Kwan & Schwanen,

2009). Limited geographic scope and incorporation of contextual data in analysis have been shown to yield more nuanced results than are possible through traditional methods and metrics alone. For instance, recent research has indicated that conventional assumptions about residential exposure to air pollutants may be insufficient to explain racial disparities in Atlanta residents' actual exposure levels, which appear to be exacerbated by travel patterns and proximity to public transit (Park & Kwan, 2020). This contextually based logic underscores GISG's use of historical records, which are used to make sense of complex mapped data. GISG's complementary written historic and visualized spatial data approach is a form of mixed-methods research. In particular, it is similar to grounded visualization, a research method used for, "blending spatially referenced quantitative and categorical data with qualitative data about places and the uses and constructions of space" (Knigge & Cope, 2009, p.97).

2.3: Visual considerations

The basic layout of a StoryMap web page is functional, attractive, and largely preset. Essentially, StoryMap authors can alter the color scheme or typeface, and insert or rearrange blocks of text, images, and interactive maps. I found Esri's design choices sufficiently polished looking to lend the necessary sense of competence and trustworthiness to my lesson plan. I only tweaked the web page color scheme to include University of Washington purple and gold, reflecting the fact that GISG is a thesis project. These changes were very minor and superficial, both because of the professional quality of the default settings, and to keep the use of color generally accessible for users with visual impairments.

I made more significant design choices on the maps embedded in the webpage. Maps can be used for different purposes. They can function as (1) reference materials, (2) visualizations of spatial data for analysis and (3) art or aesthetic objects (Kent & Klosterman, 2000). The Esri

StoryMap platform relies on professionally designed default settings for many of its aesthetic choices for embedded maps, similar to the way it does for default settings for layouts. Nevertheless, I attempted to honor and balance Kent and Klosterman's three functions in my design choices when making both the embedded interactive maps and a couple slightly more analytic static maps from scratch in ArcGIS Pro. I found the maps' reference function useful for enhancing the lesson's adherence to the "Triple E" pedagogical framework, so I made sure to utilize basemap layers that included familiar information like streets and modern neighborhood boundaries. To improve the data visualization and aesthetic value dimensions, I made sure never to overlay more than two data layers over basemaps. This generated clean, clear maps, as well as a visual implication of dependent and independent variables. To further enhance data visualization, I was extremely mindful of color throughout. I attempted to use only thematically appropriate (Krause, 2004), visually distinct tones, with the exception of the redlining map color scheme, which I left in its original palette, as is customary.

The form of GISG was also strongly influenced by the Gapminder Foundation's vision of "correcting the market failure in distributing global data" by making it "more accessible and easier to use for instant visual analysis" (Frequently Asked Questions, n.d.). Creation of free, user-friendly, interactive learning materials for students is one of the most direct means of advancing this goal. Also similar to Gapminder, I place great value on the ability of online learning materials to convey information in a way that feels nearly instantaneous and fundamentally intuitive for the user. This led me to prioritize simple data visualization, rather than heavy quantitative analytics, in GISG's development. GISG is not a tool for quantitative analysis. Instead, it primarily functions as a data visualization tool that invites the user to make

subjective assessments of relationships between various quantitative (discrete and continuous data) layers.

To reflect Gapminder's ideal of immediate, intuitive qualitative analysis and Kent and Klosterman's recommendations regarding visual clarity in using maps as data visualization tools, I decided against attempting to include every available variable in GISG's maps. To do so would recreate the state of information overload GISG is intended to reduce, become more difficult for users to navigate, and, most importantly, obscure visual patterns. In addition to the previously mentioned constraints, I maintained clarity by using quantitative labels only as an elaboration on data already provided in a visually intuitive manner.

Chapter 3: Product

GISG: Lesson 1 is designed to guide students through a progression of local spatial data depicting core EJ concepts in Seattle. By the end of the lesson, they should be able to assess whether they believe the datasets from the exercise to provide evidence of environmental racism in previously redlined Seattle neighborhoods. Advanced students might begin to imagine what environmental justice looks like in their local context and consider other variables and hypotheses to further explore these questions.

The lesson begins by providing a brief overview of the origins of the Environmental Justice movement. It then delves into Seattle's history of racial segregation and explains that EJ literature links policies like redlining to modern inequities in environmental quality, as was summarized in Schell et al. The first map of the lesson, a simple interactive map zoomed out to show several Midwestern cities' digitized redlining maps, helps introduce this idea. The concept

is made more immediate with the next map, a still image of Seattle's hand drawn 1936 HOLC map showing redlined neighborhoods.

Discussion questions:

- Had you heard about redlining before this lesson?
- What did you know about it?
- Did you connect it to Seattle, or any other specific cities?
- Thinking back to the article, what ways would you expect past redlining to affect Seattle neighborhoods today?

The next section introduces Seattle's digitized redlining map. In its interactive form, the user can zoom and pan to explore familiar places. This is followed by text linking to detailed explanations of the assigned ratings, and a discussion of specific neighborhoods' ratings. We relate all this to the reading assignment with the next map, which overlays the redlining map with NLCD canopy cover data.

Discussion questions:

- Are you especially surprised or unsurprised about the amount of canopy in any neighborhoods you spend time?
- Do you have any observations about specific areas?
- Do you see any potential trends between different areas?

Although there is a lot to look at, the data is overwhelming and difficult to understand. To help interpret it, the next section begins with a chart comparing average canopy cover by HOLC grade. Perhaps surprisingly, "D" rated neighborhoods average the second highest canopy cover.

Discussion questions:

- What pattern do you see in average canopy cover between ratings?

- Did you expect “D” rating assigned neighborhoods to have the second highest average?
- Do you think this supports, contradicts, or does not address the article's finding that redlining corresponds to lower environmental quality today?

To make more sense of this, we revisit local historical context. Looking at the breakdown of mean canopy cover by HOLC neighborhood in a static map, we can see that the areas that were explicitly redlined because of the race of their inhabitants do indeed have below average canopy cover today. The high average, it turns out, is the result of a few very sparsely inhabited neighborhoods with terrain unsuited to construction also being assigned the “D” rating in 1936.

Discussion questions:

- Do you think it makes sense that so many of the places with environmental conditions considered bad for construction in the 1930s seem to have a lot of trees today?
- What do you predict the surroundings look like when you walk around those places? Find them on the map below to find out.

To help explore what different canopy cover looks like in real life, an interactive map overlays a realistic image of Seattle with the NLCD layer. Users can look up addresses in the search bar or pan and zoom to their locations of interest.

Next, we look at areas with notably high canopy density. A static map shows the redlining map overlaid with polygons depicting areas in Seattle with canopy cover over 50% and numeric labels showing the average percent of the neighborhoods’ area covered by high canopy.

Discussion questions:

- If you see any places with especially large or small areas of high tree density, what patterns do you notice about them?
- What places do you recognize that are marked as high canopy cover?
    - What do you do there?

Finally, greenspace is related to wildlife habitat by mapping Washington Department of Fish and Wildlife Priority Habitat Species data over canopy cover and HOLC rating. The maps show clear overlap between priority habitat and high canopy cover, which is noticeably less present in the neighborhoods discriminated against through redlining practices.

Discussion questions:

- Where do you notice priority habitats?
    - Do you see any particular factors that seem to make them more or less likely?
    - How does it match up to tree density?
    - What about redlining history?
- Do you think the distribution of priority habitats is a good way of looking at environmental equity?
    - If so, do you think the Priority Species Habitat maps show a fair distribution?
- What does a fair distribution look like to you?

To close, the exercise ends on some big picture questions:

- Do you think the distribution of canopy cover in Seattle was consistent with the finding that systemic racism causes lasting differences in environmental quality?
    - If so, what provided the strongest evidence?

    - If not, what evidence would you have needed to see to be convinced?
- What differences in environment do you think would show that there was systemic bias against the population of a certain area?
    - What kind of data do you think could be used to measure those differences?
- What part of the lesson was most interesting to you?
- What did it make you curious to learn more about?
- Using this activity jumping off point, what data would you use to map your observations or questions about the world around you?

Chapter 4: Discussion

4.1: Outcomes

GISG is intended to serve a target audience of Seattle high school students, with a secondary audience of Seattle-area residents more broadly. As of the date of this publication, the inaugural lesson is available online. It introduces the concepts of GIS, offers a set of discussion facilitation materials, and provides a lesson plan built off of Schell et al.'s *The ecological and evolutionary consequences of systemic racism in urban environments*. The lesson functions as an introduction to real, local examples of environmental justice principles by showing tangible, ongoing environmental and societal injustices. It also provides a succinct history lesson covering redlining and racially restrictive covenants, focusing on documented occurrences thereof in Seattle.

4.2: Current applications

The lesson plan is operational and, as intended, is particularly relevant to Seattle high school students and to a general audience familiar with Seattle. Additionally, all of the data layers used in the interactive maps in the lesson span the entirety of Washington state. All except one layer cover the contiguous United States. The interactive maps could, therefore, be used to explore the same concepts in most other U.S. cities without making any changes to the website, although the unique history and geographic characteristics of each city would need to be considered to proceed with vital supporting analysis and local context.

Chapter 5: Limitations

5.1: Academic scope

The current iteration of GISG is heavily geared toward qualitative exploration in life science adjacent disciplines. Although the webpage layout and general lesson format are certainly adaptable to other fields, the data layers depicted in GISG: Lesson 1 are directly inspired by a transdisciplinary work heavily grounded in ecology and EJ. Users interested in exploring other topics using the data layers provided in the interactive maps are likely to find the supporting text and more quantitative, static maps entirely unhelpful.

Additionally, both because of the non-specialist target user of the product and the functionality limitations inherent to the StoryMap platform's interactive mapping capabilities, GISG is not intended to prove or disprove trends to a professionally rigorous standard. GISG was designed to provide individuals who do not necessarily engage in scientific research an opportunity to find conceptual insights about their home and community, inviting them to think tangibly about how to shape the world around them. Scientists, or other folks inclined to pursue

self-guided quantitative analysis, would likely find GISG more useful as a tool to help brainstorm or refine hypotheses for later exploration.

4.2: Geographic

GISG utilizes Seattle-specific reference materials to explore the geography that is local to my target user and myself, as product designer. While many of the data layers used in the interactive maps are national in scale, the text of the lesson plan, static maps, and overall analysis, at minimum, would need to be updated to maintain the informed, local perspective at the core of the lesson plan's logic.

4.3: Functionality

GISG's design is the result of both purposeful choices (see Section 2) and technological limitations. Esri StoryMaps provides an excellent medium to curate and contextualize simple interactive maps, but the platform is not designed to support rigorous quantitative analysis. For the purposes of GISG's high school grade level user base, this is mostly desirable. It did, however, become necessary to provide structure to the lesson plan's primarily qualitative discussion with a small amount of quantitative clarification. I found that a few small calculations helped keep the complexity of the data from becoming overwhelming. This was easily accomplished using ArcGIS Pro, but would likely be a difficult undertaking without access to and proficiency with comparable analytic software.

Chapter 6: Possibilities for future development

The narrow geographic and academic scope of GISG: Lesson 1 was intentionally chosen to reflect areas I was reasonably confident speaking on, and to establish and better serve a target

user. The underlying concept of using GIS to relate scholarship to one's local context is adaptable far beyond the spatial data layers I chose, the location I grounded the lesson plan's inquiry in, or any particular audience. Indeed, in the early stages of project planning, I had intended for the published lesson to be an introductory chapter, with several more offerings providing Seattle-based lessons on different subjects, from statistics, to horticulture, to additional scholarship related to equity and environmental justice. My particular perspective and consequent subject choices were always somewhat arbitrary to the format overall.

GISG is intended to draw users in with inviting aesthetics, an intuitive interface and an array of engaging data layers to spark user generated inquiry. I would characterize GISG as highly promising in this regard. This success indicates strong potential for significant elaboration, improvement, and evolution of the product by myself or, more excitingly, by others.

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Chapter 7: Appendices

The following appendices document the content of GISG at the date of thesis publication. They have been copied here for your convenience, and to preserve the content in the event that the online version is updated or removed. If possible, I highly recommend interested parties experience the GISG lesson plan in its intended form online.

7.1 Text of online materials

Introduction

I put this StoryMap collection together as a resource for Seattle residents, especially students. The interactive maps depict a collection of data I consolidated to show how abstract concepts, like academic research and political policy, become real in Seattle daily life. Together the series connects cutting edge scientific articles and past historic events to you, through the places you go every day. I set it up as an interdisciplinary study guide for high school level students, but also with the hope that whoever happens upon it might be inspired to use the mapping components to share their observations and analyses beyond the classroom.

The maps' layers of data are pieces of our shared story as inhabitants of this city. They expose past and ongoing events we may not have been fully conscious of, but that quietly shaped the trajectories of our lives and surroundings. In doing so, these maps invite us to consider where we are, where we would like to go, and to brainstorm how to get there. At least, that is what they do for me. I hope they do for you, too.

Seattle's Sept. 20 march from Cal Anderson to City Hall, part of the global youth climate strike demonstrations that week, is shown above. There is a huge amount of amazing data online that students can use to learn, teach others, and inform their priorities for local activism. Maps can be an especially intuitive way to quickly share important information about the world.

I made the Geographic Information Study Guide to help introduce folks, especially students, to GIS. I began learning about GIS in graduate school and found it extremely interesting and surprisingly personally empowering. But it was difficult to get started. Geographic information systems, or GIS, can be intimidating when you're new to them. They certainly were for me. Fortunately, you're probably already very familiar with GIS. Chances are, you've been using it online without realizing for a long time. A geographic information system is just a way to collect, organize, visualize (in a map or chart) and analyze data about places. Google Maps uses GIS. In conversation, people also often say "GIS" to refer to the GIS software that performs those key GIS functions. The rest is just details.

Even though you likely find the basic idea of GIS intuitive, making your first projects from scratch might be tricky. There is an incredible wealth of data available, but much of it is totally irrelevant to non-technical audiences or buried in a maze of webpages. At times it can be very overwhelming. When you do track down something interesting, sometimes you download it only to find the data in a weird, unfamiliar file type. These experiences are a natural part of learning how to use GIS, but can be discouraging at first. That is where this Geographic Information Study Guide comes in. It consolidates a variety of relevant, reputable data, so you can get to the exciting stuff without getting bogged down by the technical parts before you're ready.

The Geographic Information Study Guide Storymap series connects already published Seattle geographic information, mostly public data originally from government agencies, to literature in a variety of fields. This lesson format serves a few purposes. First, using public data allows you the freedom to access it yourself, if you want to go deeper into any subject or learn more about how the data was collected. Secondly, it shows how valuable data can be: once you find a good data set, you can use it many times, for totally different purposes. Finally, it gives you the opportunity to explore a wide range of subjects and perspectives using the common theme of Seattle's geography.

Lesson 1: Environmental Justice

This StoryMap was the main inspiration for this series. It is an interdisciplinary lesson that addresses environmental justice, urban planning, policy, and ecology. It features maps of variables described in Dr. Christopher Schell and his co-authors' 2020 publication "The Ecological and Evolutionary Consequences of Systemic Racism in Urban Environments" to explore ways in which the patterns identified in the paper can be measured in Seattle. It also provides a small lesson about the history of racially segregated housing in Seattle.

A quick note before you dive in: The materials provided in this series are intensely intellectually and emotionally challenging. Active moderation will be necessary during class discussions. I have compiled a few relevant facilitation resources that may be of interest to teachers and other discussion leaders. They are linked in the lesson guides for each section, as well as highlighted below.

Discussion Guidelines published by the MIT Teaching and Learning Lab

Making the Most of Hot Moments in the Classroom published by the University of Michigan Center for Research on Learning and Teaching

Responding to Microaggressions in the Classroom by Dr. Tasha Souza on Faculty Focus

Can We Talk? Tips for Respectful Conversations in Schools, Workplaces and Communities published by the Anti-Defamation League

The creation of Geographic Information Study Guide was heavily informed by the following works:

The intuitive, exploratory tone of Gapminder's Bubbles tool has been a key source of inspiration throughout development of this project.
Trendalyzer. (n.d.). Bubbles. Gapminder. http://www.gapminder.org/tools

The techniques from Introduction to GIS for the Earth Sciences were used extensively for behind-the-scenes data manipulation.
Walters, S. (2021). Introduction to GIS for the Earth sciences. McGraw Hill.

GIS Fundamentals was used as a technical and conceptual reference.
Bolstad, P. (2019). GIS fundamentals: A first text on geographic information systems (6th edition). XanEdu Press.

"GIS and Mapping" informed my understanding of the functions of maps and best practices in map making.
Kent R. & Klosterman, R. (2000) GIS and mapping. Journal of the American Planning Association.

The guidance of Design Basics Index was used to make it all much prettier and more informative.
Krause, J. (2004). Design basics index. HOW Design Books.

Geographic Information Study Guide: Reading Academic Papers

high school level reading guide for "The Ecological and Evolutionary Consequences of Systemic Racism in Urban Environments" by Schell et al.

content warning: in-depth discussion of racism and systemic inequity
Estimated total lesson time: 1.5-2 hours

This lesson helps introduce high school level students to the formal writing style and complex topics covered in "The Ecological and Evolutionary Consequences of Systemic Racism in Urban Environments" and could easily be adapted to other academic articles. The homework provides instructions for how to approach reading the paper, and a few written questions to help structure your personal reflections to get more out of it. The recommended seminar structure offers guidelines for talking about charged topics and a chance to share your ideas with classmates. After completing them, you should be well prepared to begin the mapping activities in Geographic Information Study Guide Lesson 1: Environmental Justice.

Seminar Prep Homework (~30-45 minutes)

Before class, read pages 1-3 of the free structured abstract of "The Ecological and Evolutionary Consequences of Systemic Racism in Urban Environments" and skim the first eight pages of the longer free version of the article here . If you have access to a printer, you might find it useful to print out and take notes on the pages. It's OK if you're not used to the writing style or scientific terms. If you get really stuck on a new word, just write it down for later. This article is very technical and dense, so don't worry about understanding everything. Even small sections are interesting. Look for main ideas, and whatever sentences or paragraphs stand out to you. If you don't understand something, re-read it once, then move on.

Write your responses to the following prompts. Try to answer each question, even if your answer is only a few words.

- What three quotes stood out to you most? Highlight or copy them so you can easily find them later.
- How did the article connect to what you already know about U.S. history, systemic racism, and the environment? See if you can give an example from different parts of the reading, including one about the big picture from the structured abstract, one from the chart, and one related to a quote.
- What questions did the article bring up for you about U.S. history, systemic racism, or the environment? What ideas did the authors talk about that you would like to learn more about?
- Did it conflict with anything you learned before, or give new details that make you understand things differently? Did it make you think of science, like ecology or biology, differently?
-

Class Discussion (~1 hour)

Before diving into the class discussion, take some time to set up. The class should agree on discussion ground rules, or do a quick refresher if you already have some in place. Due to the intellectually and emotionally challenging subject of the article, active moderation from the teacher will be necessary during seminar. Instructors and interested students can refer to the resources listed here for guidance on facilitating discussions of charged topics.

When ready, talk about the article in small groups using a “Save the Last Word” discussion style:

Break into groups of 4 students. It is OK to have fewer members, but no groups should have more.

Choose one person with a phone or timer to act as timekeeper.

- Spend about 1 minute silently selecting your favorite quote from the reading. Feel free to use one of the passages from your written assignment.
- When everyone has found a quote, have one person volunteer to share theirs first.
- Have them read it aloud, without explaining why they chose the quote or how they interpreted it.
- Pause for a few seconds to think about your own response to the quote.
- In a circle, every other group member gives a 1 minute response (timed by the timekeeper) to the quote. It can be how you understood it, what it made you think of, or any other reaction you had.
- Once everyone else has responded to the quote, the person who chose it gets 3 (timed) minutes to explain why they chose it and respond to their group members.
- Repeat this process for everyone's quote until each member has had a turn. If you have a small group, you might have the chance to end early or share twice.
- Make sure to reserve time at the end of class for large group reflections. Processing, alone and as a group, is especially important for challenging material like environmental justice articles!

This lesson plan draws from the following works:

The written homework assignment was based on the "Connect, Extend, Challenge" lesson structure.

Facing History and Ourselves. (n.d.). Connect, extend, challenge. https://www.facinghistory.org/resource-library/teaching-strategies/connect-extend-challenge
The in-class discussion exercise uses the "Save the Last Word for ME" format.

Averette, P. (n.d.). Save the last word for me. National School Reform Faculty Harmony Education Center. https://www.nsrfharmony.org/wp-content/uploads/2017/10/save_last_word_0.pdf

Geographic Information Study Guide: Discussion Resources

recommended facilitation materials for group discussions

Many of the subjects covered in the Geographic Information Study Guide series are intensely intellectually and emotionally challenging, making active moderation necessary for any group discussions. I recommend the following readings to teachers and discussion facilitators who do not have established protocols in place for class discussions of charged topics:

"Discussion Guidelines" published by the MIT Teaching and Learning Lab (includes an especially helpful example of ground rules for productive classroom discussion)

"Making the Most of Hot Moments in the Classroom" published by the University of Michigan Center for Research on Learning and Teaching

"Responding to Microaggressions in the Classroom" by Dr. Tasha Souza on Faculty Focus

"Can We Talk? Tips for Respectful Conversations in Schools, Workplaces and Communities" published by the Anti-Defamation League

Geographic Information Study Guide: Lesson 1

a data consolidation inspired by "The Ecological and Evolutionary Consequences of Systemic Racism in Urban Environments" by Schell et al.

Nikki Canning

April 27, 2022

content warning: in-depth discussion of racism and systemic inequity

This lesson is a high school level study companion to "The Ecological and Evolutionary Consequences of Systemic Racism in Urban Environments," originally published in Science in 2020. Through this StoryMap, you should be able to get a good idea of some simple ways of using GIS to think about how environmental justice and equity are present in the places we go everyday.

In the article, Dr. Schell and his coauthors summarize the findings of previous research on the connection between housing segregation in U.S. cities and measurements of environmental health. The authors provide overviews of many important areas in which social inequity, especially racial segregation in housing, has been shown to cause differences in the physical characteristics of neighborhoods, and even influences the types and amounts of wildlife that live there. Longstanding racist biases in urban planning and mainstream environmental conservation, they explain, have created and perpetuated environmental conditions that are harmful for human beings and overall ecosystem health. The patterns they describe are examples of environmental racism, or violations of the principle of environmental justice.

The United States Environmental Protection Agency defines environmental justice as “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental

laws, regulations, and policies." The concept of environmental justice, or EJ, is usually traced back to the early 1980s, when Black civil rights activists worked with the NAACP to protest government disposal of poisonous PCBs into the soil of predominantly Black Warren County, North Carolina. Dr. Benjamin Chavis Jr., a protégé of Dr. Martin Luther King Jr., coined the term "environmental racism" during the protests. While local, state, and federal governments have increasingly adopted policies designed to advance environmental justice in recent years, the movement remains grounded in BIPOC community self-defense efforts against unfair or unhealthy environmental conditions.

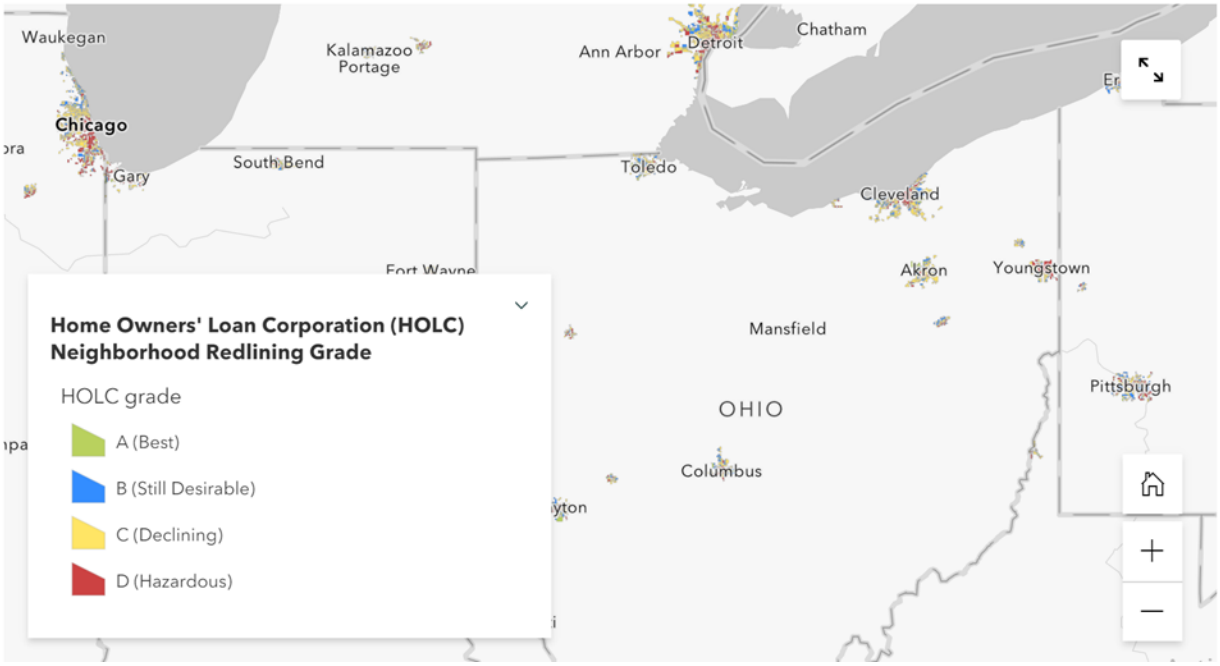
"The Ecological and Evolutionary Consequences of Systemic Racism in Urban Environments" gives a lot of examples of areas where environmental justice overlaps with scientific research. Folks familiar with the paper can stay on this page to see a few examples of how core concepts from the article can be explored in Seattle using publicly available data. Students or anybody new to the article are welcome to use this lesson plan to prep first.

Even though Seattle isn't specifically addressed in "The Ecological and Evolutionary Consequences of Systemic Racism in Urban Environments," we can still see if the same patterns from the article hold true. One of the main points of the paper is that racial segregation causes measurable changes in ecology and environment, to the extent that historical segregation corresponds to decreased environmental and human health today. With a little bit of data and some background knowledge of Seattle's history of urbanization, we can see what that legacy looks like in our city using GIS.

Like most major American cities, Seattle does have a history of both legally enforced and more covert racial segregation. From 1926-1948, most Seattle neighborhoods used racially restive

covenants, which were legal documents forbidding racially minoritized groups from living there. In 1948, a federal ruling made it technically illegal for the government to enforce racially restrictive covenants. It did, however, remain commonplace and functionally legal for individuals to be openly racist in deciding who to sell or rent to until the Housing Rights Act of 1968.

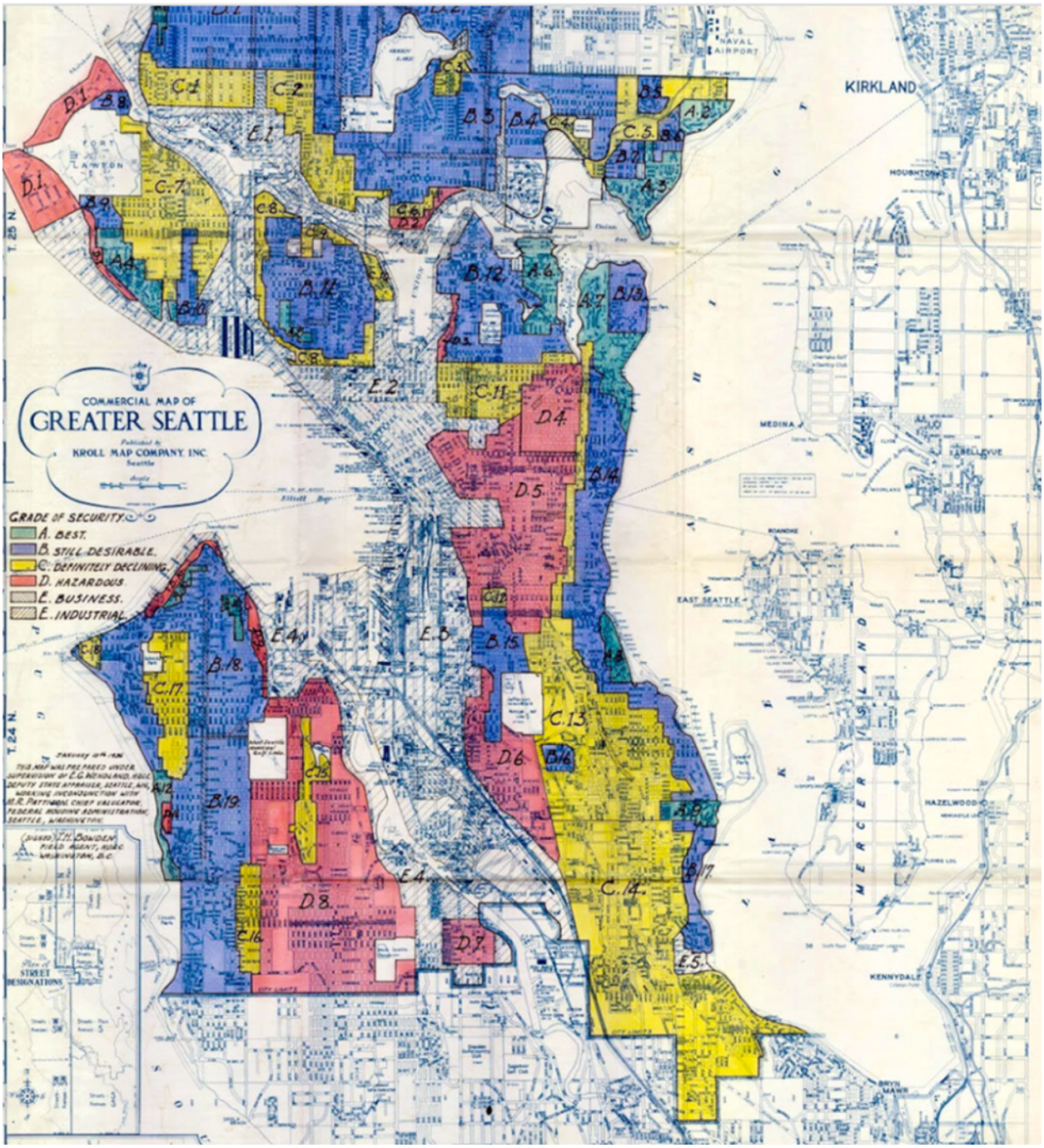
During the same time as the peak of racially restrictive covenants, the federal government was making unprecedented changes in cities across the country. As part of the New Deal, an enormous piece of legislation designed to help people recover from the devastating poverty of the Great Depression, the government made it much easier for the middle class to buy single-family houses. They did a lot of that work through a new company, called the Home Owners' Loan Corporation, or HOLC. Through the HOLC, the government recommended banks offer home loans to people in what they considered good neighborhoods. Across the country, they defined good neighborhoods to be middle- or upper class and mostly to entirely white. The HOLC deliberately excluded racialized groups, specifically Black people, from the opportunity to buy houses by classifying their neighborhoods as too "high risk" or "hazardous" to offer home loans. They published maps of all major U.S. cities, most of which are now available online, to document their neighborhood ratings. The maps used a standardized color system for rating neighborhoods, ranging from red (worst) to green (best). The red that marked areas where banks were instructed to deny home loans is where we get the term "redlining."



The legacy of redlining can be found across the United States. This map shows the HOLC neighborhood ratings for several Midwestern cities. You can zoom in to see these neighborhood ratings in greater detail, or scroll to other areas of the U.S., most of which have cities with digitized records of redlining maps. Seeing collections of redlining maps together helps show the scale of harm caused by redlining. Please note that the explanations of why neighborhoods were given their ratings are generalized in these maps. The place-specific, more detailed reasons are given here (link content warning: language, racism).

Coupled with racially restrictive covenants and other barriers against moving elsewhere, Black Americans were often trapped renting homes in devalued neighborhoods, while residents of white neighborhoods were given economic and material resources to become prosperous. Redlining officially ended with 1968's Housing Rights Act, but many of its racist patterns of resource distribution continued. Redlining is generally considered a root cause of lower rates of

home ownership and suppressed accumulation of intergenerational wealth among Black Americans today.

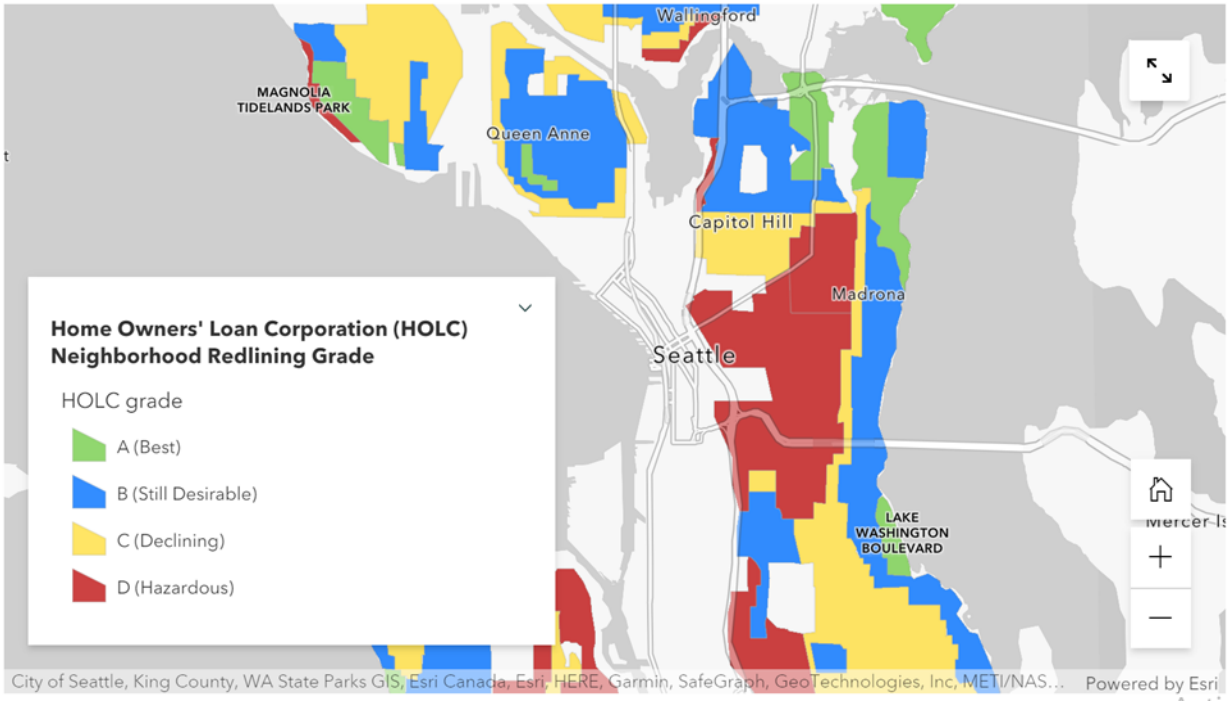


This image shows Seattle's 1936 HOLC ratings. In addition to the residential areas, it also shows a few neighborhoods zoned for business and industry, especially downtown and along the

Duwamish River. The interactive maps that this StoryMap uses from this point on leave out the "E" rated non-residential areas, but you might notice that some patterns there, too.

Discussion questions

- Had you heard about redlining before this lesson? What did you know about it?
- Did you connect it to Seattle, or any other specific cities?
- Thinking back to the article, what ways would you expect past redlining to affect Seattle neighborhoods today?

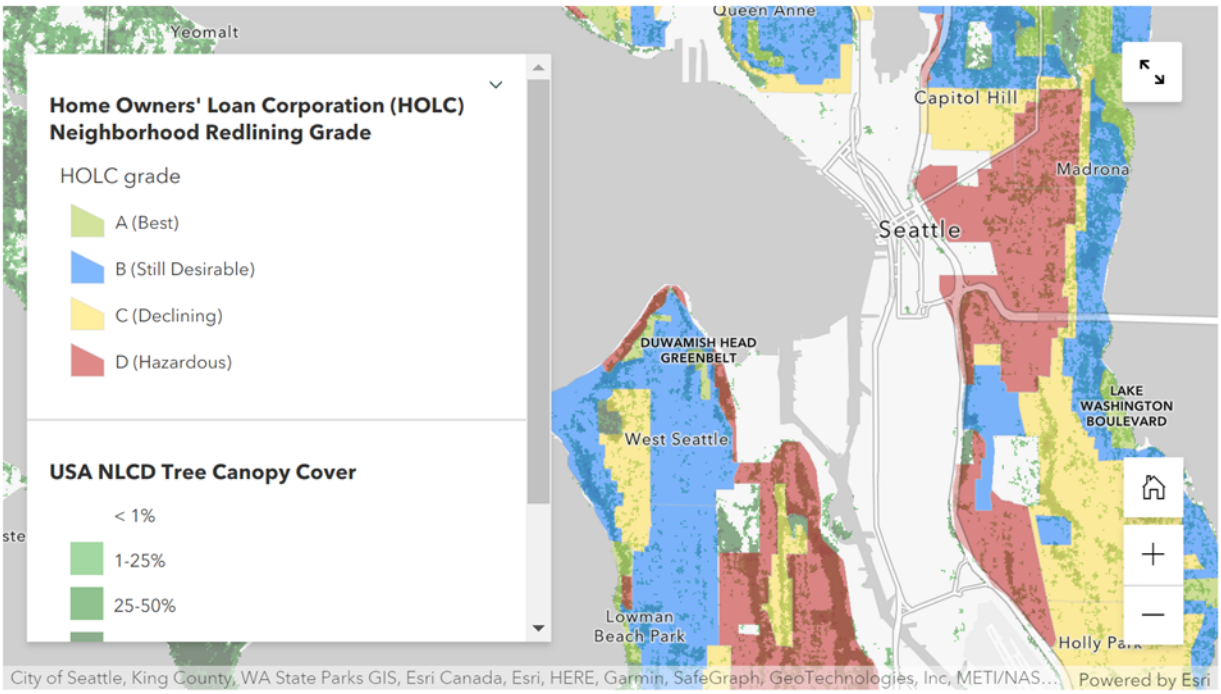


An interactive copy of the Seattle HOLC map from 1936, showing redlining in the modern Central District and parts of the International District. Some areas, like the northern tip of West Seattle, were not recommended for home loans because of environmental conditions that made building difficult or unsafe, for instance being prone to landslides. Low HOLC ratings were most

famously used, however, to support home ownership in overwhelmingly white neighborhoods, while preventing it in Black and racially diverse ones.

The detailed text of Seattle's HOLC map (content warning: racism, language) says outright that the northern section Central District was given the lowest rating due to its Black population. Similarly, it redlined the area of the Central District closest to the modern International District for its racial diversity , likely referring in part to the Asian communities already established there. Most other areas of Seattle to be given a "D" rating were recommended for denying home loans because of environmental conditions that were bad for construction, or lacked infrastructure like roads. Additionally, many residents lived in areas that were zoned for industry or business, including a large Indigenous community living in Pioneer Square in the 1930s. These populations are not measurable through studying redlined neighborhoods, but they were systemically denied resources by the policy regardless.

"The Ecological and Evolutionary Consequences of Systemic Racism in Urban Environments" notes that historic redlining corresponds to decreased greenspace in many U.S. cities. To explore this possible correlation in Seattle, we can see if the redlined districts have less vegetation than other neighborhoods today. There are many different ways to try to capture how much vegetation an area has, but trees are an easy simplification. To compare the density of trees, we can overlay the HOLC map with Seattle's tree canopy cover data:



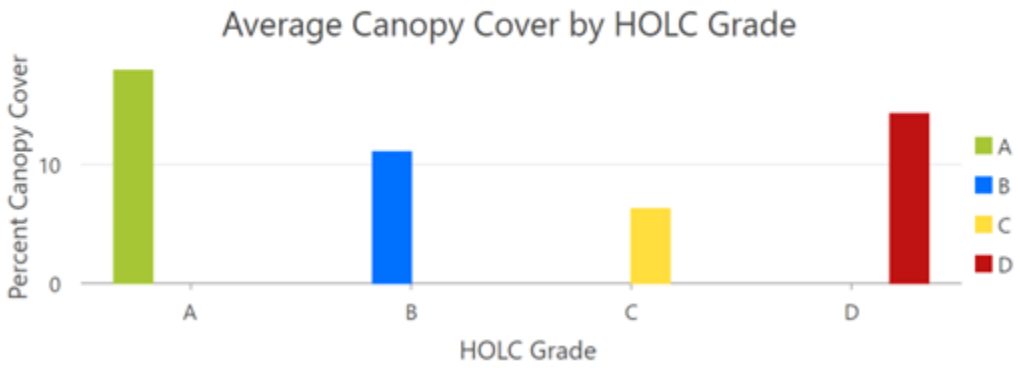
Tree Canopy Cover over HOLC Grade: This map shows the 2016 National Land Cover Database measurements of tree canopy cover (the government's authoritative national data set) over the 1936 HOLC neighborhood ratings. As before, you can zoom in for more detail, or pan to other cities.

Discussion questions

- Are you especially surprised or unsurprised about the amount of canopy in any neighborhoods you spend time?
- Do you have any observations about specific areas?
- Do you see any potential trends between different areas?

The data looks a bit chaotic with so much to take in. You may be able to see areas where a high HOLC rating seems to correspond to high canopy cover, and others where it doesn't. Even focusing on the northern and southern sections of the Central District we identified earlier, it is

hard to tell if our prediction of low canopy cover is observable. To get a simple, objective measurement of whether there is a difference, I loaded the data into some heavier duty software to run some simple analysis. I calculated the mean percent canopy cover across each neighborhood, then averaged that average for each HOLC rating.

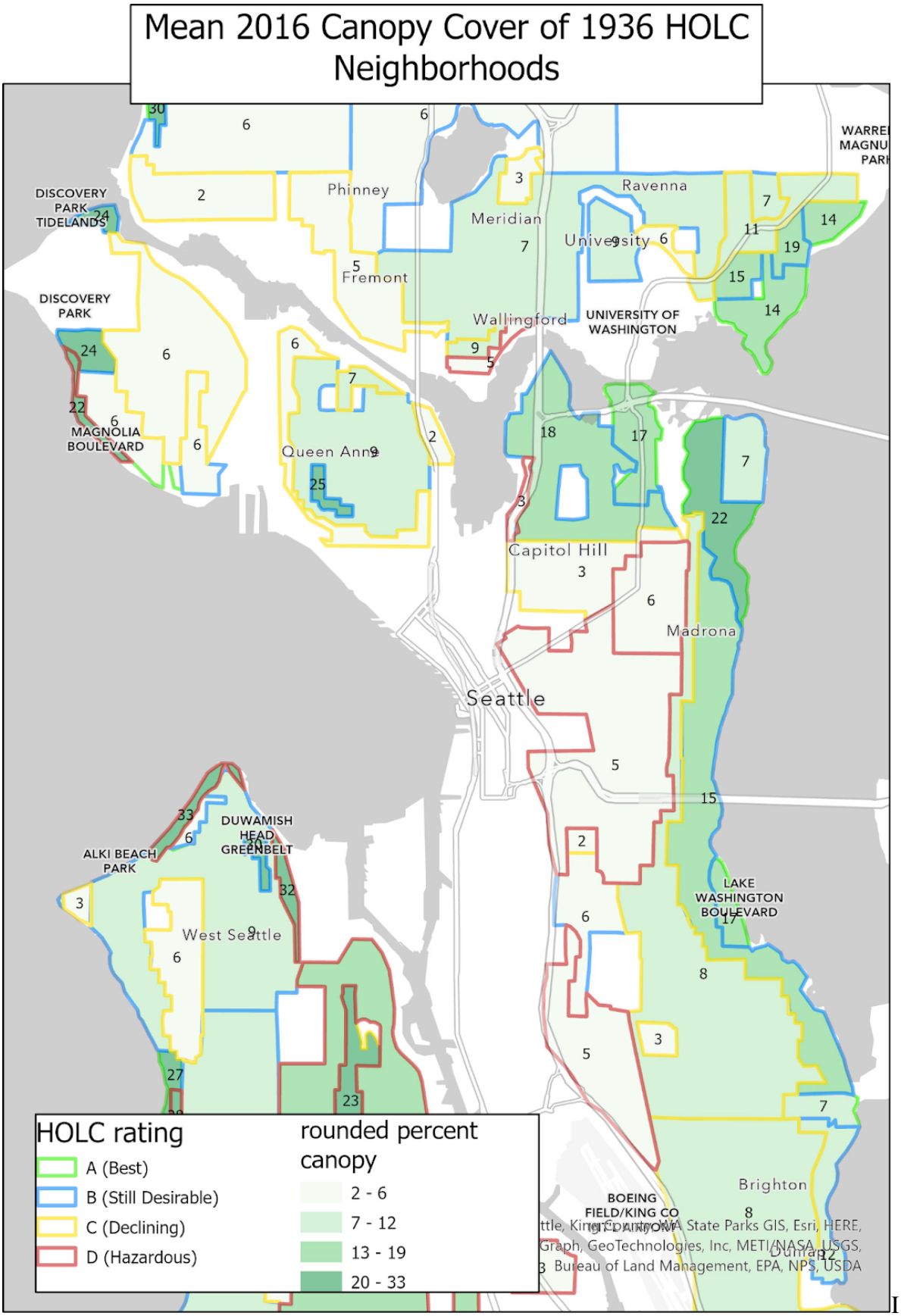


This might not look consistent with the article's findings. We can see that in Seattle, a "D" HOLC rating alone does not correspond to a low average canopy cover today.

Discussion questions

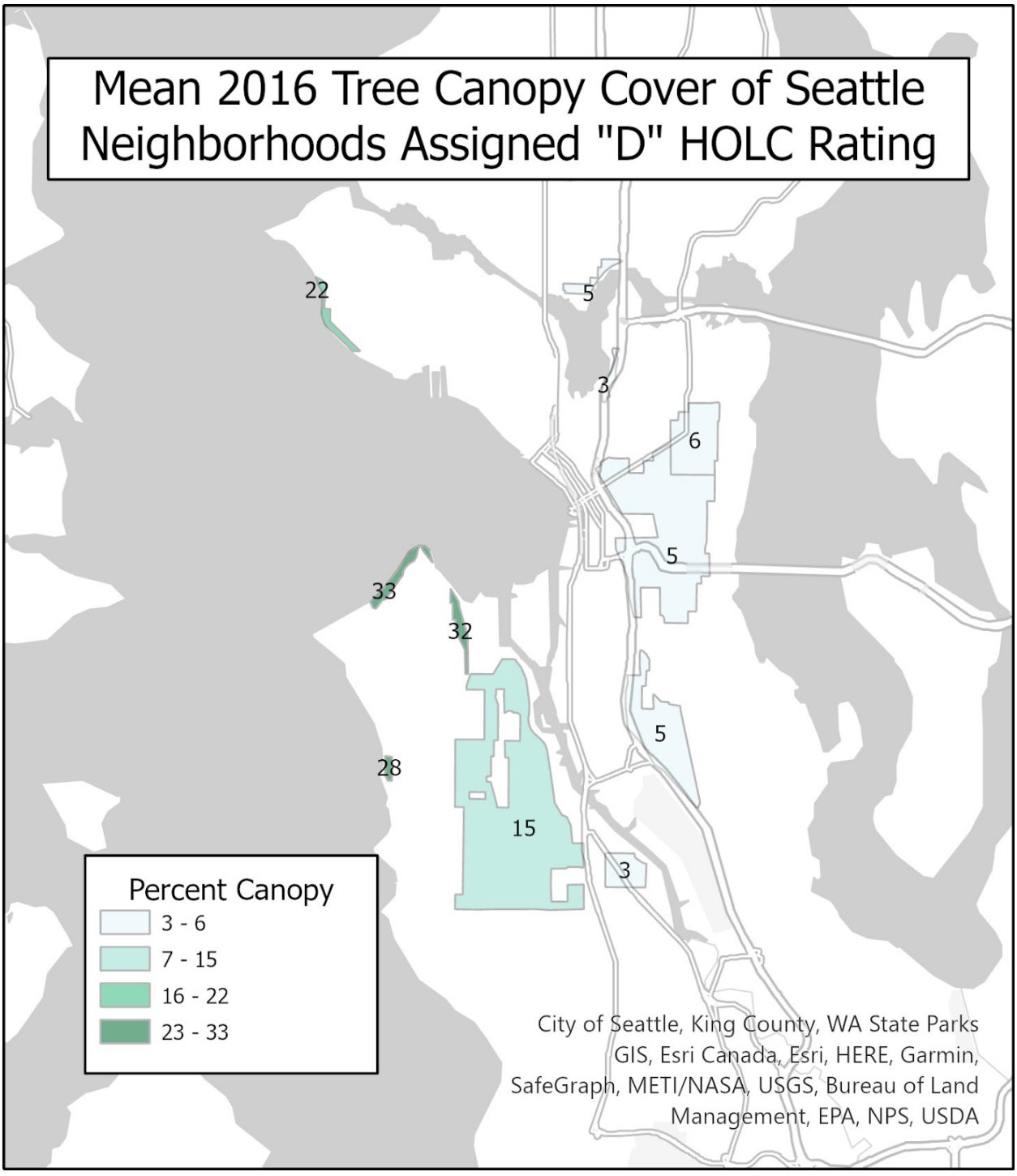
- What pattern do you see in average canopy cover between ratings?
- Did you expect "D" rating assigned neighborhoods to have the second highest average?
- Do you think this supports, contradicts, or does not address the article's finding that redlining corresponds to lower environmental quality today?
- Even though the "A" rated neighborhoods average the highest percentage of canopy cover, HOLC rating does not seem to have a straightforward linear relationship with canopy. Perhaps surprisingly, it even looks like "D" rated areas have the second highest density of tree cover.

To get more information, I pulled up the average canopy cover of each individual neighborhood. It turns out, the high average is not an accurate representation of the areas we identified as redlined specifically because of the race of the inhabitants. The two neighborhoods, called "D4" and "D5" in the HOLC documentation, have averages of only 6% and 5% canopy cover across their areas. While those aren't the very lowest average canopy covers in the city, both fall within the lowest quarter of canopy cover and are considerably lower than the citywide average for "D" graded neighborhoods. This is probably closer to what you might have predicted.


Mean 2016 Canopy Cover of 1936 HOLC Neighborhoods
Phinney
Ravenna
Meridian
University
Fremont
Wallingford
UNIVERSITY OF WASHINGTON
DISCOVERY PARK TIDELANDS
DISCOVERY PARK
MAGNOLIA BOULEVARD
Queen Anne
Capitol Hill
Madrona
Seattle
DUWAMISH HEAD GREENBELT
ALKI BEACH PARK
West Seattle
LAKE WASHINGTON BOULEVARD
BOEING FIELD/KING CO INTL (BOEING FIELD)
Brighton
Dunlap
HOLC rating
A (Best)
B (Still Desirable)
C (Declining)
D (Hazardous)
rounded percent canopy
2 - 6
7 - 12
13 - 19
20 - 33
ttle, King County, WA State Parks GIS, Esri, HERE, Graph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA

made this using the exact same data as our earlier maps, with a little tweaking in some of Esri's more technical mapping software, ArcGIS Pro. It uses the same borders as the HOLC map, but the colors and number labels show the average percent canopy cover in 2016, rounded to the nearest whole number.

Looking closer, the average is high because it was dragged up by a few areas with extremely high canopy cover. The northern tip of West Seattle, the area that was given a "D" rating because it is in a landslide zone, has the highest average percent cover of any neighborhood in the dataset.

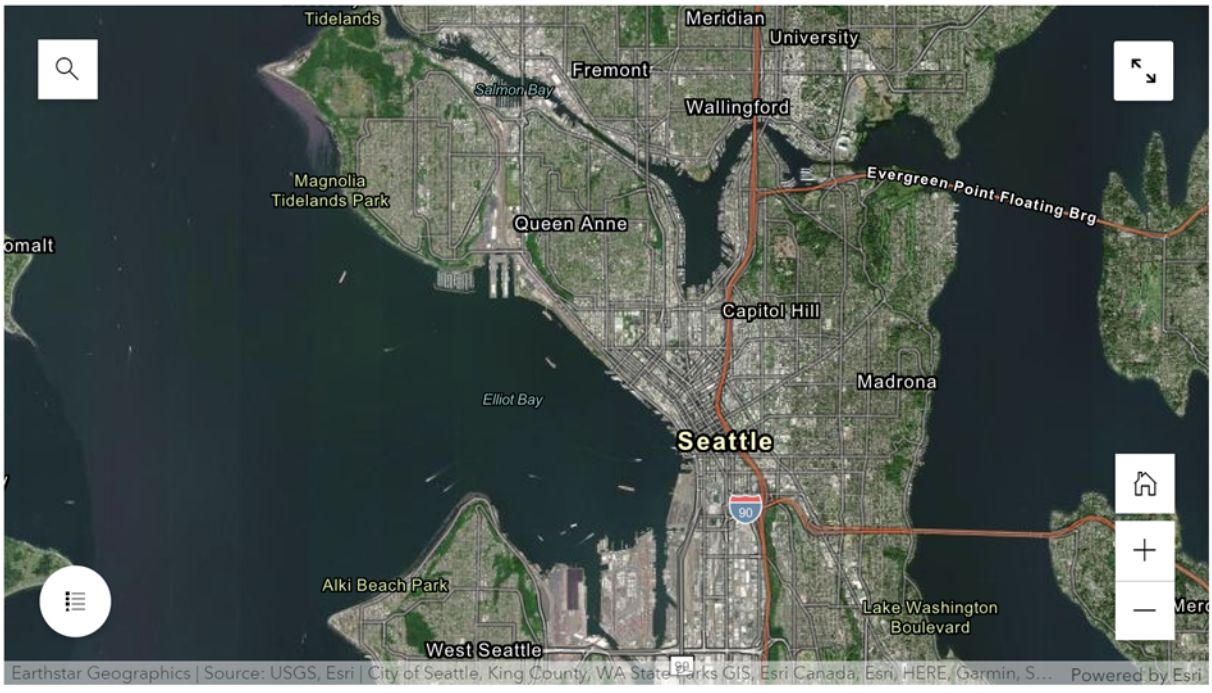


Taking out the neighborhoods that were assigned other ratings, you can see that the high average canopy cover was skewed by a few areas. Using context from the written HOLC assessment, we

know that the areas driving the increase in average canopy cover were given low ratings because they were "undeveloped" and often difficult to build on.

Discussion questions

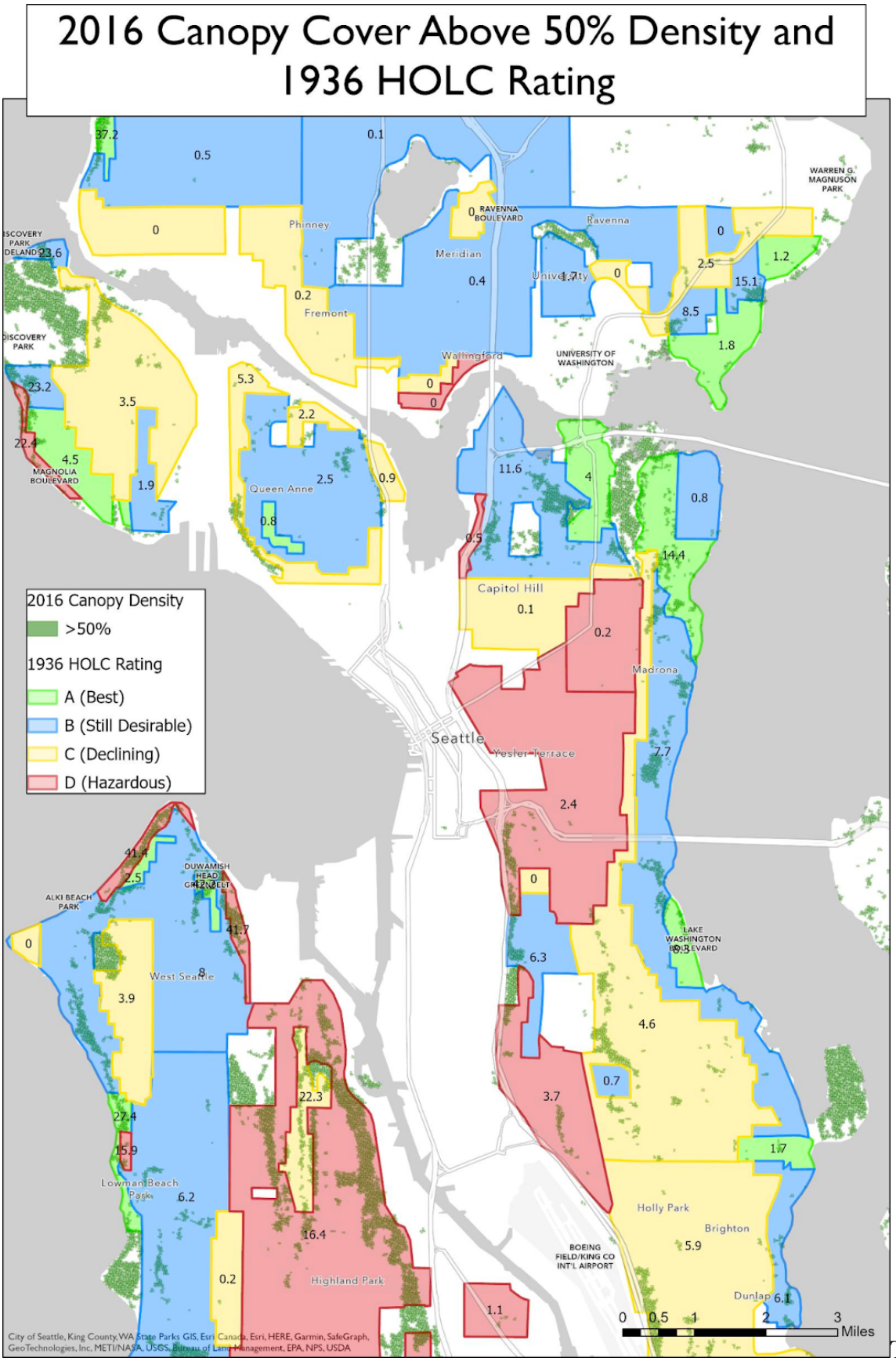
- Do you think it makes sense that so many of the places with environmental conditions considered bad for construction in the 1930s seem to have a lot of trees today?
- What do you predict the surroundings look like when you walk around those places?
- Find them on the map below to find out.



Zoom in to look at places you identified as having high average canopy cover. You can also use the search bar in the upper left to find specific places, and click on the map to find out exactly what percent a small area has.

Other than the two Central District neighborhoods and the small rectangular area on the southern shore of the Duwamish River, all of the neighborhoods in Seattle to receive a "D" HOLC rating were described as having very low populations and obvious environmental reasons not to build homes. Going off the descriptions from the HOLC map, we do not have evidence that all the areas to receive "D" ratings were necessarily deliberate targets of systemic racism, only the two Central District neighborhoods blatantly were. The high overall average, then, might not be compelling evidence against the article's findings of ongoing consequences of residential segregation. One could even argue that the average canopy cover of the Central District being significantly below the average canopy of the "D" rated areas overall is evidence that supports Dr. Schell and his colleagues' findings.

We can analyze the same canopy data in a different way to further explore our question about redlining and vegetation. Areas of especially high canopy density, rather than just the average, are another way to measure greenspace. Focusing on high tree density could even be considered more informative, based of the authors' statement that bigger, connected greenspaces are often better habitat for plants and animals than smaller, more sparce natural areas. To explore this new metric, I filtered the canopy cover data to focus on spaces with canopy densities greater than 50%.


2016 Canopy Cover Above 50% Density and 1936 HOLC Rating
2016 Canopy Density
>50%
1936 HOLC Rating
A (Best)
B (Still Desirable)
C (Declining)
D (Hazardous)
Seattle
Capitol Hill
Madrona
Yesler Terrace
Queen Anne
Phinney
Fremont
Wallingford
Meridian
Ravenna
University
West Seattle
Highland Park
Holly Park
Brighton
Dunlap
Lowman Beach Park
Alki Beach Park
Duwamish Head Greenbelt
Magnolia Boulevard
Ravenna Boulevard
Lake Washington Boulevard
University of Washington
Boeing Field/King Co Int'l Airport
Warren G. Magnuson Park
Discovery Park
0 0.5 1 2 3 Miles
City of Seattle, King County, WA State Parks GIS, Esri Canada, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA

This

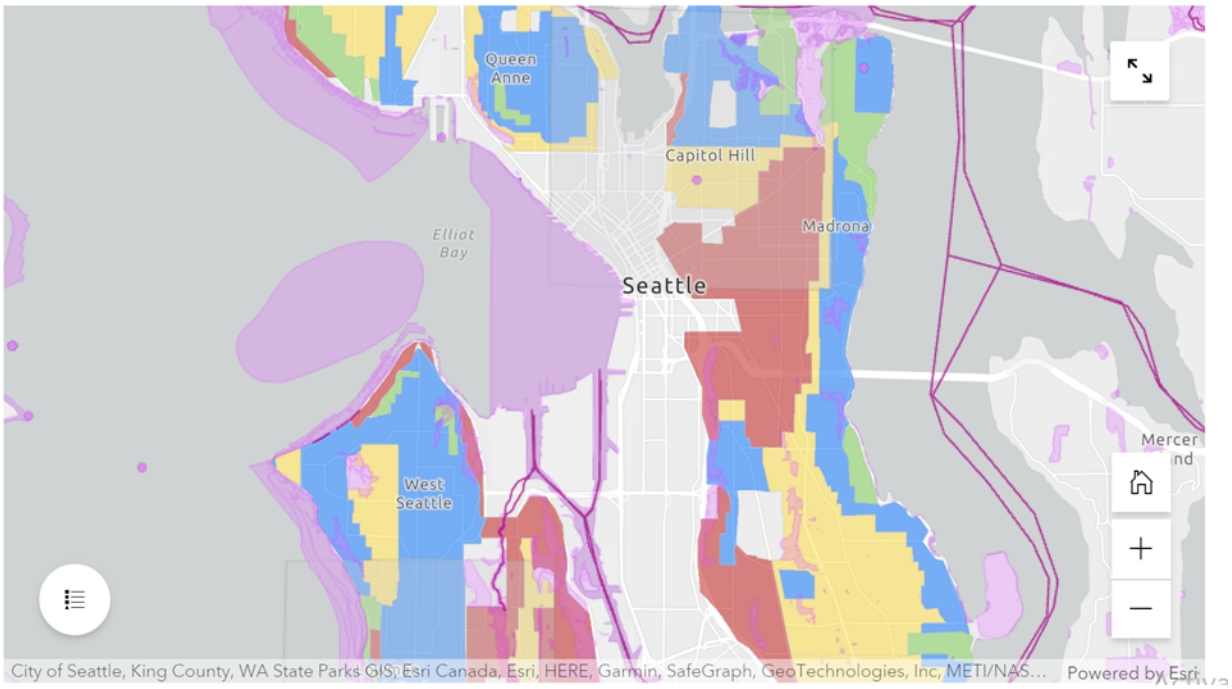
map shows the areas with canopy cover above 50% in dark green. I also added labels that give the percentage of each HOLC neighborhood's area that is covered by those dense canopy zones.

Discussion questions

- If you see any places with especially large or small areas of high tree density, what patterns do you notice about them?
- What places do you recognize that are marked as high canopy cover?
- What do you do there?

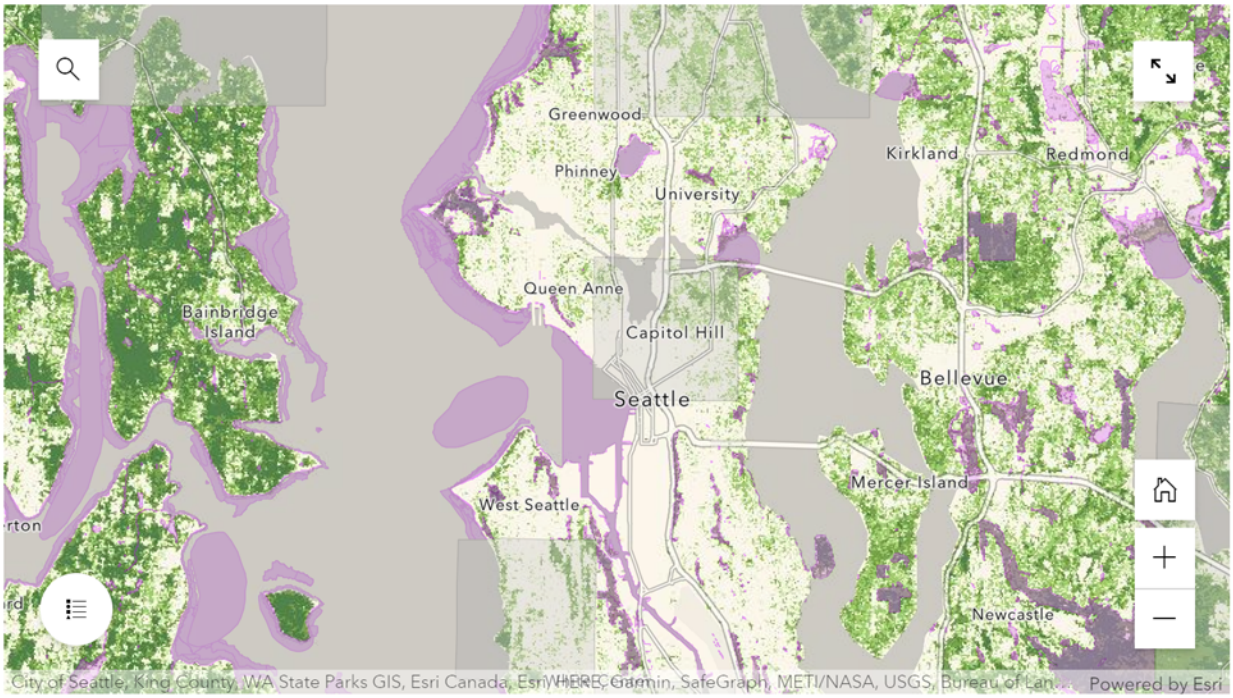
We can even look into the connection between habitat and redlining or habitat and amount of canopy cover directly. You may need to be patient loading the maps below. The habitat dataset it uses is extremely large and detailed, covering the whole state of Washington.

Here is habitat and redlining:



This map overlays the HOLC ratings with Washington Department of Fish and Wildlife public Priority Habitat Species data . The purple polygons show areas identified as especially important for species conservation. The lone purple dots are places where an endangered species has been identified, and the large, transparent gray squares are general areas where there have been records of endangered species. You can zoom in to get a better look, or zoom out to see how many habitat areas have been cataloged across the state.

And here is habitat and canopy cover:



Priority habitat areas mapped over canopy cover. Try zooming in to get a better look at the places where high canopy density and priority habitats overlap. These areas should generate a popup with information about the type of priority habitat area and percent canopy cover. You might also think back to the Schell paper and try to notice where there don't seem to be as many priority habitat areas.

To my eye, it does look like there are some visible patterns in this map. While most priority habitats are not located directly in residential neighborhoods, there does seem to be a noticeably large share in and immediately beside areas that were assigned "A" and "B" HOLC ratings, along with the high canopy cover "D" rated areas in White Center and West Seattle we looked at earlier. There is also large priority habitat in Beacon Hill along I-5, called the East Duwamish Greenbelt that overlaps with one of our redlined Central District HOLC neighborhoods and does have a high percentage of canopy cover.

Discussion questions

- Where do you notice priority habitats?
- Do you see any particular factors that seem to make them more or less likely?
- How does it match up to tree density?
- What about redlining history?
- Do you think the distribution of priority habitats is a good way of looking at environmental equity?
- If so, do you think the Priority Species Habitat maps show a fair distribution?
- What does a fair distribution look like to you?

Canopy cover is just one variable you can use to look at environmental quality and environmental justice. Similarly, redlining is one of the most popular ways of measuring histories of environmental racism, but there are many others, including current demographics, history of racially restrictive covenants, land use zoning policies, and many more.

Wrap-up discussion questions

- Do you think the distribution of canopy cover in Seattle was consistent with the finding that systemic racism causes lasting differences in environmental quality?
    - If so, what provided the strongest evidence?
    - If not, what evidence would you have needed to see to be convinced?
- What differences in environment do you think would show that there was systemic bias against the population of a certain area?
    - What kind of data do you think could be used to measure those differences?
- What part of the lesson was most interesting to you?

- What did it make you curious to learn more about?
- Using this activity jumping off point, what data would you use to map your observations or questions about the world around you?

This page draws upon the following highly recommended works:

The full text of the article used to inform the overarching structure and variable selection of this StoryMap.

Schell, C. J., Dyson, K., Fuentes, T. L., Des Roches, S., Harris, N. C., Miller, D. S., Woelfle-Erskine, C. A., & Lambert, M. R. (2020). The ecological and evolutionary consequences of systemic racism in Urban Environments. Science, 369(6510). https://doi.org/10.1126/science.aay4497

A page-long summary and 35 minute interview providing an introduction to the history and modern consequences of redlining.

Gross, T. (2017). A "forgotten history" of how the U.S. government segregated America. Fresh Air. https://www.npr.org/2017/05/03/526655831/a-forgotten-history-of-how-the-u-s-government-segregated-america

A history of racial segregation in the United States. I referred to the chapters on redlining and zoning.

Rothstein, R. (2017). The color of law: A forgotten history of how our government segregated America. Liveright.

An overview of racially restrictive covenants (also often called "racial covenants" or "racial restrictive covenants" by different sources) in Seattle.

Silva, C. (2008). Racial restrictive covenants history: Enforcing neighborhood segregation in Seattle. Seattle Civil Rights & Labor History
Project. https://depts.washington.edu/civilr/covenants_report.htm
Online database of racially restrictive covenant records in King County. Subject to updates. Authors credited here are not comprehensive due to the ongoing and highly collaborative nature of this project. (content warning: language)

Gregory, J., Heslop, M., Woods, J., Dowling, S., Boren, N., Cebula, L., Kelly, T., Camporeale, L., Schons, C. (2022). Racial restrictive covenants: Neighborhood by neighborhood restrictions across King County. Seattle Civil Rights & Labor History
Project. https://depts.washington.edu/civilr/covenants.htm
An interactive map that shows changing racial demographics of Seattle neighborhoods using census data form 1940-2020.

Yoon, A., Lam, B., Du, G., Jiang Wu, J., Harada, Y., & Gregory, J. (2020). Mapping race Seattle/King County 1940-2020. Seattle Civil Rights & Labor History Project. https://depts.washington.edu/civilr/maps_race_seattle.htm
Online collection of archived HOLC maps that includes explanations of ratings. Please note that authoritative records of some cities' HOLC maps have not been digitized at the time of this publication. (content warning: language)

Nelson, R. K., Winling, L., Marciano, R., Connolly, N., et al., Mapping inequality: Redlining in New Deal America. American Panorama. https://dsl.richmond.edu/panorama/redlining/#loc=11/47.594/-122.498&city=seattle-wa&area=C11

A history of Indigenous groups and individuals during the colonization and urbanization of Seattle by American settlers.
Thrush, C. (2007). Native Seattle: Histories from the crossing-over place. University of Washington Press.

7.2 List of figures referenced in online materials

In instances where an interactive map was included as a component of GISG, screenshots have been provided instead. Figures that were the product of my own analysis using ArcGIS Pro are supplemented with brief documentation.

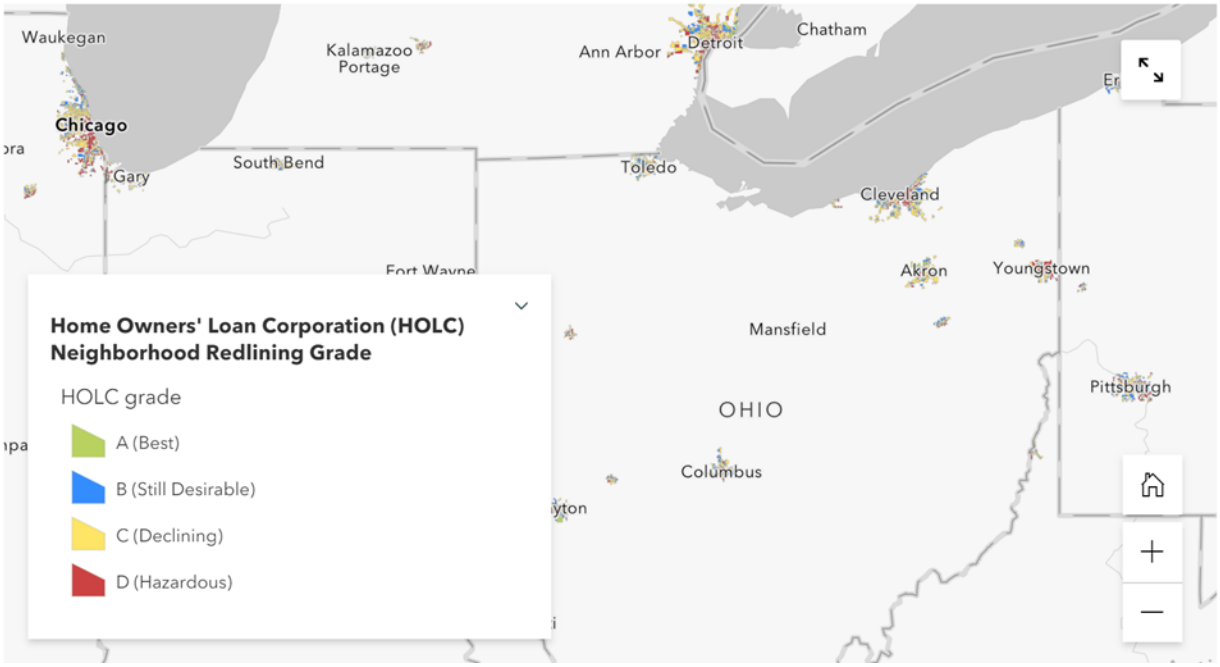


Fig. 1, Digitized Midwest HOLC maps. Screen capture of interactive, authoritative (but still incomplete) data layer providing consolidated official digitized copies of U.S. cities' HOLC maps. Area was chosen to help show the scale of this national policy. Data credits: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS | University of Richmond's Digital Scholarship Lab. Powered by Esri.

Subtitle in lesson plan: The legacy of redlining can be found across the United States. This map shows the HOLC neighborhood ratings for several Midwestern cities. You can zoom in to see these neighborhood ratings in greater detail, or scroll to other areas of the U.S., most of which have cities with digitized records of redlining maps. Seeing collections of redlining maps together helps show the scale of harm caused by redlining. Please note that the explanations of why neighborhoods were given their ratings are generalized in these maps. The place-specific, more detailed reasons are given here *(content warning: language, racism)*.

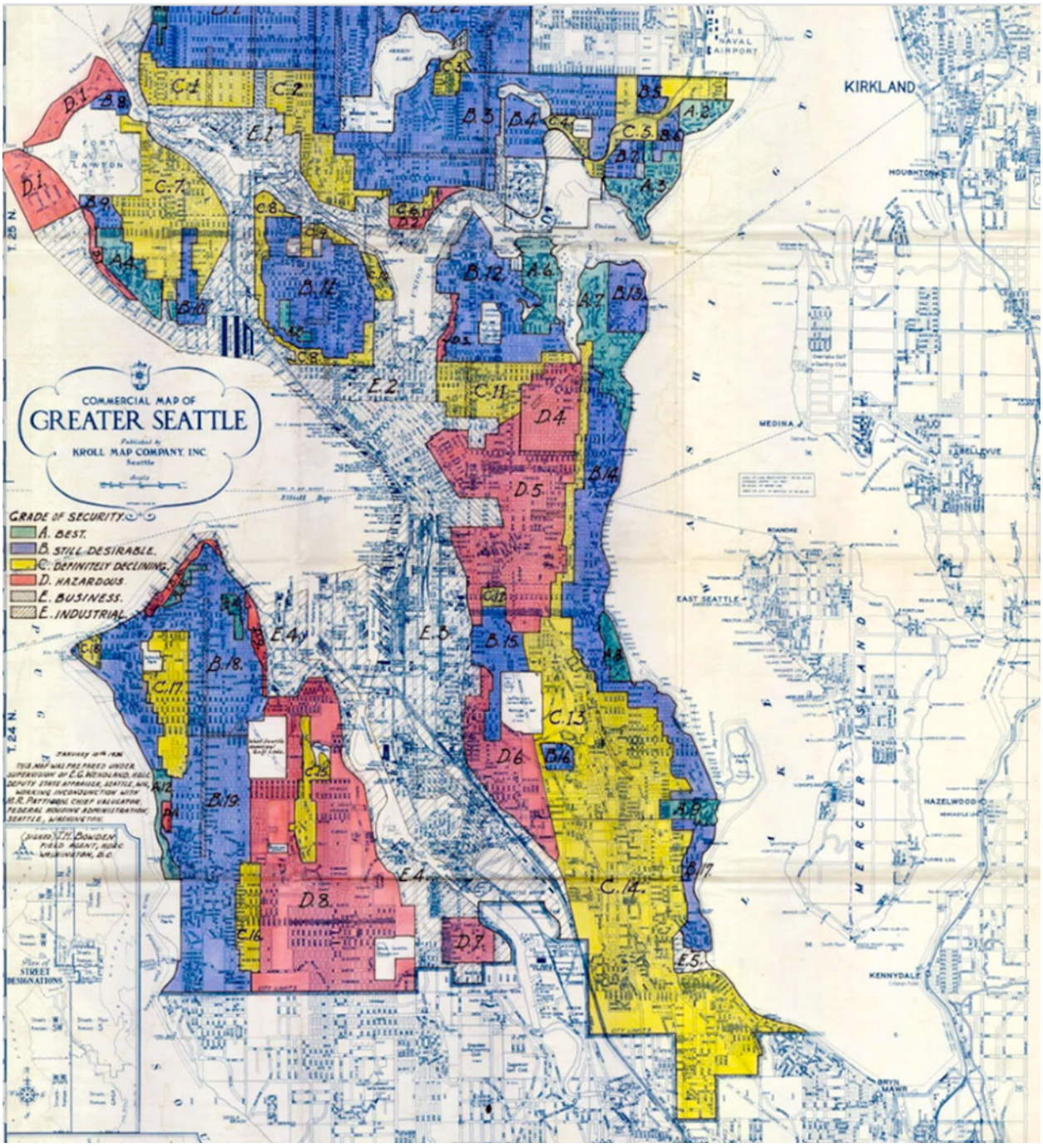


Figure 2, 1936 Seattle HOLC map. Available in the public domain. Used as webpage header and to introduce local historical context of redlining.

Subtitle in lesson plan: This image shows Seattle's 1936 HOLC ratings. In addition to the residential areas, it also shows a few neighborhoods zoned for business and industry, especially downtown and along the Duwamish River. The interactive maps that this StoryMap uses from

this point on leave out the "E" rated non-residential areas, but you might notice that some patterns there, too.

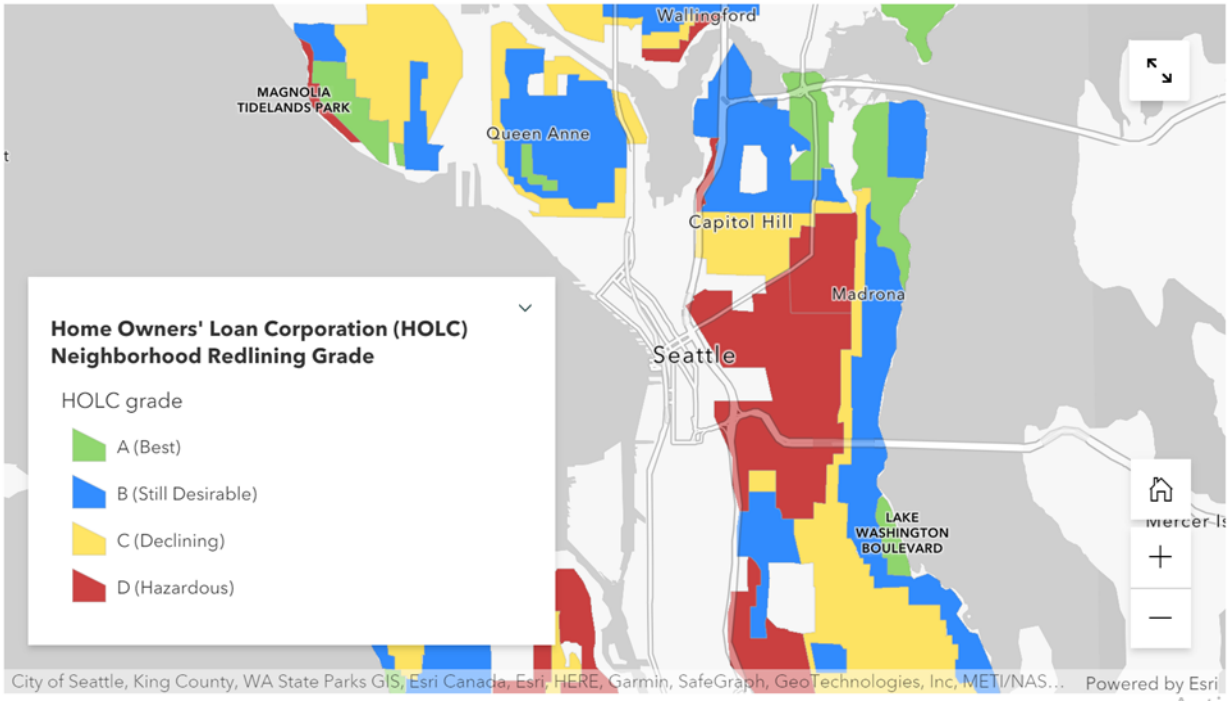


Figure 3, Digitized Seattle HOLC map. Screen capture of interactive National HOLC layer over a simple basemap zoomed to downtown Seattle. This image progression was chosen to bridge the image of the historic, hand drawn HOLC map with the more dynamic data sets the students will interact with as the lesson progresses. Data credits: City of Seattle, King County, WA State Parks GIS, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA | University of Richmond's Digital Scholarship Lab. Powered by Esri

Subtitle in lesson plan: The Seattle HOLC map from 1936, showing redlining in the modern Central District and parts of the International District. Some areas, like the northern tip of West Seattle, were not recommended for home loans because of environmental conditions that made building difficult or unsafe, for instance being prone to landslides. Low HOLC ratings were most famously used, however, to support home ownership in overwhelmingly white neighborhoods, while preventing it in Black and racially diverse ones.

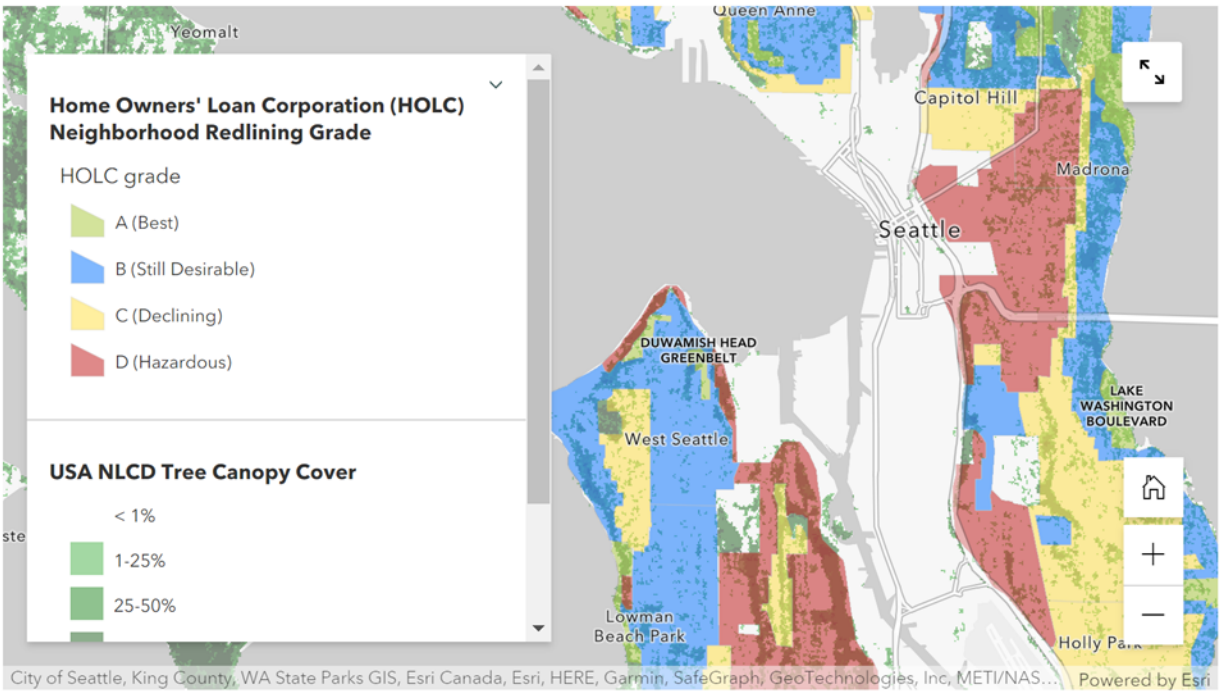


Fig. 4, Seattle HOLC and tree canopy map. Screen capture of interactive United States Geological Survey National Land Cover Database tree canopy layer overlaid with HOLC map. These layers were brought together to begin to apply Schell et al.'s findings to the users' lived experiences. Data credits: City of Seattle, King County, WA State Parks GIS, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA | Source: USGS, Esri | University of Richmond's Digital Scholarship Lab. Powered by Esri

Subtitle in lesson plan: Tree Canopy Cover over HOLC Grade: This map shows the 2016 National Land Cover Database measurements of tree canopy cover (the government's authoritative national data set) over the 1936 HOLC neighborhood ratings. As before, you can zoom in for more detail, or pan to other cities.

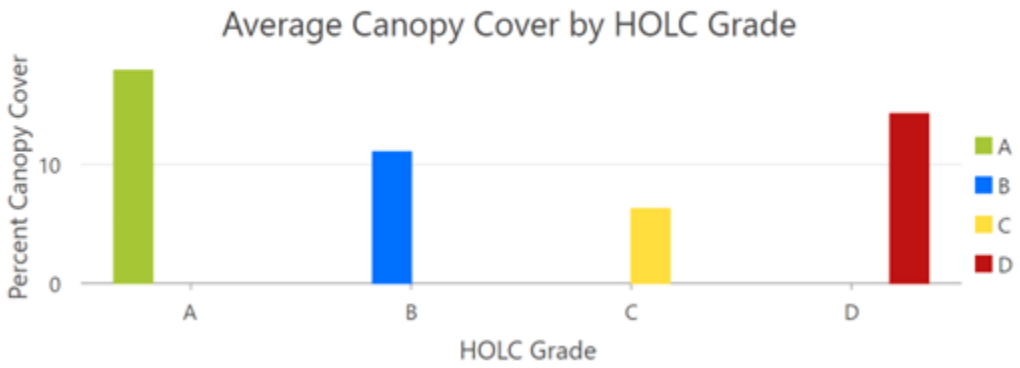


Fig. 5, Average canopy by HOLC grade. To generate the data for this chart, I clipped the canopy data to the area of the Seattle HOLC polygons and converted it from raster to polygon form. I then performed a spatial join and calculated the mean percent canopy cover over the area of each HOLC rated neighborhood. This percent value was rounded to the nearest whole number. Finally, to visualize the averages as a simple chart, I calculated the mean percent canopy cover per grade.

Subtitle in lesson plan: This might not look consistent with the article's findings. We can see that in Seattle, a "D" HOLC rating alone does not correspond to a low average canopy cover today.

Mean 2016 Canopy Cover of 1936 HOLC Neighborhoods

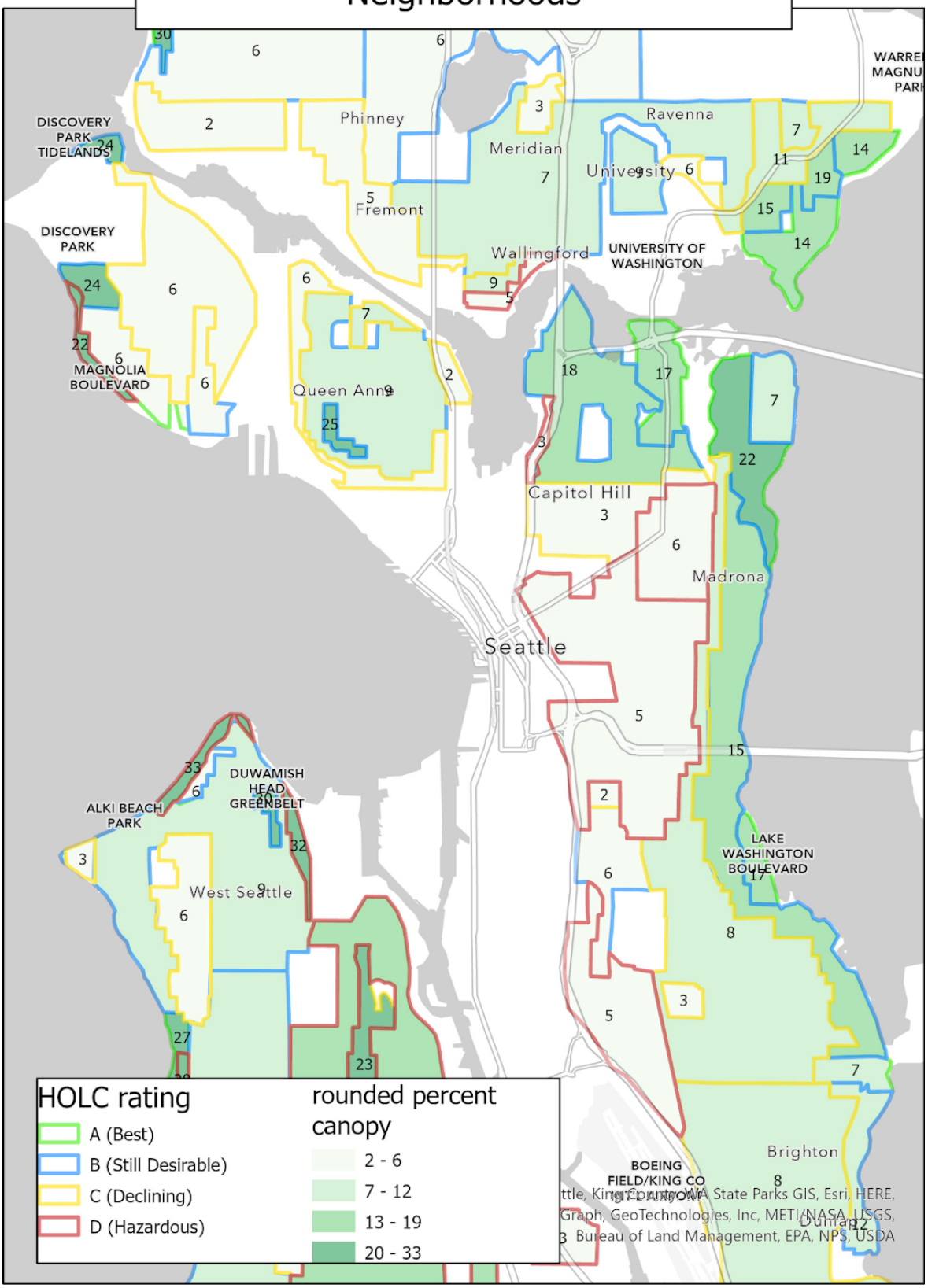


Fig. 6, Mean 2016 canopy of 1936 HOLC neighborhoods map. This still image was made using ArcGIS Pro. To generate the map, I utilized the spatially joined canopy and HOLC data from Figure 4. I removed the color fills associated with HOLC rating and visualized the 2016 canopy averages on the map by neighborhood polygon. To provide both a quick, qualitative comparison as well as a more precise, quantitative one, I provided the average as a floating label, and as a graduated color fill.

Subtitle in lesson plan: I made this using the exact same data as our earlier maps, with a little tweaking in some of Esri's more technical mapping software, ArcGIS Pro. It uses the same borders as the HOLC map, but the colors and number labels show the average percent canopy cover in 2016, rounded to the nearest whole number.

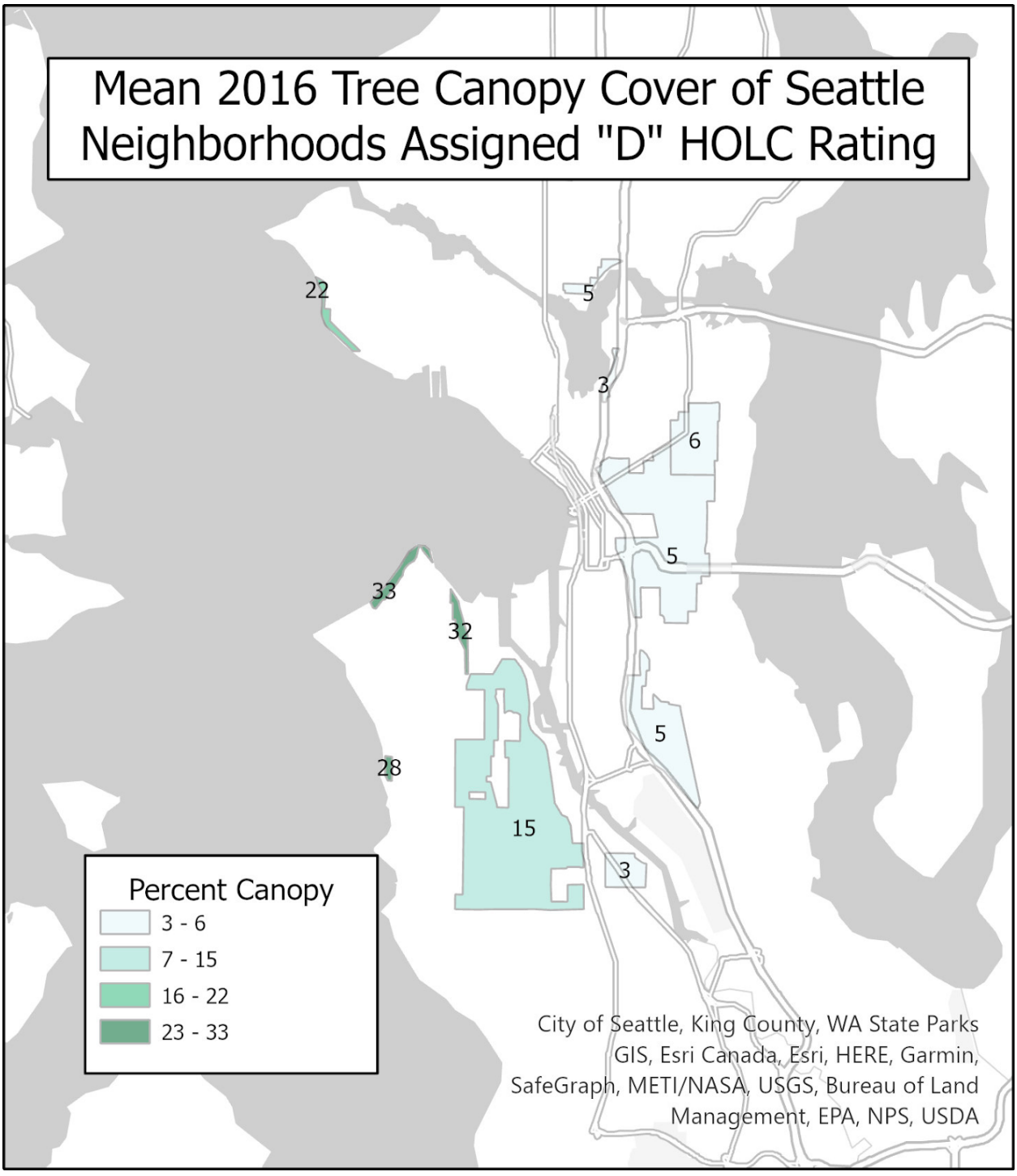


Fig. 7, Mean canopy of neighborhoods assigned "D" rating. This map was generated by filtering the map depicted in Figure 5 to show only "D" assigned neighborhoods.

Subtitle in lesson plan: Taking out the neighborhoods that were assigned other ratings, you can see that the high average canopy cover was skewed by a few areas. Using context from the

written HOLC assessment, we know that the areas driving the increase in average canopy cover were given low ratings because they were "undeveloped" and often difficult to build on.

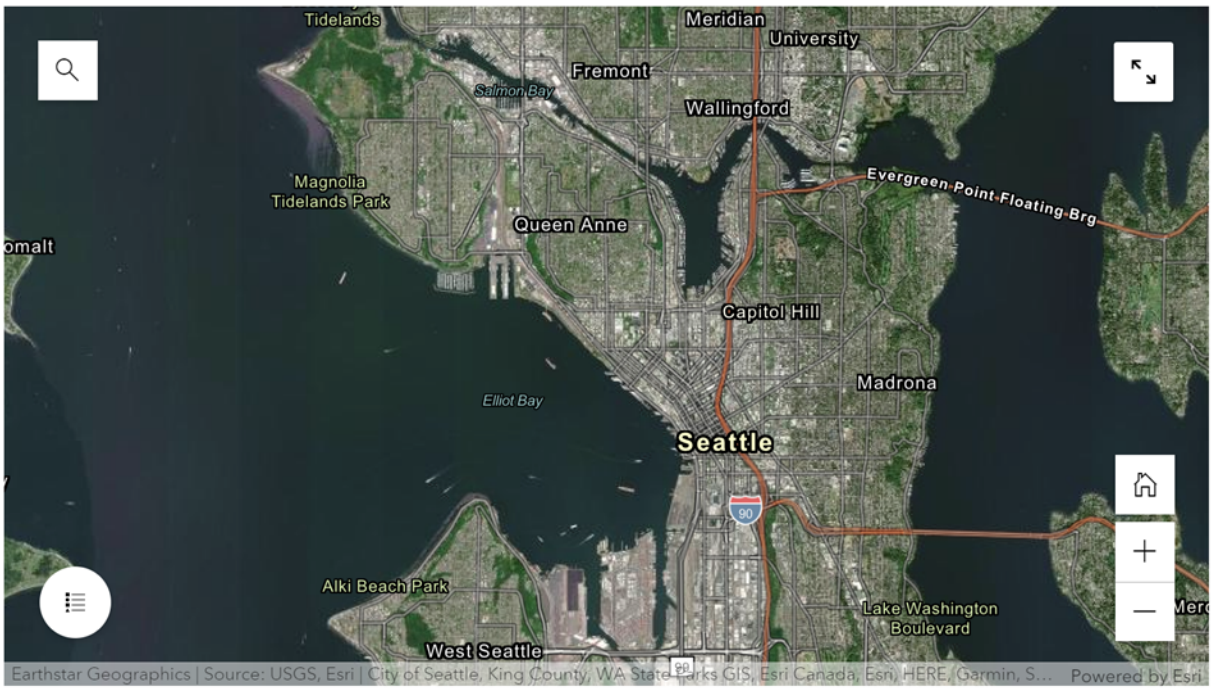


Fig. 8, Canopy over aerial view. This screen captured map is a return to the interactive, but less analytic, capabilities of the maps embedded in StoryMaps. The map utilizes the original raster form of the canopy data. The intention is for users to find the lesson content increasingly personally relevant as they click on familiar places and are provided with pop up readings of their canopy cover. Data credits: Earthstar Geographics | Source: USGS, Esri | City of Seattle, King County, WA State Parks GIS, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA. Powered by Esri

Subtitle in lesson plan: Zoom in to look at places you identified as having high average canopy cover. You can also use the search bar in the upper left to find specific places, and click on the map to find out exactly what percent a small area has.

2016 Canopy Cover Above 50% Density and 1936 HOLC Rating

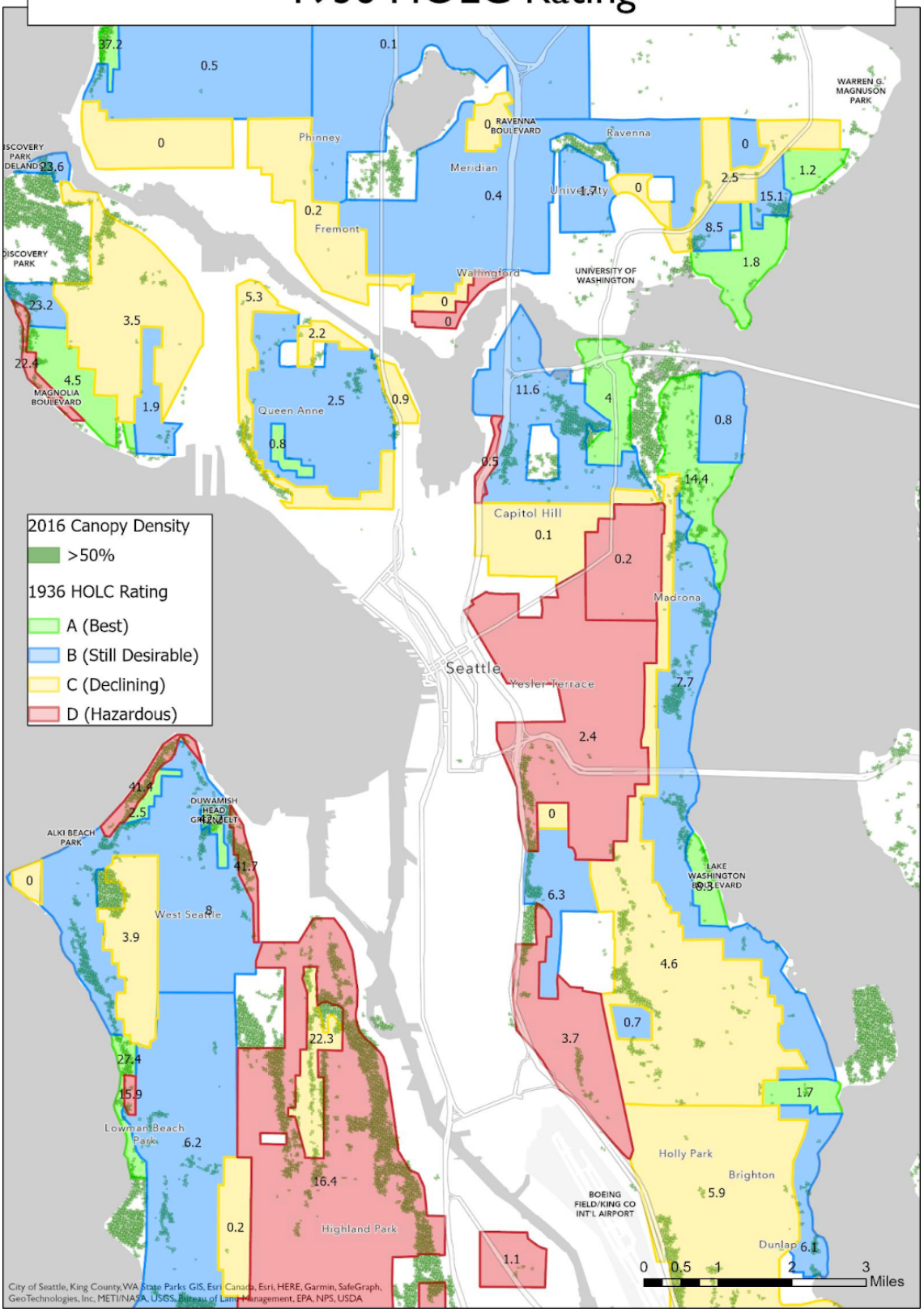


Fig. 9, Canopy above 50% density and HOLC rating. This image is also the product of some minor manipulation and analysis in ArcGIS Pro. I filtered my un-joined canopy polygons to create a >50% density canopy layer. I then performed overlay analysis to determine the percent of overlap their area represented within each HOLC polygon (overlapping area / total HOLC polygon area). Providing the percentage of high canopy cover area as a label was the visually clearest way I found to provide this data.

Subtitle in lesson plan: This map shows the areas with canopy cover above 50% in dark green. I also added labels that give the percentage of each HOLC neighborhood's area that is covered by those dense canopy zones.

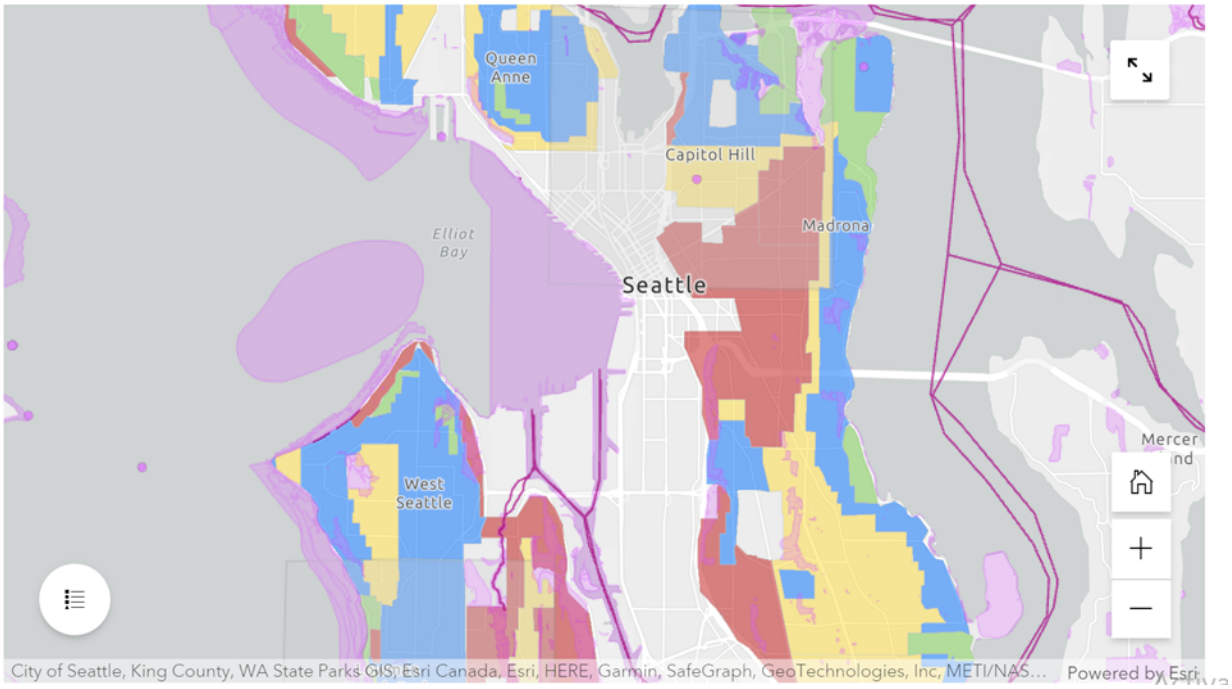


Fig. 10, Priority Species Habitat (PSH) and HOLC map. Screen capture of interactive map. This dataset was technically public, but had significant restrictions preventing quantitative analysis. Nevertheless, it provides ample opportunity for qualitative exploration, and shows a very literal overlap between past policy and present ecological research and environmental equity. Data credits: City of Seattle, King County, WA State Parks GIS, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA | University of Richmond's Digital Scholarship Lab. | WDFW. Powered by Esri

Subtitle in lesson plan: This map overlays the HOLC ratings with Washington Department of Fish and Wildlife public Priority Habitat Species data . The purple polygons show areas identified as especially important for species conservation. The lone purple dots are places where an endangered species has been identified, and the large, transparent gray squares are general areas where there have been records of endangered species. You can zoom in to get a better look, or zoom out to see how many habitat areas have been cataloged across the state.

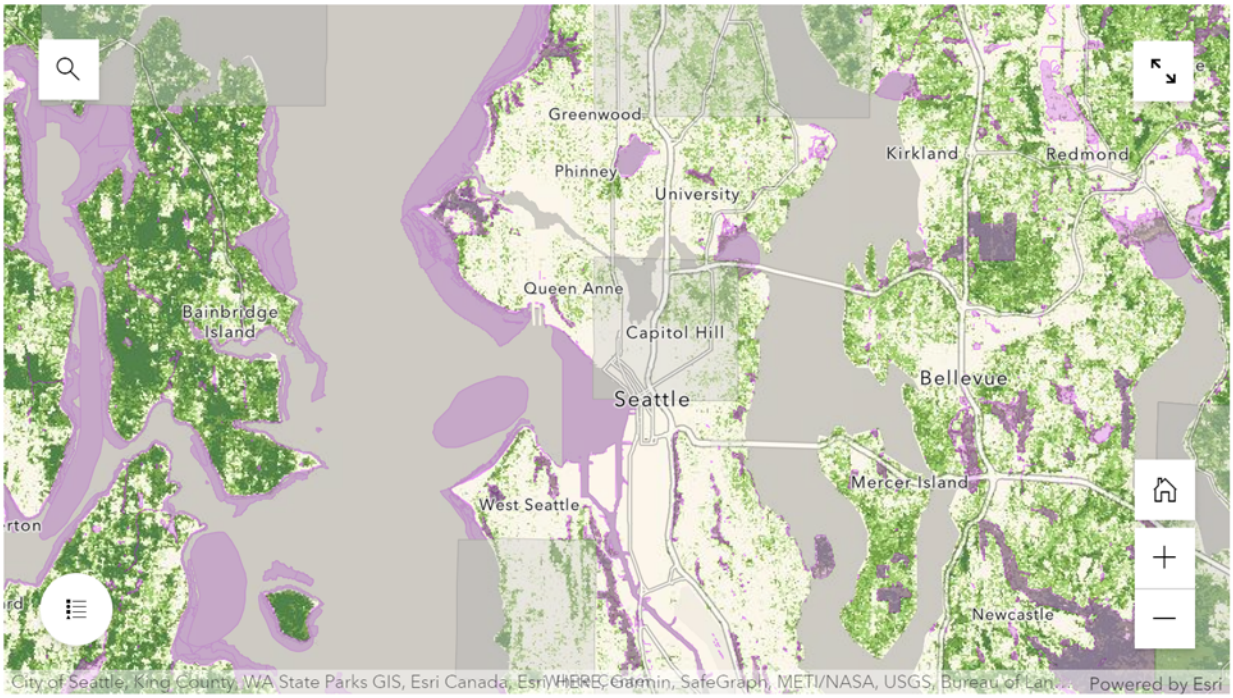


Fig. 11, Priority Species Habitat (PSH) and canopy map. Screen capture of interactive map. Again qualitative, but certainly thought-provoking. Data credits: City of Seattle, King County, WA State Parks GIS, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA | Source: USGS, Esri. Powered by Esri

Subtitle in lesson plan: To my eye, it does look like there are some visible patterns in this map. While most priority habitats are not located directly in residential neighborhoods, there does seem to be a noticeably large share in and immediately beside areas that were assigned "A" and "B" HOLC ratings, along with the high canopy cover "D" rated areas in White Center and West Seattle we looked at earlier. There is also large priority habitat in Beacon Hill along I-5, called the East Duwamish Greenbelt that overlaps with one of our redlined Central District HOLC neighborhoods and does have a high percentage of canopy cover.