Cinching the Sunbelt: The Socioeconomic and Environmental Legacies of Redlining in the American Southwest

by

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Dedication

For anyone who has struggled with their health, be it mental or physical, and has had to take off time from school to recover. Know that there is no “peak” academic age, and your lived experiences will enrich your given field of study.

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Preface

History shows again and again
How nature points out the folly of man

Blue Öyster Cult, 1977

Table of Contents

List of Tables

List of Figures

Abstract

Redlining was a segregatory lending practice instituted by the United States federal government during the New Deal. Although redlining is now illegal, it laid a foundation for disparities that are still present today. A growing body of research has linked redlining to disparities in health, socioeconomics and the environment. This study builds on this body of research within the context of historical redlining in the Sunbelt. The selection of Sunbelt cities, including Los Angeles (CA), Fresno (CA), San Jose (CA) and Phoenix (AZ), also recognizes the relevance of water scarcities, as the areas selected for this study experience persistent drought. As such, this study investigates the poorly studied topic of surface water equity within drought-affected areas. Finally, this study seeks to determine the interplay between socioeconomic factors and the environment in redlined cities using statistical methods. The data selected to capture socioeconomics in the study cities were housing prices (as determined by Zillow Zestimates), composition of zoning codes, and racial demographics. The data selected to investigate the environment were the amount of green and blue space, determined by the Normalized Difference Vegetation Index (NDVI) and the mapping of residential surface water (i.e. pools and fountains), respectively. Overall, this study has provided statistical evidence that disparities still remain in socioeconomics and the amount of blue and green spaces within historically redlined Sunbelt cities, however, more work is needed to fully understand the interplay between these two topics, as well as to establish solutions for an equitable future.

Chapter 1: Introduction

1.1 Overview of the History of Redlining

The present-day segregation found in the American cities of Phoenix, San Jose, Los Angeles and Fresno is largely a byproduct of governmental policy instituted by the Home Owners Loan Corporation (HOLC). Created as part of the New Deal in the 1930s, the HOLC created maps to assess financial risks of neighborhoods for investors (Hillier, 2003). These grades assigned to the neighborhoods of HOLC maps were evaluated on the presence of industry, housing values, and notably, race (Gee, 2008). Areas were graded as A for “best”, B for “still desirable”, C for “declining” and areas outlined in red as D for “hazardous”. The designation of a D grade was dependent on HOLC appraisal forms, which included questions about the presence of an “infiltration of” people of color (Gee, 2008). These red colored areas on HOLC maps, called “redlined” neighborhoods, are still found to have greater rates of poverty and crime (Mitchell and Franco, 2018), as well as disparities in health (Lee et al., 2021), environment (Bravo et al., 2016), thermal equity (Li et al., 2022; Wilson, 2020), and amount of green and blue space (Napieralski et al., 2022; Nardone et al., 2021).

1.2 The Significance of Green and Blue Spaces in the Sunbelt

Historically, the cities in the Sunbelt have endured racial segregation, with significant demarcations of race still present in three of the cities in this study (Los Angeles, Phoenix and San Jose), placing them among the top 70 most segregated cities in America (Menendian et al., 2021). The warm climate of the Sunbelt, with its rising temperatures, has been found to affect minorities and low-income residents within the city cores more than those living in suburban areas due to historic and contemporary policies that place residents in areas with high rates of impervious surface cover (Bolin et al., 2013). These aforementioned factors emphasize the need for equitable distribution of blue and green spaces.

Green space (i.e. areas covered with vegetation) plays a significant role in establishing environmental and socioeconomic equity due to its association with better air quality (Nowak et al., 2006), a decrease in heat islands (Jesdale et al., 2013), lower rates of poverty (Schwarz et al., 2015), higher socioeconomic status (Dai, 2011) and delayed mortality (Fong et. al, 2018). Countless studies have highlighted the importance of adequate green space and its various benefits (Zhou and Rana, 2012; Heidt and Neef, 2018; Van Den Berg et al., 2015). Comparatively, blue space (i.e. the presence of surface water), and its role in shaping a community's well-being, is less understood in comparison to the literature surrounding the benefits of green space.

Blue space, or surface water, is recognized as beneficial for communities and their residents. Increased physical activity, decreased rates of obesity, and better respiratory health have been associated with the presence of blue space (Bauman et al., 1999, Halonen et al., 2014, Moitra et al., 2018). Blue space has been recognized as a mitigator of urban heat islands, where areas with greater impervious surface cover have warmer temperatures than outside the city centers (Gunawardena et al., 2017; Yuan and Bauer, 2007). Areas of concentrated impervious surface cover (such as the metal and concrete that form buildings and their surroundings in a built environment) disproportionately affect low-income and Black, Indigenous and People of color (BIPOC) communities (Harlan and Ruddell, 2011), making blue space an important factor in reaching thermal equity. Blue space has also been linked to wealth, and is considered to be a positional good in certain forms, like swimming pools (Hirsch, 1976). A type of residential blue space that is often overlooked in water equity research, swimming pools can increase property values and use more than twice the amount of water compared to homes without pools (Carroll et al., 1996, Wentz and Gober, 2007). Furthermore, pools reduce air temperatures by acting as heat sinks (Wooley et al., 2011). The cooler microclimates that pools provide are often desired in arid cities, such as the metropolitan areas of the Sunbelt (Larson et al., 2009). Green and blue spaces have both been identified as important factors for a multitude of outcomes. Their effects on socioeconomics have been studied in recent years, although not as in-depth as the environmental benefits they provide for communities.

1.3 Problem Statement

Climate change has ushered in an "eco-apartheid", where BIPOC and less affluent residents are left to bear the brunt of inequitable resource distribution within the communities they have been deliberately trapped in (Checker, 2010; Cohen, 2019). The United States has a known history of racial segregation, however, research is only now beginning to investigate the various harmful legacies it continues to impart on communities. As such, several gaps in the literature still remain. Although other forms of racial sorting exist in America, HOLC maps are tangible records of segregation and are well suited to be used in a Geographic Information System (GIS). Each redlined polygon visualizes the lack of financial opportunity in a community, which can be used in conjunction with other data. Previous studies have determined that redlining has degraded both the socioeconomics and environment of residents that currently live in historically HOLC graded communities, creating legacies that are only recently being identified. Decreased green space (Nardone, 2021; Lewis, 2021; Cassini, 2020), health inequities (Lee et al., 2022), greater rates of poverty and crime (Mitchell and Franco, 2018) and gun violence (Benns et al., 2020; Poulson et al., 2021) have all been found in increased rates within redlined areas. Although studies have shown the separate environmental and socioeconomic legacies of redlining, the integration of these two topics remains as a gap in the literature. Therefore, the intent of this research is to expand on past work by investigating both environmental and socioeconomic legacies of redlining, as well as the interplay between the two in the context of redlining in the Sunbelt cities of Phoenix, Los Angeles, Fresno and San Jose. These cities are crucial to the goal of this research, as they are located in areas that have experienced prolonged drought, and thus provide an added value to the quantification of water and vegetation conducted in this study. This work also seeks to find the interplay, if any, between socioeconomic conditions and consumption of water.

1.4 Study Objectives

The objectives of this research are threefold: The first objective is to determine the environmental legacies left by the historical practice of redlining in the Sunbelt. This was accomplished by quantifying vegetation intensity through Normalized Difference Vegetation Index (NDVI) and the amount of outdoor residential water features (e.g., pools and fountains) within the selected HOLC graded neighborhoods. The secondary objective of this project is to assess the socioeconomic legacy of redlining. The amount and distribution of residential and industrial zoning, current racial compositions, and home values (as a proxy for income) were used to determine if lasting socioeconomic impacts were present. The final objective was to assess the correlation between the environmental and socioeconomic legacies of redlining using the statistical methods of linear regression and one-way ANOVAs with resulting Tukey tests.

These three overarching objectives were differentiated into the following research questions:

Q1) Do more favorable HOLC grades correlate with the amount of residential outdoor water features (pools, water fountains, etc)?

Q2) Is the intensity of vegetation (as NDVI), and thus the water used for irrigation, less in areas that have experienced redlining?

Q3) Are the home values of a HOLC graded community affected by historical disinvestment from lenders, and are any financial trends apparent from grade to grade?

Q4) Do previously redlined communities have more or less industrial and residential zoning than non-redlined areas?

Q5) What residents (i.e., racial demographics) are in the redlined areas of the study cities, and are thus affected by this bygone policy with regards to environmental and socioeconomic equity?

Chapter 2: Literature Review

2.1 Racial Covenants and Zoning as a Segregatory Tool in Pre-Redlined America

Prior to the advent of redlining in 1933 (Rothstein, 2017), racial covenants and zoning laws were used to exclude BIPOC residents in areas that were most desirable for the white members of nearby communities (Whittemore, 2017). Racial covenants were clauses added into property deeds that made purchasing illegal for anyone not of Caucasian descent (Jones-Correa, 2000). The use of racial covenants in America was legally supported by the Supreme Court, which validated their use in the 1926 *Corrigan v. Buckley* decision. Racial covenants were not made illegal until 1948, when the *Corrigan v. Buckley* decision was reversed, however, institutionalized segregation in the United States still endured through municipal zoning and redlining. For instance, private deeds still utilized racial covenants despite the Supreme Court's 1948 ruling, and were not made illegal until the Fair Housing Act of 1968 (Brooks and Rose, 2013).

Racial zoning is another tool that has been used to implement segregation in America. Baltimore was the first city in the U.S. to institute racial zoning in 1910 as a means of separating African Americans from preexisting white communities as they arrived during The Great Migration (Silver, 1991). Baltimore's zoning ordinance made it illegal for African Americans to live or gather on blocks that were predominantly white, as well as the opposite phenomena of Whites living or gathering on predominantly African American blocks (Taylor, 2014). Many other cities in America also followed suit and enacted their own racial zoning ordinances, even after the Supreme Court declared this practice unconstitutional in the 1917 decision of *Buchanan v. Warley*. A list of cities that enacted racial zoning from 1910-1917 can be found in Table 1. After the federal ruling of *Buchanan v. Warley,* New Orleans (1924) and Indianapolis (1926) still utilized racial zoning until it was again made illegal in the Supreme Court ruling of *Harmon v. Taylor* in 1927 (Jones-Correa, 2000). Supreme Court rulings declaring racial zoning unconstitutional were again disregarded by cities in America. West Palm Beach adopted racial zoning in 1929, and did not remove it until 1960, the same year the city of Apopka removed their racial zoning laws (Rothstein, 2017). More recently, the cities of Norfolk and Kansas City had racial zoning until 1987 (Rothstein, 2017).

Explicit racial zoning has been made illegal in several Supreme Court decisions, however, coded segregatory language is still woven into planning laws that cover the majority of America today (Manville et al., 2020). In the suburbs of America, where income is high and crime is low, single-family zoning is consistent throughout (Hirt, 2015). The proliferation and subsequent ubiquity of single-family zoning (also called R1 zoning) is largely due to the 1926 Supreme Court decision of *Village of Euclid v. Ambler Realty*, where it was decided that cities had the right to decide what types of buildings (like apartments, which were described in the ruling as "Parasites") could be erected on the basis of protecting the "value and character" of single-family homes (Manville et al., 2020). Single-family zoning is exclusionary in that it is comparatively expensive to other forms of housing like apartments and duplexes. Towards the end of the 1920s, cities began to cover themselves in single-family zoning as a way to box out lower income residents, typically BIPOC, and to preserve the white, upper-class composition of the suburbs. *Euclid v. Ambler* marked the shift from the overtly racist language of past zoning ordinances, to a new codified one using classism as a proxy.

2.2 History of Redlining in America

After the Great Depression, the US government created the Home Owners' Loan Corporation (HOLC) in 1933 to identify and grade the financial risks of 239 cities for the purpose of home lending (Hillier, 2003). The parent organization of the HOLC, the Federal Home Loan Bank Board, created the City Survey Program which graded and mapped neighborhoods to assign one of four categories: A (most desirable), B (still desirable), C (definitely declining), and D (hazardous) (Hillier, 2003). Hazardous grades were outlined in red, hence the term redlining, although the term extends to any discriminatory practices in lending. Many unfavorable grades were designated based on the presence of African Americans, immigrants, and other non-white racial groups, with racist language being used in federal documentation to describe lower-graded neighborhoods as "infiltrated" by "negroes", "asiatics", and "inharmonious" populations (Nelson et al., 2020).

The HOLC maps were not public knowledge, and were discovered by Kenneth Jackson during research for the book *Crabgrass Frontier* (Hillier, 2003). Jackson posited that the maps were used by the Federal Housing Administration (FHA), as well as private lenders, to influence where lending occurred, although work conducted by Hillier (2003) challenges this idea. Hillier argued that lenders did not have access to HOLC maps, since they were not openly distributed, and instead lenders used a variety of housing and demographic data to deny loans to communities. Furthermore, the leading real estate documents prior to the creation of the HOLC called for assessing a community's racial composition, as well as its neighborhood and housing conditions (HIllier, 2003). Despite this argument, HOLC maps are the tangible manifestations of racial prejudice institutionalized via the federal government, and are thus used by researchers as invaluable data sources to link disinvestment to a large body of detrimental outcomes. Many studies have used HOLC maps to seek correlation and posit “cause and effect” patterns, however there is a need in the current body of literature to look into the other drivers of redlining that shaped both the HOLC and private lender’s discriminatory practices.

The HOLC distributed loans until 1936, and ceased operations in 1951 (Jackson, 1980). Redlining legally persisted until 1968, when the Fair Housing Act outlawed racial discrimination in housing (Mitchell and Franco, 2018). Despite this, the discriminatory practices of the HOLC were integrated into the Federal Housing Administration (FHA), which still exists today. In 1938, the FHA created its Underwriting Manual, which dictated "if a neighborhood is to retain stability, it is necessary that properties shall continue to be occupied by the same social and racial classes." (Jones-Correa, 2000). Additionally, the FHA instructed users of its manual to predict "the probability of the location being invaded by incompatible racial and social groups." (Jones-Correa, 2000). The Underwriting Manual still had instructions referencing race until they were deleted in 1947 (Jones-Correa, 2000).

Simply put, redlining is any form of discriminatory lending practice. Although HOLC maps are the most notable example of redlining in American history, they are not the only instance of this practice. Therefore, redlining goes beyond a single governmental institution making racially motivated decisions, it is the policies before, during, and after the HOLC that shape the inequities that are still found in American communities.

2.3 Economic Legacies of Redlining

The financial disinvestment instituted by the HOLC in communities that were once graded as "hazardous" created neighborhoods that are economically disadvantaged when compared to non-redlined areas. Hillier (2003) found that loans bestowed by the HOLC in D graded areas had higher interest rates in comparison to better graded areas. Greer (2014) discovered that HOLC maps were used to influence lending decisions in Chicago, where loans were prevented in many sections of the city. Appel and Nickerson (2016) found that redlined communities had 4.8% lower housing values than adjacent non-redlined neighborhoods. Furthermore, higher concentrations of residents with a lower socioeconomic status reside in redlined areas, which is linked to higher rates of violent crime in these same areas (Powell and Porter, 2022).

The practice of redlining has been linked to an increase in racial segregation within cities, and a decrease in rates of housing values, ownership, and rent prices (Aaronson et al 2021). Housing is the building block of a community, and thus impacts a wide range of socioeconomic factors. Aaronson et. al. (2021) determined a causal relationship between redlining and negative labor market outcomes, increased rates of incarceration and the disruption of family structures, all found to persist several decades after the creation of the maps. A 2018 report conducted by Mitchell and Franco for the National Community Reinvestment Coalition found that both racial and economic segregation still remain in neighborhoods previously graded as D by the HOLC.

Of these formerly redlined neighborhoods, 74% are listed as “low-to-moderate income”, and 64% are considered to be “minority neighborhoods” (Mitchell and Franco, 2018).

2.4 Environmental Legacies of Redlining

The economic legacies of redlining created a lack of financial resources within communities leading to greater environmental vulnerability. Concentrated BIPOC residents in redlined areas were thus exploited by industry for the creation of factories and highways, leading to an increase in impervious surface cover, decreased vegetation, and as a result, higher temperatures. An analysis within 37 redlined cities determined that A graded areas had almost twice (43%) as much tree canopy as communities graded as D (Locke et al., 2021). Vegetation intensity, measured by NDVI, is also lower across all D graded cities when compared to areas graded more favorably by the HOLC (Nardone et al., 2021). Nowak et al. analyzed all redlined cities in America and found that D graded communities have lower tree cover and higher impervious surface cover. Furthermore, redlined areas were also found to have lower ecosystem service values (the monetary value from services provided by nature, like flood mitigation, pollution reduction and erosion control) when compared to non-redlined grades, with losses totaling up to $100 million per year (Nowak et al., 2022). As such, redlined areas are hotter than communities that received favorable grades from the HOLC (Wilson, 2020; Napieralski et al., 2022). A study conducted by Hoffman et al. within 108 redlined cities found on average, redlined areas are 2.6 °C warmer than non-redlined cities. In the Sunbelt city of Phoenix, Arizona, redlining has been associated with decreased access to surface water (Napieralski et al., 2022), another important factor in mitigating urban heat islands. The A graded communities of Phoenix have 1 pool for every 5 residents, while D grades have 1 pool for every 1000 residents, signaling a disparity in both wealth and water availability (Napieralski et al., 2022). Consequently, Napieralski et al. (2022) found that 86% of D grades in Phoenix are affected by the Urban Heat Island effect, compared to 0% of A grades. Increased temperatures negatively impact the health of those living in redlined communities, where residents have increased rates of both inpatient and outpatient visits due to heat-related illness (Li et al., 2022).

Other environmental legacies have stemmed from the industrial exploitation of redlined communities. Redlining was used to legally permit the creation of industrial sites in and around D graded areas (Rothstein, 2017). As such, redlined areas are found to experience greater rates of air pollution when compared to better HOLC grades (Lane et al., 2022). Levels of NO_2 between HOLC grades are especially disparate, with D grades having >50% greater exposure compared to A grades (Lane et al., 2022). Redlined neighborhoods also have twice the density of oil and gas wells when compared to better A graded neighborhoods (Gonzalez et al., 2022). In historically redlined Indianapolis, about 60% of brownfield sites were located in D grades (Moxley and Fischer, 2020). Additionally, all superfund sites (4) that fell within the HOLC grades of Indianapolis, Indiana were located in D grades. Approximately 50% of industrial waste sites were located in D grades, despite comprising only 27% of the total HOLC graded areas. Additionally, of the two interstate highways that cut through the city of Indianapolis, 69.2% of the mile markers were present in D graded areas, indicating greater highway coverage of the former neighborhoods. The creation of environmentally deleterious developments in redlined areas is a less studied phenomenon, especially when compared to studies investigating tree cover and health outcomes. To date, no studies on the zoning composition of redlined areas have been conducted, despite the importance zoning plays in understanding a community's health outcomes.

2.5 Health Legacies of Redlining

Several studies have identified the link between redlining's effect on residential security and health. Redlined areas in Detroit have higher rates of foreclosure, and the residents of these communities also self-report greater rates of poor health when compared to non-redlined areas (McClure et al., 2019). In historically redlined Milwaukee, the current rates of lending discrimination, and measures of poor mental and physical health were greater when compared to non-redlined areas (Lynch et al., 2021).

Other health outcomes have been linked to redlining without also considering the interplay of housing. Preterm birth and mortality (Nardone et al., 2020), gun violence (Benns et al., 2020; Poulson et al.,2021, Powell and Porter, 2022), cancer (Krieger et al., 2020), asthma (Nardone et al., 2020), and cardiovascular health (Mujahid et al., 2021) are other negative health outcomes that have been associated with redlining. A 2022 meta-analysis conducted by Lee et al. examined 12 articles that assessed redlining and its implications on health outcomes. The analysis yielded associations with redlining and the outcomes of preterm birth, gun related injuries, heat-exposure injuries, multiple chronic conditions, certain types of cancer, and asthma. A large-scale study by the National Community Reinvestment Coalition in 2020 found increased rates of disease-causing factors in 142 D graded neighborhoods (NCRC, 2020). Statistically significant associations were found between the pre-existing conditions of COPD, diabetes, asthma, hypertension, high cholesterol, obesity, kidney disease and stroke. These conditions were also found to present a greater risk of morbidity in Covid-19 infections, as well as a life expectancy that is 3.6 years shorter than higher HOLC graded neighborhoods.

City	State	Year Passed
Abilene	Texas	1916
Anadarko	Oklahoma	1913
Anderson	South Carolina	1914
Ashland	Virgina	1913
Atlanta	Georgia	1913
Baltimore	Maryland	1910
Birmingham	Alabama	1913
Clifton Forge	Virgina	1917
Colwyn	Pennsylvania	1916
Dallas	Texas	1916
Danville	Virgina	1913
Greensboro	North Carolina	1914
Greenville	South Carolina	1912
Houston	Texas	-
Hyattsville	Maryland	1915
Louisville	Kentucky	1914
Lynchburg	Virginia	-
Madisonville	Kentucky	1913
Miami	Florida	1915
Mooresville	North Carolina	1912
Norfolk	Virginia	1913
Oklahoma City	Oklahoma	1916
Richmond	Virginia	1913
Roanoke	Virginia	1913

Spartanburg	South Carolina	1916
St. Louis	Missouri	1916
Winston-Salem	North Carolina	1912

Table 1. The 27 cities with racial zoning ordinances passed between 1910 and 1917. Historical newspaper databases were used to collect zoning laws by Troesken and Walsh, 2019.

Chapter 3: Methods

3.1 Study Area

The four cities selected for analysis were Phoenix (AZ), Los Angeles (CA), San Jose (CA) and Fresno (CA) (Fig. 1). These cities are located in the Sunbelt, a geographic region of the United States characterized by warm climates, and in the case of states Arizona and California, a persistent 22-year long drought (Williams et. al., 2022). Los Angeles is the most complex city within this study. It is both the most populous and largest city in this study, with a population of just over 10 million (US Census Bureau, 2020) and an area of 1302.76 km^2. The HOLC map of Los Angeles (Fig. 2) is also the largest of the four study cities with an area of 849.62 km^2, and encompasses 70 cities and 35 unincorporated territories. Some of the more notable cities included in the Los Angeles map are Beverly Hills, Hollywood, Burbank, Santa Monica, Glendale and Pasadena.

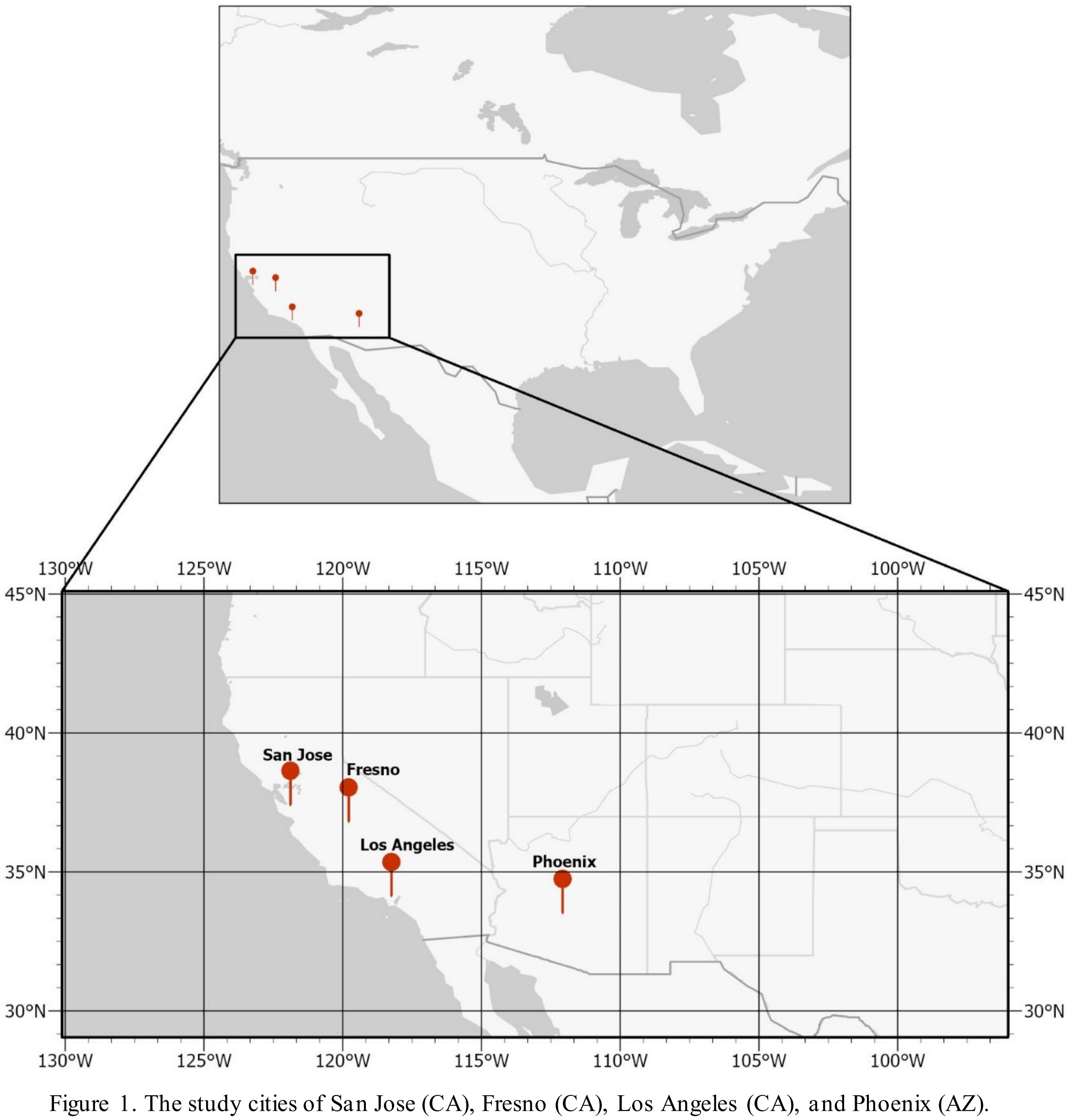
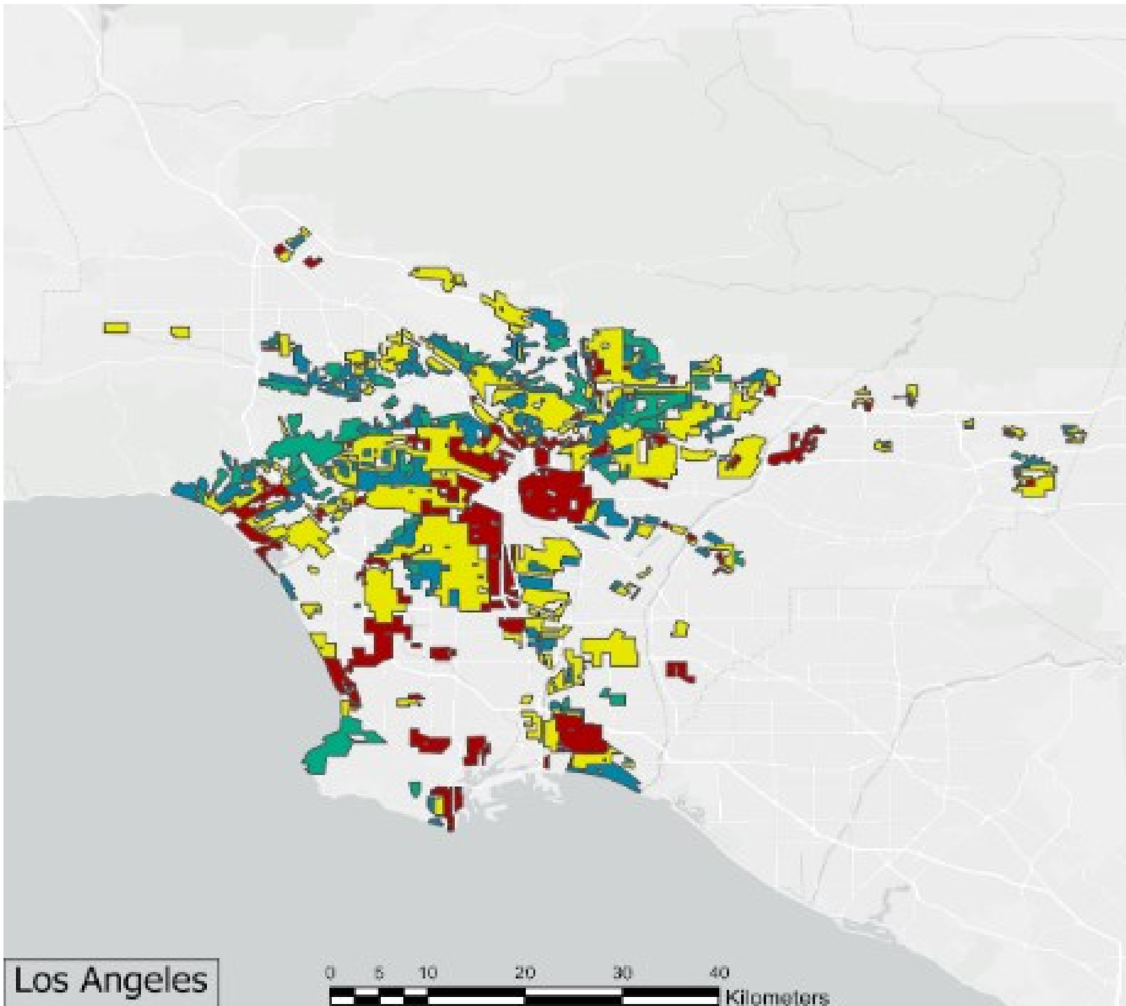


Figure 1. The study cities of San Jose (CA), Fresno (CA), Los Angeles (CA), and Phoenix (AZ).

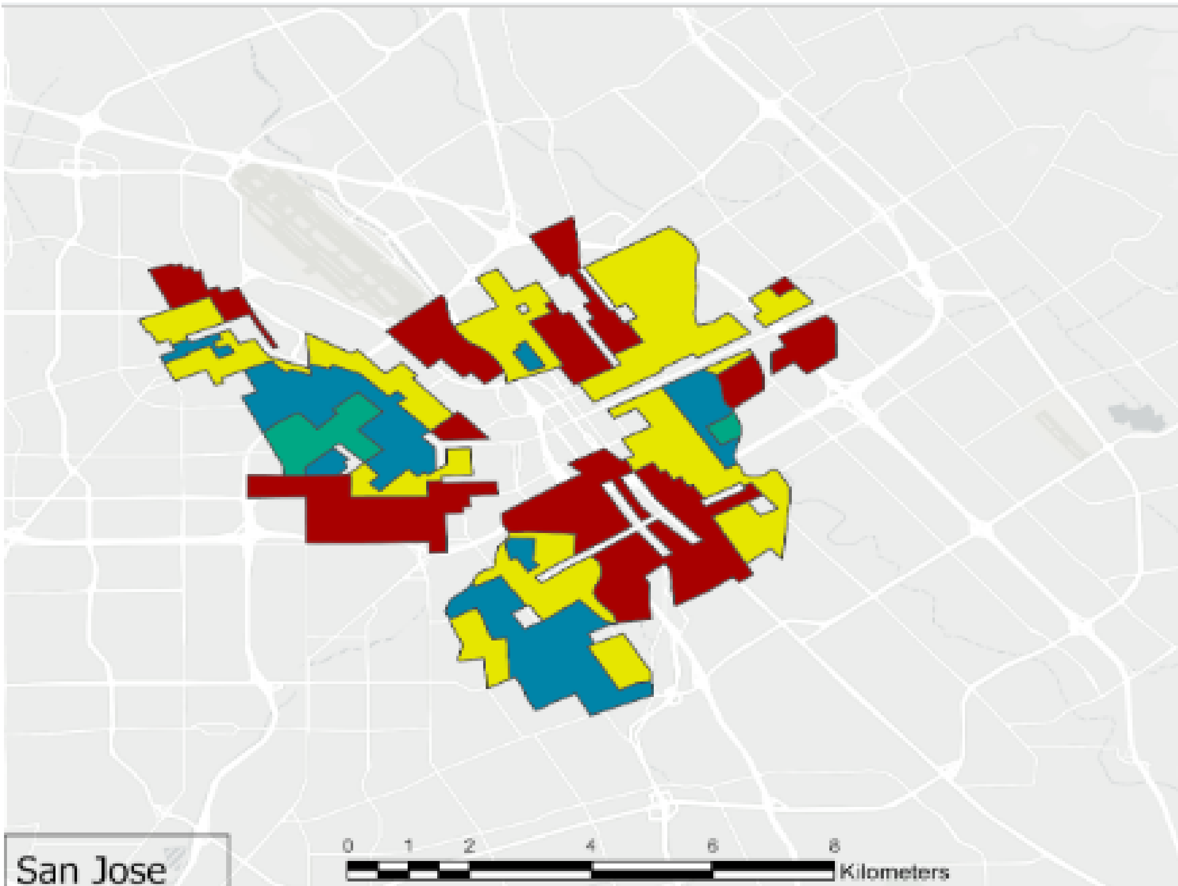
Fresno is the smallest of the study cities in population and area. Just over half a million people reside within the 300 km^2 of Fresno (US Census Bureau, 2020), of which almost 30 km^2 was graded by the HOLC (Figs. 2-5). Similar to Fresno, San Jose (Fig. 3) had 30.47 km^2 graded by the HOLC. Portions of the city of Santa Clara were also included in the HOLC map of San Jose. According to the 2020 US Census, 1 million people live within the 470 km^2 of San Jose. Phoenix, AZ, (Fig. 5) encompasses 1339 km^2 and has a population of 1.6 million people (US Census Bureau, 2020). The total area graded by the HOLC is 36.55 km^2. In total, 946.44 km^2 of HOLC graded polygons in the four study cities were assessed (Figs. 2-5).

All four cities selected for analysis experienced population growth in 2020 (United States Census Bureau, 2020). Los Angeles, San Jose, Phoenix and Fresno are among the most populous cities in America, with respectively the second, tenth, fifth and thirty-fifth largest populations (United States Census Bureau, 2020). These large, continuously growing populations in persistent drought with historically segregated communities provide the necessary components to assess the equity of blue and green space distribution in urban areas.



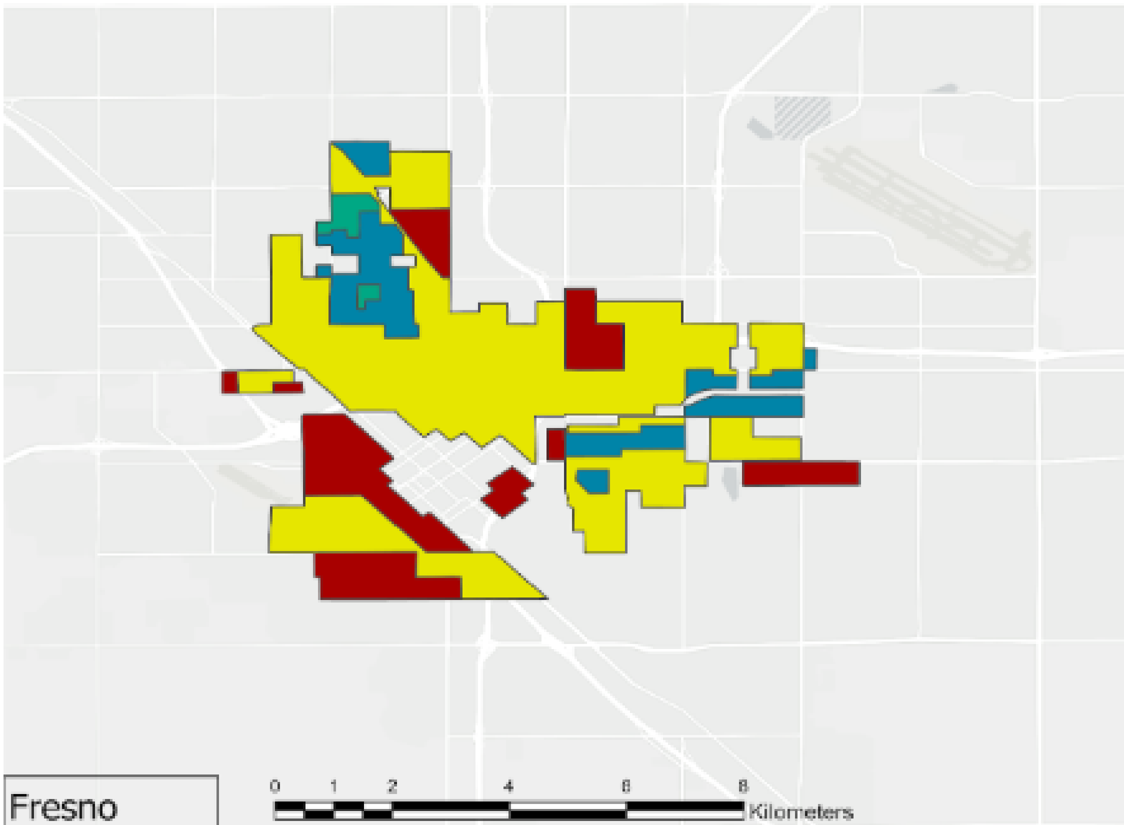
HOLC Grade	Area (km^2)	Population
A	104.41	186,878
B	166.41	648,291
C	391.43	2,418,520
D	187.37	1,160,707

Figure 2. The city of Los Angeles, CA. Population data acquired from the 2020 US Census.



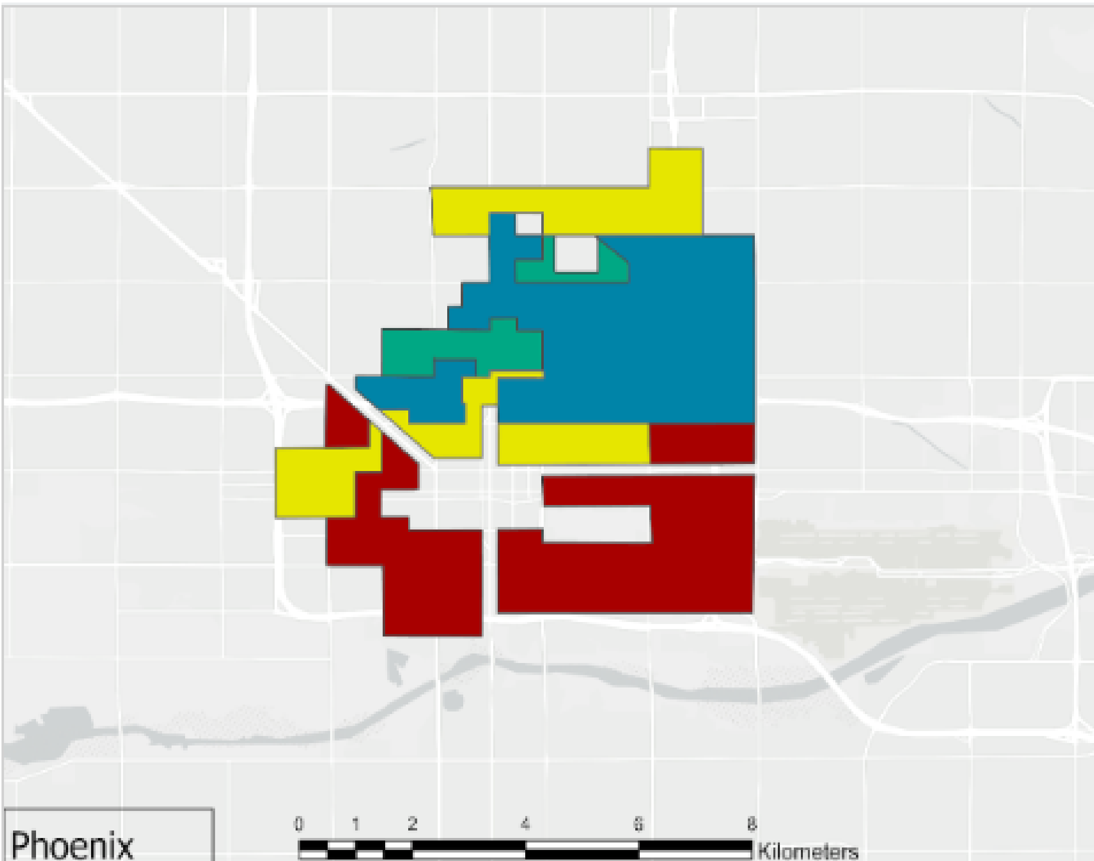
HOLC Grade	Area (km^2)	Population
A	1.26	3,056
B	6.22	19,662
C	11.93	48,886
D	11.06	45,831

Figure 3. The city of San Jose, CA. Population data acquired from the 2020 US Census



HOLC Grade	Area (km^2)	Population
A	0.49	1,121
B	4.00	10,894
C	19.10	58,671
D	6.27	15,801

Figure 4. The city of Fresno, CA. Population data acquired from the 2020 US Census



HOLC Grade	Area (km^2)	Population
A	2.45	4,453
B	12.80	27,148
C	8.06	24,661
D	13.24	15,909

Figure 5. The city of Phoenix, AZ. Population data acquired from the 2020 US Census

3.2 Selection of Study Area, Housing Values and Identification of Outdoor Water Features

Parcel maps with addresses for each city were added to ArcGIS Pro. Addresses were selected by generating 25 random points for each HOLC grade, totaling 100 points for every city selected for study. Points that didn't land on a single residence home with a Zillow Zestimate were moved to the nearest parcel meeting the aforementioned criteria. The 25 Zestimates for each grade were recorded in a new field in ArcGIS Pro, and averaged to obtain a mean home value using the Statistics function.

Block maps from the 2020 US Census were then added to ArcGIS Pro. Using the previously generated 25 address points, four points within the same HOLC grade were selected. These four points were then used to select four separate census blocks, totaling 16 blocks selected for each city. HOLC maps do not overlay exactly with Census boundaries, thus blocks were only selected if they were covered 50% or greater by a grade. Once selected, the entire census block was used for identification of outdoor water features. Any outdoor water features on the census block were digitized (e.g., in-ground pools, hot tubs, above ground pools, water fountains).

3.3 Green Space Assessment

National Agriculture Imagery Program (NAIP) Imagery for the entire state of California was used to calculate the Normalized Difference Vegetation Index (NDVI) scores for Fresno, Los Angeles and San Jose. A 1-meter resolution with four bands from 2014 was used, as it is the most recent NAIP imagery for California at that resolution. Band 1 (red) and band 4 (near infrared) were used to calculate the NDVI using the equation: NDVI = $(Band\ 4 - Band\ 1)\ /\ (Band\ 4 + Band\ 1)$. The NDVI data were then clipped to each of the three cities'

HOLC maps using the Extract by Mask tool in ArcGIS Pro. The 2017 NDVI for Phoenix was downloaded from Arizona State University at a 1-meter resolution. The data were then clipped to the boundaries of the Phoenix HOLC map with the Extract by Mask tool.

Zonal Statistics in ArcGIS Pro was used to obtain the mean NDVI for each HOLC grade of the study cities. The NDVI data were then reclassified in ArcGIS Pro using methodology from Halper et. al. (2015), where any score of 0.15 or above was designated as vegetated. These pixels were reclassified as “2”. Scores below 0.15 were considered non-vegetated pixels and classified as “1”. The percentage of vegetation for each HOLC grade was calculated by dividing the number of pixels with a score of “2” by the total number of pixels.

3.4 Census Demographic Data

The 2020 United States Census was used to obtain population and racial demographic data. Population data were collected at the block level for the 16 selected blocks of each city (four in each HOLC grade). Racial data is not available at the block level, and thus the remaining blocks in the block group were then aggregated to calculate the percentage of racial demographics. Using the aggregated block group data, the same 16 blocks of each city were used to capture the four categories of “Black or African American alone, non-Hispanic”, “Hispanic or Latino”, “White alone, non-Hispanic” and “Asian alone”. This yielded four percentage values for every race selected in each HOLC grade. The four percentages for each race were averaged to create a single percentage for each city’s HOLC grades totaling 16 rates of race for each city in this study.

Block level data from the 2020 United States Census were again used to obtain the total population for each HOLC grade of every selected study city. The Summarize Within tool in ArcGIS Pro was used to count the variable “Total Population” for each census block that overlapped a city’s respective HOLC map.

3.5 Zoning of HOLC Grades

The zoning maps of Fresno, San Jose and Phoenix were used to calculate zoning area percentages. Each zoning map was clipped to the boundary of its respective HOLC map. The resulting tables from the clipped maps were used to filter by each zoning designation. Zoning designations within the same category (i.e. “single-family residential” and “multi-family residential", or “downtown commercial” and “commercial”) were merged to create main categories. The creation of main zoning categories alleviates the problem of cities using different zoning codes and names.

Los Angeles does not have a zoning map, and instead embeds zoning within its parcel data. Therefore, the parcel map from the Los Angeles GIS portal was used to calculate the percentages of each main zoning type for each HOLC grade. Parcels with the same zoning category area were merged in the same way as the zoning maps of prior cities in this study. The parcel area of each zoning category was summed for every HOLC grade, and divided by the total zoned area of the respective HOLC grade. The zoning designation of “irrigated farmland” was originally included, however it constitutes less than 0.0001% of the zoning of each HOLC grade, and was therefore removed from the analysis. Areas zoned as “null” were removed from the analysis for all four cities.

Chapter 4: Results

4.1 Identification of Outdoor Residential Water Features in Historically Redlined Communities (Q1)

There were 161 pools (both above and in-ground), hot tubs, and a single ornamental water fountain identified across the 64 census blocks. The A graded communities comprised the greatest percentage of outdoor water features (58%). Of the 161 outdoor residential water features that were identified, 94 were located in the A graded communities (Fig. 6). Los Angeles had both the greatest total number of water features with 70 being identified across all four grades, as well as the greatest number of pools in a single grade. San Jose had the least amount of total water features across the four grades with 16. Fresno was the only city where the number of pools was not greatest in the A grade, and instead had three more pools in the B grade. All cities except Los Angeles did not have a single pool identified in the D grades.

Similar to the counts of water features, Los Angeles had the largest area across all four grades with 3740.23 m^2, as well as the greatest area in a single grade at 2341.7 m^2 (Fig. 7). Additionally, San Jose had the least area of water features across all grades with 766.5 m^2.

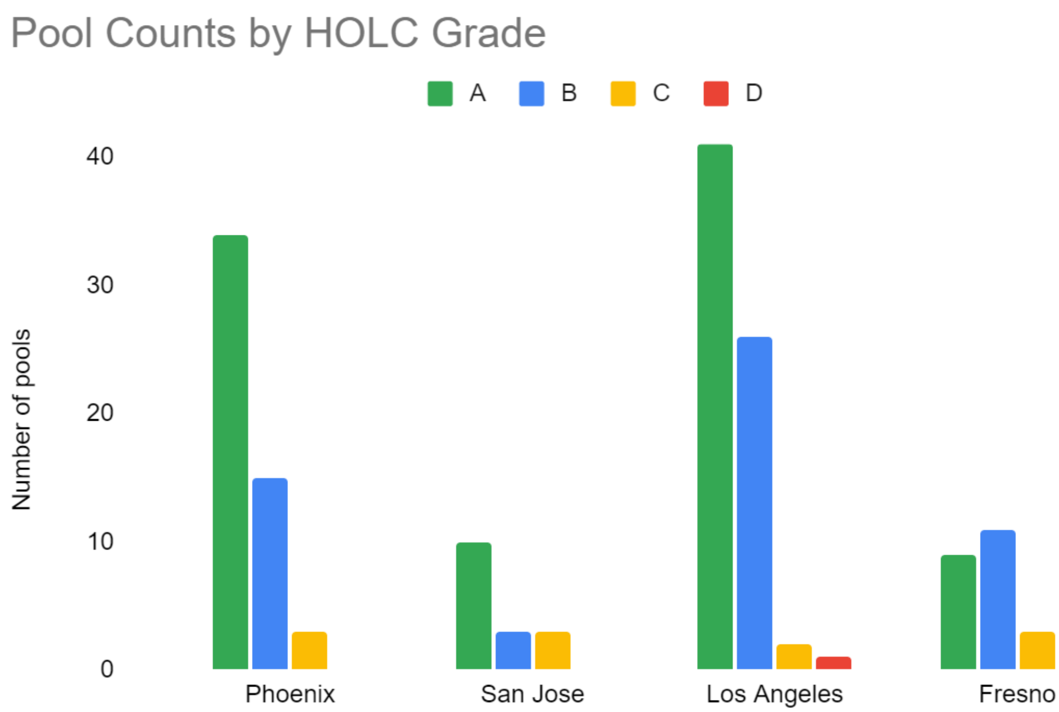


Figure 6. Counts of Pools of the four HOLC grades in each study city.

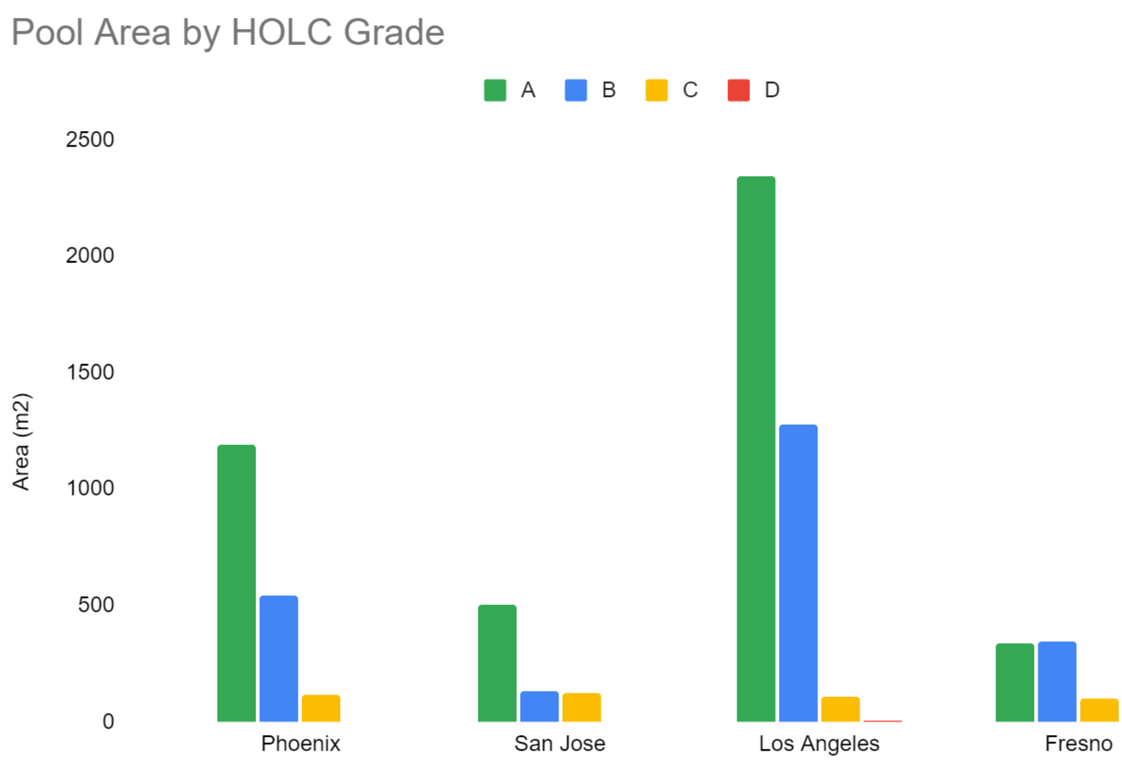


Figure 7. Pool area in meters squared of the four HOLC grades of each study city.

4.2 Assessment of Vegetation Intensity (Q2)

Mean NDVI is not necessarily reflective of an area's vegetation intensity, as it also includes natural features like bodies of water or rocky outcrops. For this reason, the

percentage of vegetation was also calculated to obtain a clearer picture of a city's intensity of vegetation. The distribution of both mean and percent vegetated NDVI exhibit a downward trend as HOLC grades go from A to D (Fig. 8, Fig. 9). The A grade of Los Angeles had the greatest mean NDVI at 0.135 and percentage of vegetation at 44.86%. The D grade of Phoenix had the lowest mean NDVI at -0.099 and percentage of vegetation at 6.16%.

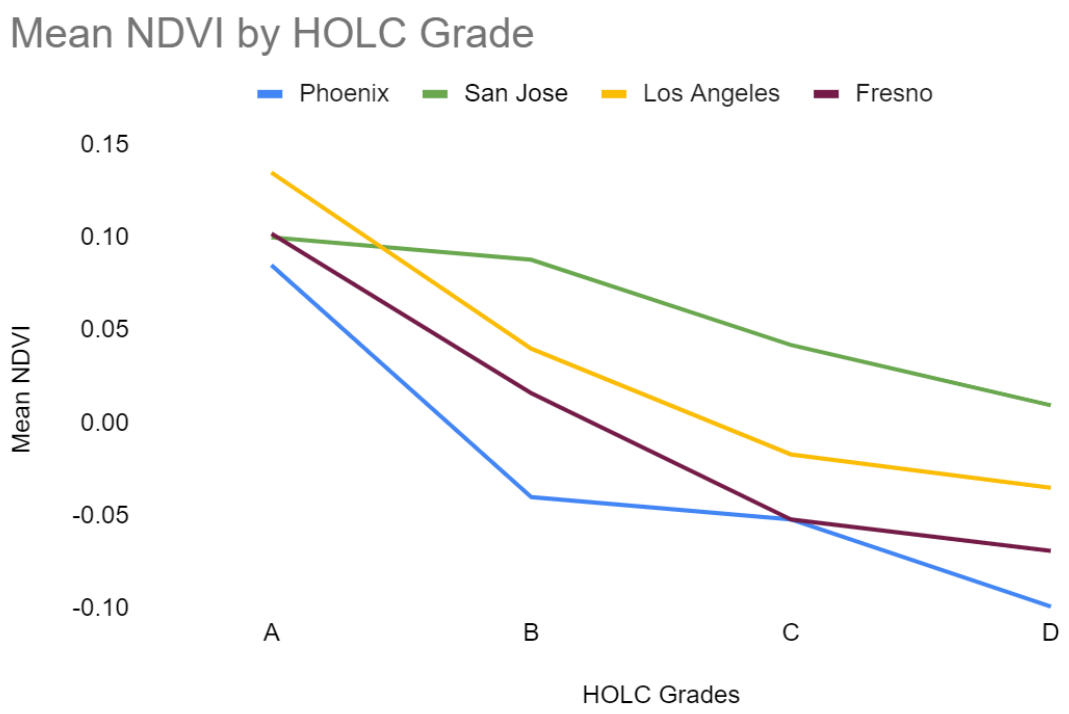


Figure 8. Mean NDVI by HOLC grade at a 1-m resolution for each study city.

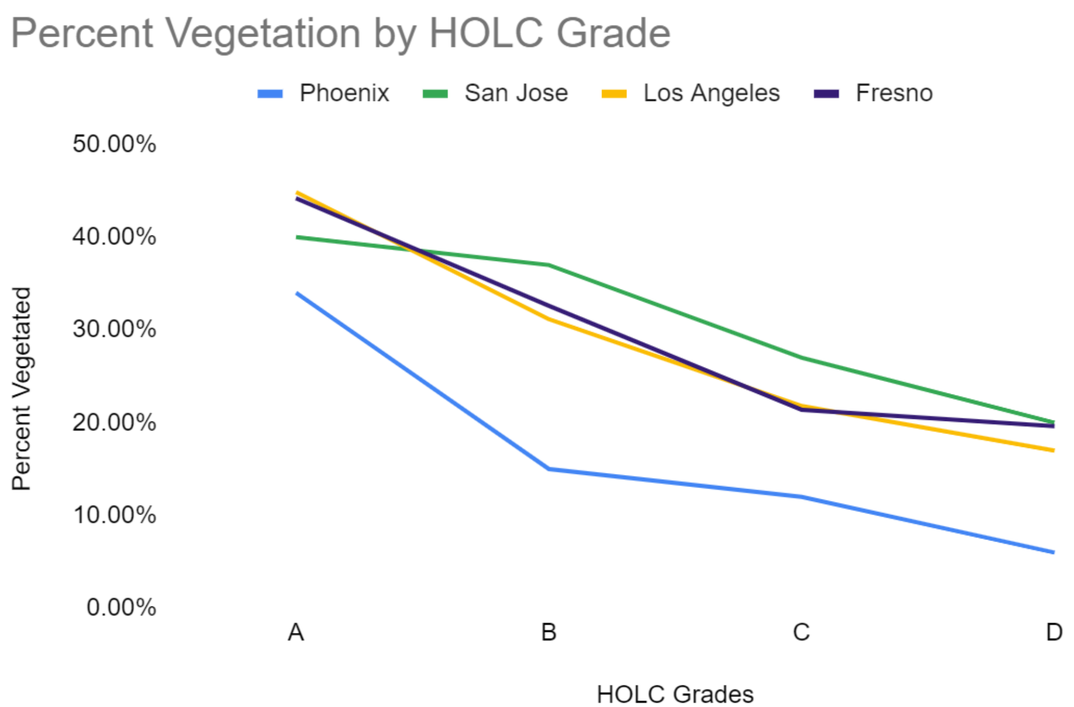


Figure 9. Percentage of vegetation, defined as NDVI > 0.15, for each study city by HOLC grade.

4.3 Housing Values (Q3)

The distribution of mean housing values by HOLC grade ranged from a maximum value of $5,179,140.00 in Los Angeles' A graded communities, to a minimum value of $211,248.00 in Fresno's D graded neighborhoods (Table 2). For every city included in this analysis, mean housing values were highest in A graded areas, and lowest in D grades. Furthermore, the mean housing values of each city are distributed in a monotonic, or stepwise manner, where B and C grades are second and third lowest respectively.

HOLC Grade	Phoenix	San Jose	Los Angeles	Fresno
A	$1,046,944.00	$1,923,680.00	$5,179,140.00	$520,752.00
B	$510,124.00	$1,806,780.00	$2,194,000.90	$322,700.00
C	$370,240.00	$1,132,044.00	$1,122,800.00	$249,880.00
D	$238,596.00	$967,832.00	$906,584.00	$211,248.00

Table 2. Mean Zestimates by HOLC grade.

4.4 Analysis of Livable Zoning (Q4)

The percentage of residential zoning was calculated for each HOLC grade to assess its livability (Table 3). Additionally, the percentage of industrial zoning was also calculated for each HOLC grade, as a way to gauge a community's lack of livability (Table 4). The A grades of Fresno had the greatest percentage of residential areas at 96.27%, while Phoenix's D grade had the lowest at 29.71%. Furthermore, The D graded areas of Phoenix had the highest amount of industrial zoning at 45.90%. All D grades in the four cities also had the highest percentage of industrial zones, while only one city (Los Angeles) had any industrial zoning in either an A or B grade. All other cities did not have any industrial zoning in the A or B grades.

HOLC Grade	Phoenix	San Jose	Santa Clara	Los Angeles	Fresno
A	80.82%	89.25%	-	88.91%	96.27%
B	70.31%	86.57%	78.95%	86.48%	81.66%
C	56.01%	75.22%	61.68%	77.17%	68.34%
D	29.71%	53.03%	57.27%	65.64%	51.75%

Table 3. The percentage of residential zoning by HOLC grade. Santa Clara is included as its own column due to it having separate zoning codes from San Jose. No A grades are located in Santa Clara.

HOLC Grade	Phoenix	San Jose	Santa Clara	Los Angeles	Fresno
A	0.00%	0.00%	-	0.29%	0.00%
B	0.00%	0.00%	0.00%	1.00%	0.00%
C	4.34%	8.64%	0.00%	2.21%	2.47%
D	45.90%	22.03%	4.19%	7.92%	11.18%

Table 4. The percentage of industrial zoning by HOLC grade. Santa Clara is included as its own column due to it having separate zoning codes from San Jose. No A grades are located in Santa Clara.

1. Zoning of Phoenix

The HOLC map of Phoenix has a total zoned area of 36.57 km^2 with six main categories (Table 5). Redlined areas of Phoenix contain the greatest amount of industrial areas, and the lowest percentage of residential areas.

HOLC Grade	Residential	Industrial	Commercial	Planned Unit Development	Downtown	County
Phoenix A	80.82%	0.00%	15.92%	0.41%	2.04%	0.82%
Phoenix B	70.31%	0.00%	19.30%	3.20%	7.19%	0.00%
Phoenix C	56.01%	4.34%	22.18%	0.74%	16.73%	0.00%
Phoenix D	29.71%	45.90%	20.99%	0.38%	3.02%	0.00%

Table 5. Zoning composition of HOLC graded areas in Phoenix, AZ.

2. Zoning of San Jose and Santa Clara

The HOLC map of San Jose covers the cities of San Jose and Santa Clara, California. These two cities use different zoning codes, so separate calculations and tables were created for each (Tables 6 and 7). The total zoned area in San Jose is 19.90 km^2 whereas Santa Clara contains 1.79 km^2. There are no A grades located in Santa Clara. San Jose has seven main zoning categories that overlap with the HOLC map, whereas Santa Clara has eight. Like Phoenix, the residential zoning in San Jose and Santa Clara are highest in A graded areas. Similarly, the industrial zoning is highest in D graded areas for both cities.

HOLC Grade	Residential	Industrial	Agriculture	Commercial	Downtown	Planned Development	Public
San Jose A	89.25%	0.00%	0.00%	4.30%	0.00%	6.45%	0.00%
San Jose B	86.57%	0.00%	0.00%	4.32%	0.00%	9.11%	0.00%
San Jose C	75.22%	8.64%	0.00%	8.14%	0.38%	6.63%	1.00%
San Jose D	53.03%	22.03%	0.12%	8.52%	3.08%	12.78%	0.44%

Table 6. Zoning composition of HOLC graded areas in San Jose, CA.

HOLC Grade	Residential	Industrial	Agriculture	Commercial	Office	Planned Development	Public	Combining
Santa Clara A	-	-	-	-	-	-	-	-
Santa Clara B	78.95%	0.00%	0.20%	8.10%	2.02%	8.10%	1.42%	1.21%
Santa Clara C	61.68%	0.00%	0.00%	7.12%	0.36%	7.12%	21.35 %	2.37%
Santa Clara D	57.27%	4.19%	0.00%	13.22%	0.22%	10.79%	14.32 %	0.00%

Table 7. Zoning composition of HOLC graded areas in Santa Clara, CA. No A grades are present in Santa Clara.

3. Zoning of Los Angeles

The total zoned area of Los Angeles is 629.1 km^2. Los Angeles had eight main zoning categories when the subtypes were combined, however, the designation of "irrigated farm" was removed, leaving only seven for this analysis. As with the other study cities, the A graded areas of Los Angeles have the highest percentages of residential zoning and the lowest industrial percentages. Furthermore, the D graded areas contain the highest amounts of industrial zones.

HOLC Grade	**Residential**	**Industrial**	**Commercial**	**Misc.**	**Institutional**	**Government**	**Recreational**
Los Angeles A	88.91%	0.29%	1.59%	0.31%	0.92%	6.90%	1.08%
Los Angeles B	86.48%	1.00%	5.45%	0.73%	1.64%	4.34%	0.36%
Los Angeles C	77.17%	2.21%	10.69%	0.95%	2.94%	5.74%	0.30%
Los Angeles D	65.64%	7.92%	11.56%	0.37%	2.86%	9.68%	0.99%

Table 8. Zoning composition of HOLC graded areas in Los Angeles, CA.

4. Zoning of Fresno

Fresno's HOLC map contains 10 main zoning categories and has a total zoned area of 19.22 km^2. As with other cities in this study, the A graded areas contain the highest amounts of residential zoning and the lowest amounts of industrial zoning. Areas graded as D contain the highest percentage of industrial zoning.

HOLC Grade	**Residential**	**Industrial**	**Commercial**	**Regional**	**Public**	**Neighborhood Mixed**	**Park and Recreation**	**Office**	**Downtown**	**Corridor/ Center Mixed**
Fresno D	1.75%	11.18%	0.58%	0.00%	11.87 %	10.18%	4.18%	0.12%	4.88%	5.26%
Fresno C	8.34%	2.47%	4.14%	0.29%	7.64%	10.43%	0.62%	0.98%	3.78%	1.32%
Fresno B	1.66%	0.00%	7.92%	0.00%	4.64%	4.31%	1.22%	0.25%	0.00%	0.00%
Fresno A	6.27%	0.00%	3.39%	0.00%	0.05%	0.29%	0.00%	0.00%	0.00%	0.00%

Table 9. Zoning composition of HOLC graded Fresno, CA.

4.5 Current Racial Compositions of Historically Redlined Communities (Q5)

The HOLC graded communities using race as a metric of risk for financial investments beginning in the 1930s. The 2020 US Census was used to determine what racial demographics in the city's population are currently residing within historically redlined areas. Although redlining was a segregatory practice of yore, findings from this study provide evidence to support that many residents living in previously redlined areas are still BIPOC, reflecting the initial intent of the HOLC to enforce the separation of races through financial disinvestment.

1. ***Phoenix***

The distribution of African Americans in HOLC graded Phoenix is highest in the C graded areas at 8%, and lowest in A at 2.38% (Fig. 10). The D and B grades had the second and third highest percentages of African Americans respectively. The percentages of Hispanic and Latino residents in Phoenix follow the same stepwise trend seen in the distribution of outdoor residential water in this study, where the A grade has the lowest amount, and each successive grade is incrementally higher (Fig. 11). The distribution of White residents follows a reverse of the stepwise trend, where A grades contain the highest rates (73.20%), and each successive grade has fewer rates (Fig. 12). The greatest rates of Asians are found in the C grades of Phoenix, and are lowest in D graded areas (Fig. 13). There is no apparent trend in the distribution of Asians in HOLC graded Phoenix.

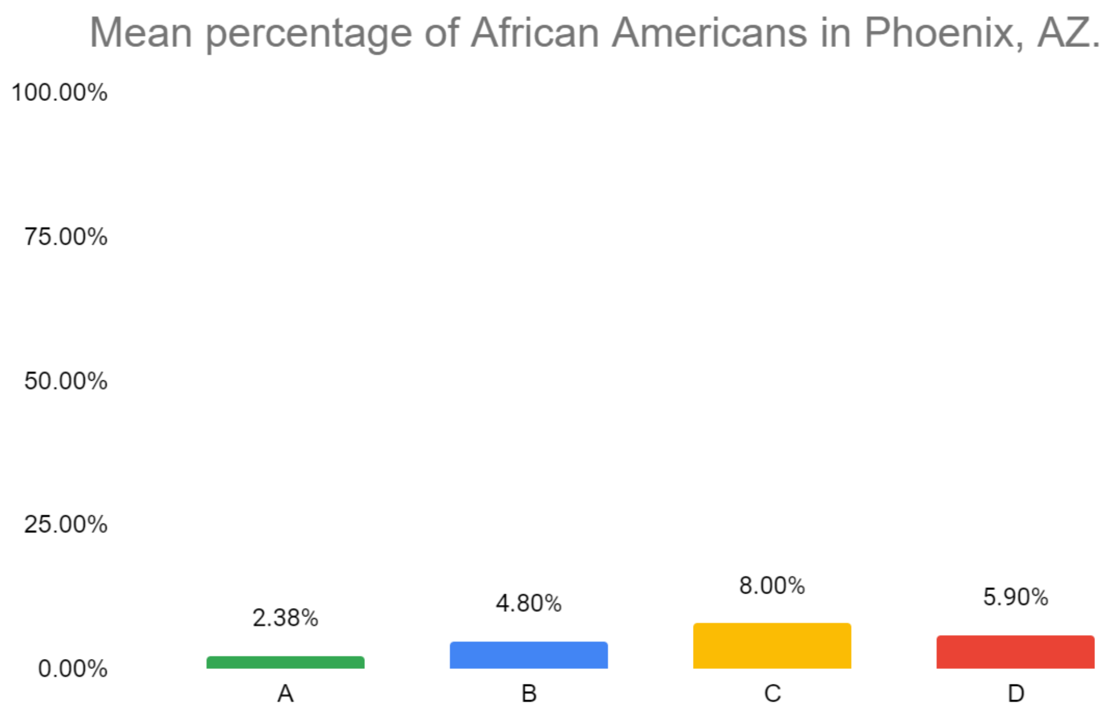


Figure 10. The percentage of African Americans obtained by averaging the four study blocks of HOLC graded Phoenix, AZ.

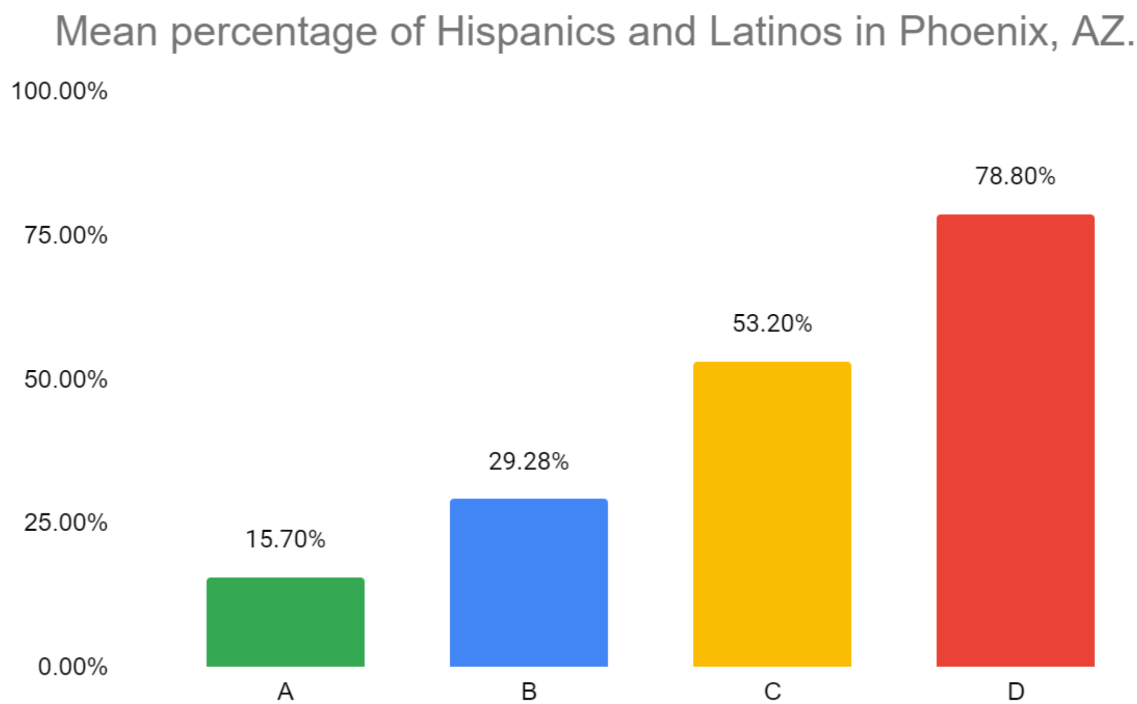


Figure 11. The percentage of Hispanic and/or Latino People obtained by averaging the four study blocks of HOLC graded Phoenix, AZ.

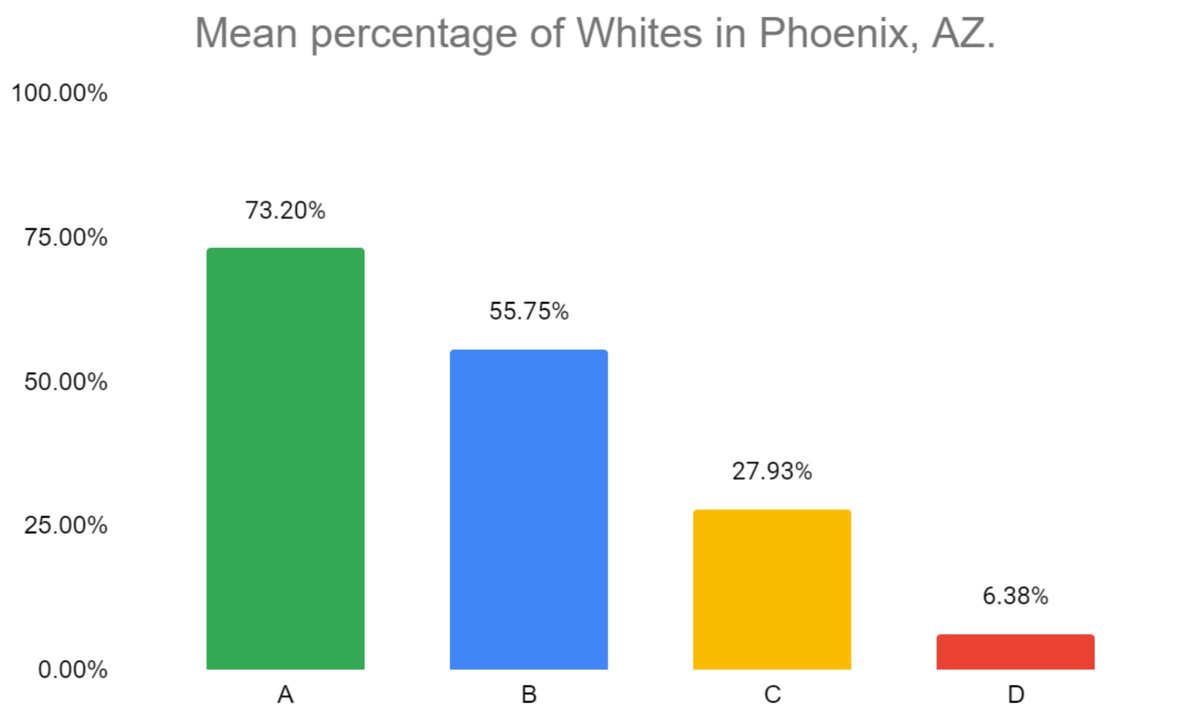


Figure 12. The percentage of Whites obtained by averaging the four study blocks of HOLC graded Phoenix, AZ.

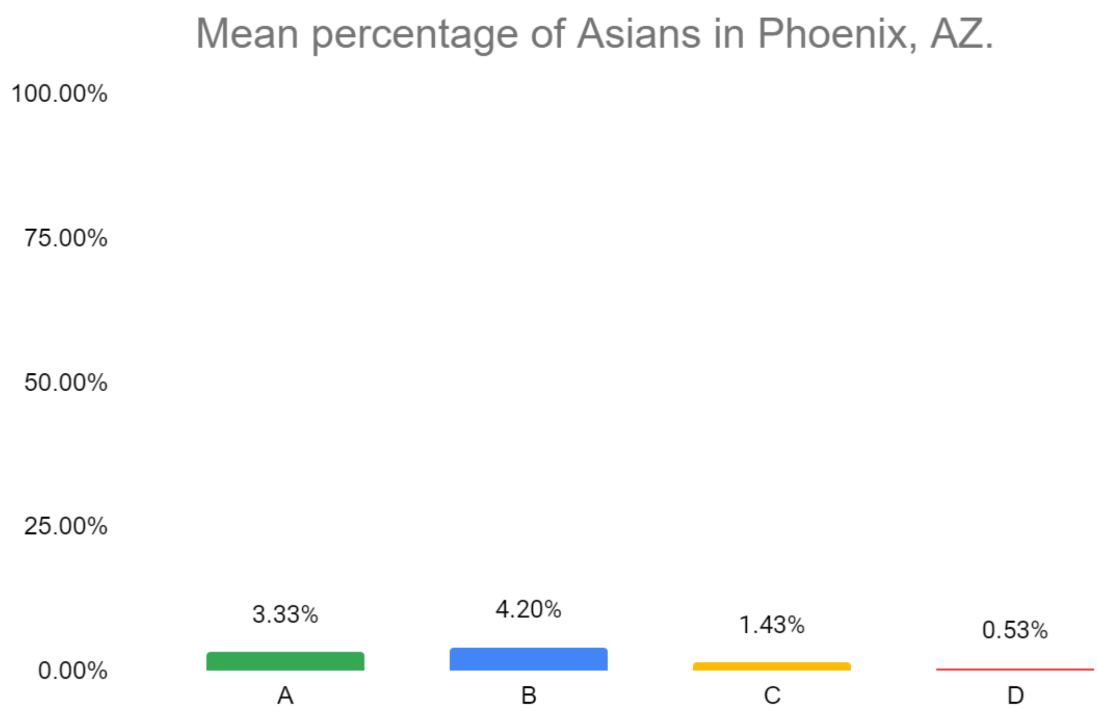


Figure 13. The percentage of Asians obtained by averaging the four study blocks of HOLC graded Phoenix, AZ.

2. San Jose

Rates of African Americans are greatest in the A graded areas of San Jose at 4.05% (Fig. 14). The C grades have the lowest percentage of African Americans at 1.55%. No apparent trend is found in the distribution of African Americans in HOLC graded San Jose. The percentage of Hispanics and Latinos exhibit a near-stepwise trend (Fig. 15). The B grades have the lowest percentage at 20.58%, and the A grades are a similar 21.23%. The C grade is third highest, and the D grade has the highest percentage at 63.23%. Similar to the Hispanic and Latino residents in HOLC graded San Jose, the distribution of White residents is a near reverse of the stepwise trend (Fig. 16). The B grades contain the greatest percentage of White residents at 58.93%, with A grades at a close 52.45%. Rates of White residents in the C grade are third highest, and D fourth. As with the percentage of Asians in HOLC graded Phoenix, no apparent trend is seen in the distribution of Asians in San Jose (Fig. 17).

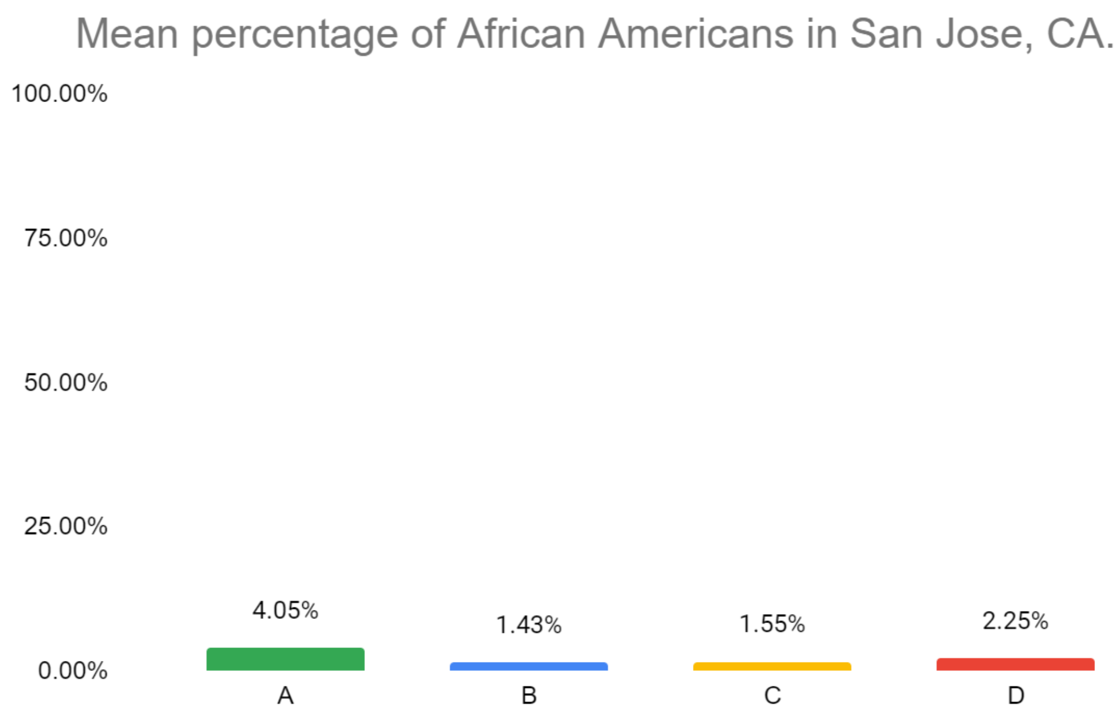


Figure 14. The percentage of African Americans obtained by averaging the four study blocks of HOLC graded San Jose, CA.

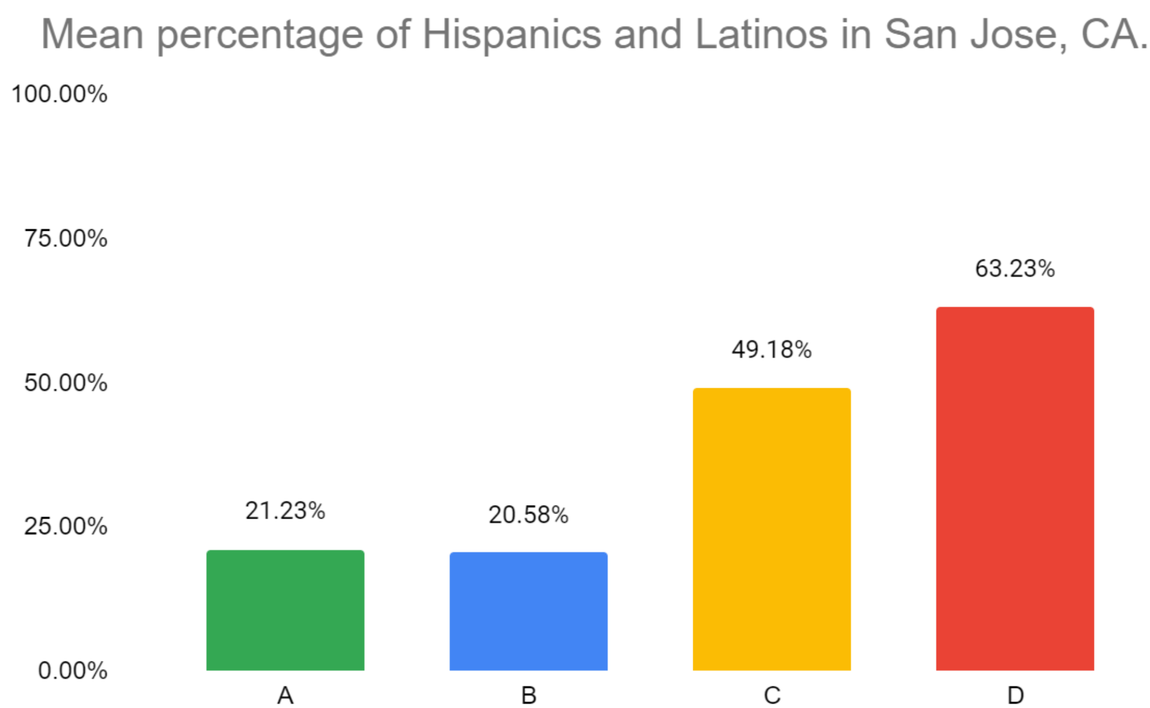


Figure 15. The percentage of Hispanics and Latinos obtained by averaging the four study blocks of HOLC graded San Jose, CA.

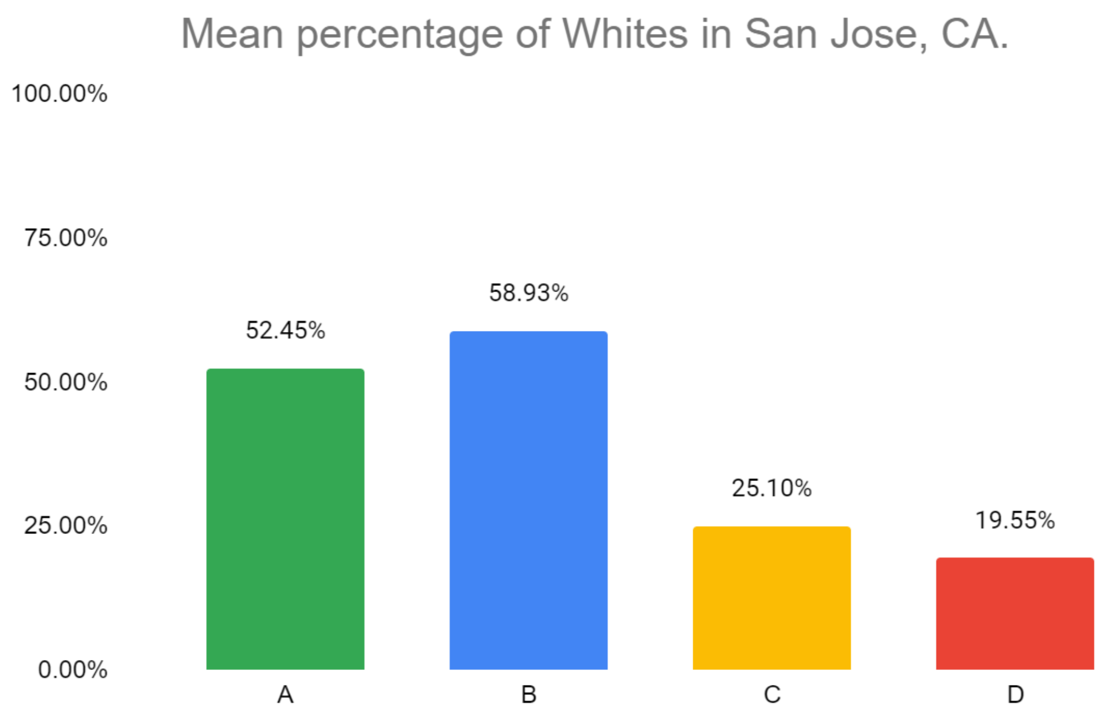


Figure 16. The percentage of Whites obtained by averaging the four study blocks of HOLC graded San Jose, CA.

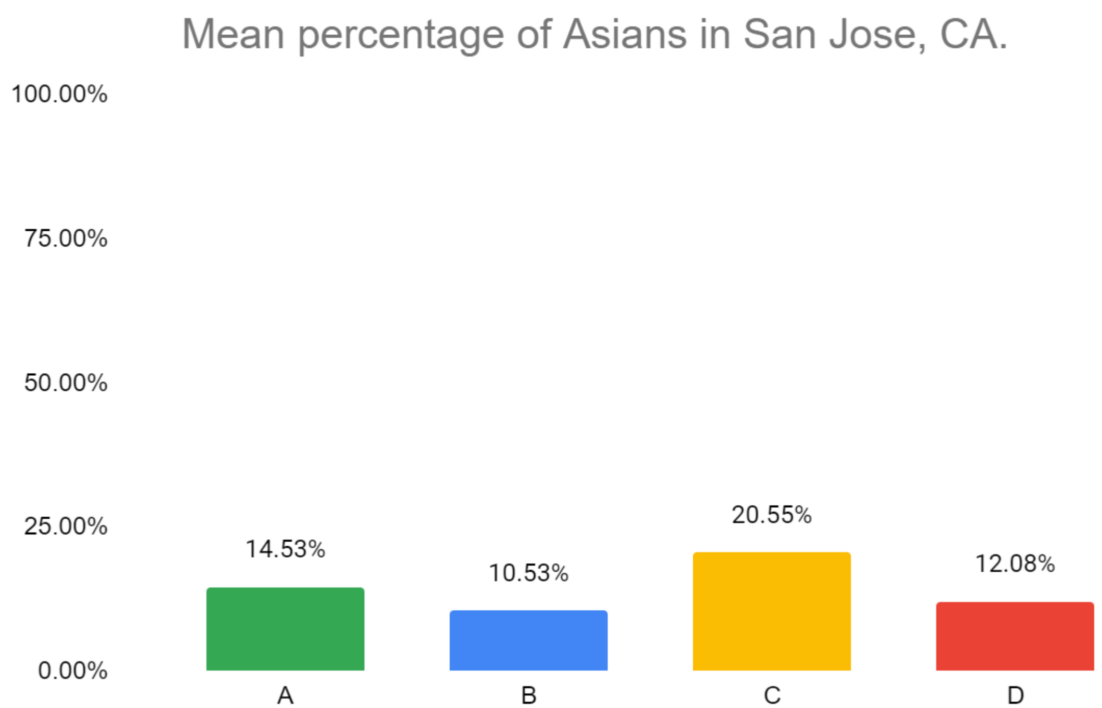


Figure 17. The percentage of Asians obtained by averaging the four study blocks of HOLC graded San Jose, CA.

3. Los Angeles

Percentages of African Americans in HOLC graded areas of Los Angeles are found in greatest amounts in C (13.45%) and D (9.28%) grades (Fig. 18). The A and B grades have the lowest amounts at 1.98% and 1.09% respectively, creating a bimodal stepwise trend. The distribution of Hispanics and Latinos in Los Angeles follow the same stepwise progression as San Jose and Phoenix, where A has the lowest percentage, and D has the highest (Fig. 19). Similar to White residents in Phoenix, the distribution of White residents in HOLC graded Los Angeles follows a reverse stepwise trend (Fig. 20). Asians in HOLC graded Los Angeles are highest in A and lowest in D, however these rates do not follow a reverse stepwise trend, as percentages in C are greater than B grades (Fig. 21).

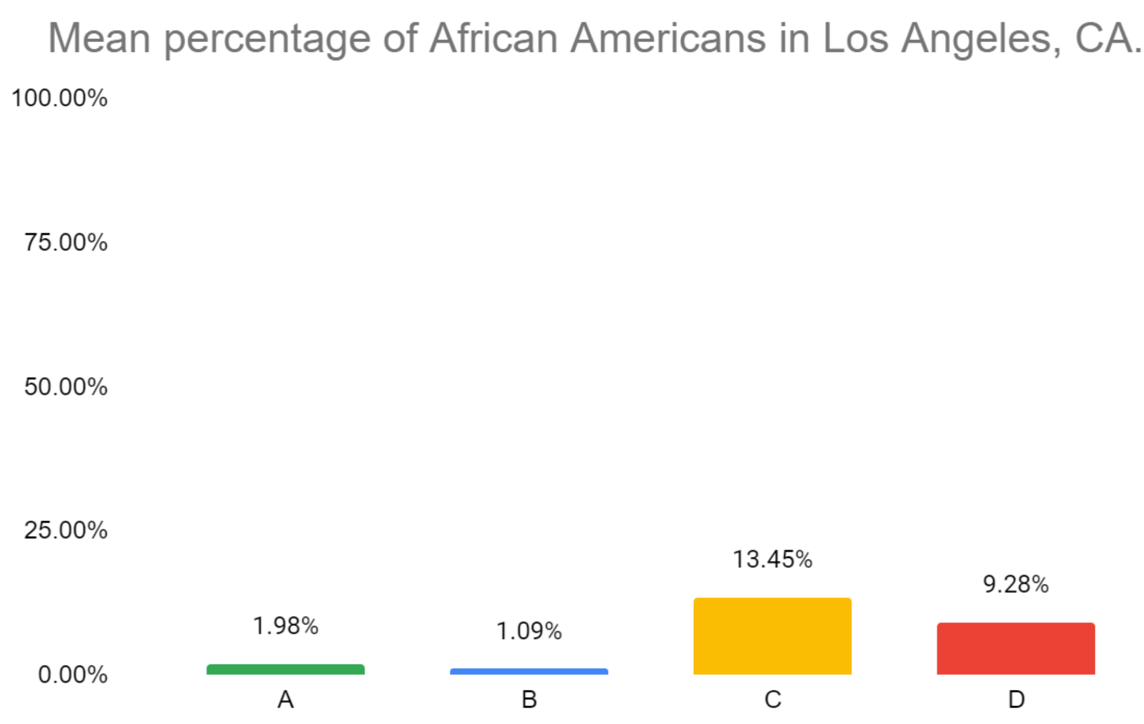


Figure 18. The percentage of African Americans obtained by averaging the four study blocks of HOLC graded Los Angeles, CA

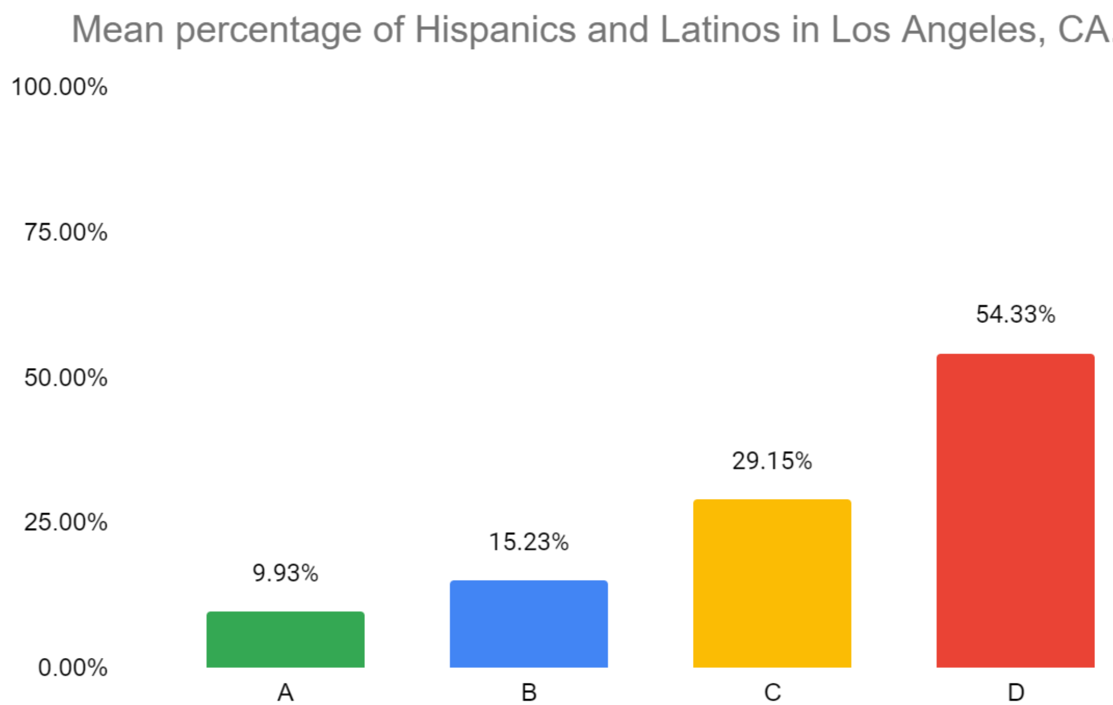


Figure 19. The percentage of Hispanics and Latinos obtained by averaging the four study blocks of HOLC graded Los Angeles, CA.

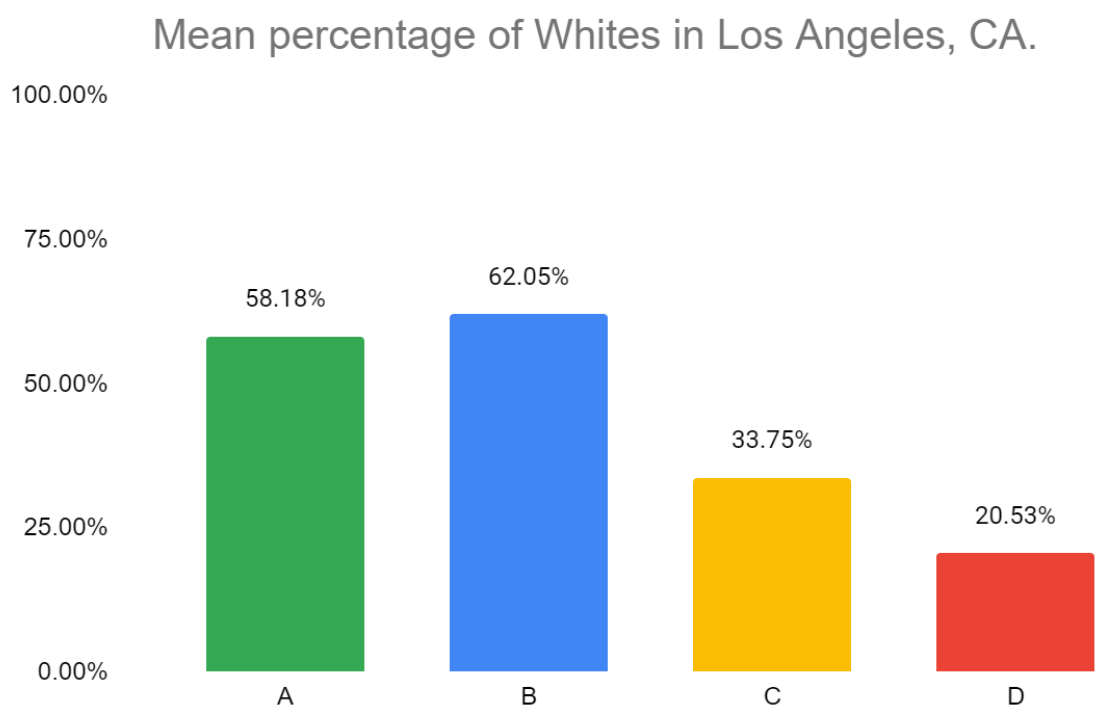


Figure 20. The percentage of Whites obtained by averaging the four study blocks of HOLC graded Los Angeles, CA.

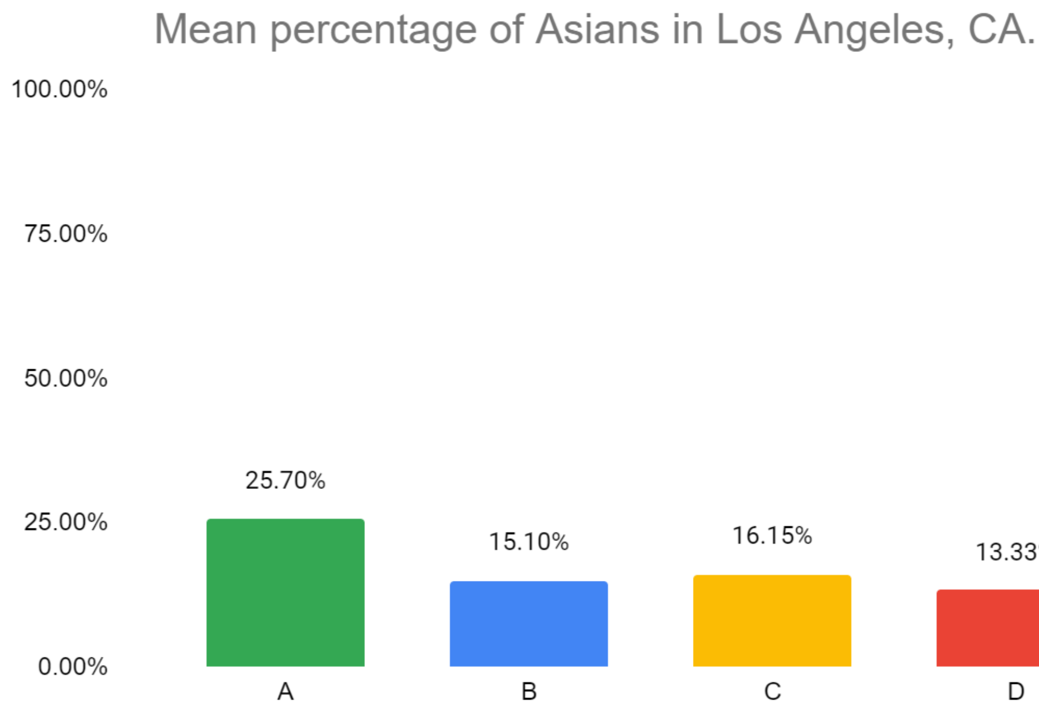


Figure 21. The percentage of Asians obtained by averaging the four study blocks of HOLC graded Los Angeles, CA.

4. Fresno

In Fresno, rates of African Americans in HOLC graded areas follow a stepwise trend where the lowest percentage of residents are found in A grades, the next greatest percentages are in B and C, and the largest amount reside in D grades (Fig. 22). Hispanic and Latino residents also follow a stepwise trend (Fig. 23). The rates of White residents in HOLC graded Fresno exhibit a reverse stepwise trend (Fig. 24). Percentages of Asians are highest in D grades, and lowest in A grades (Fig. 25). The B graded areas of Fresno contain the second highest rates of Asians, with C grades following at third highest. Asians are the only racial group to not exhibit either a stepwise or reverse stepwise trend in Fresno.

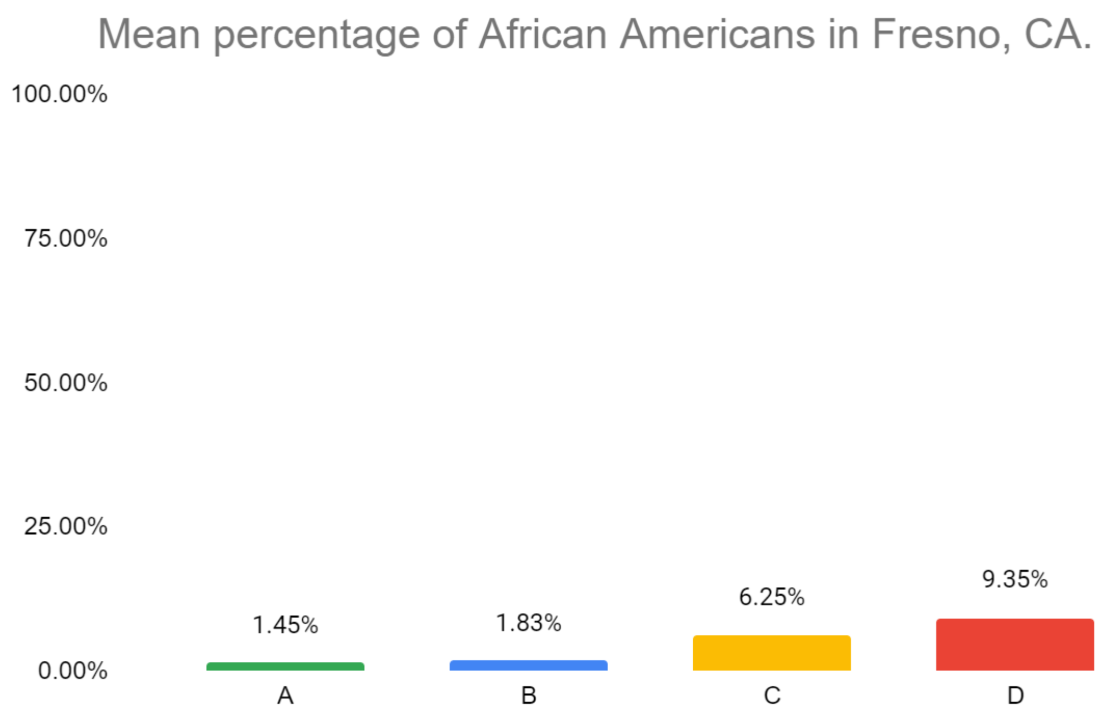


Figure 22. The percentage of African Americans obtained by averaging the four study blocks of HOLC graded Fresno, CA.

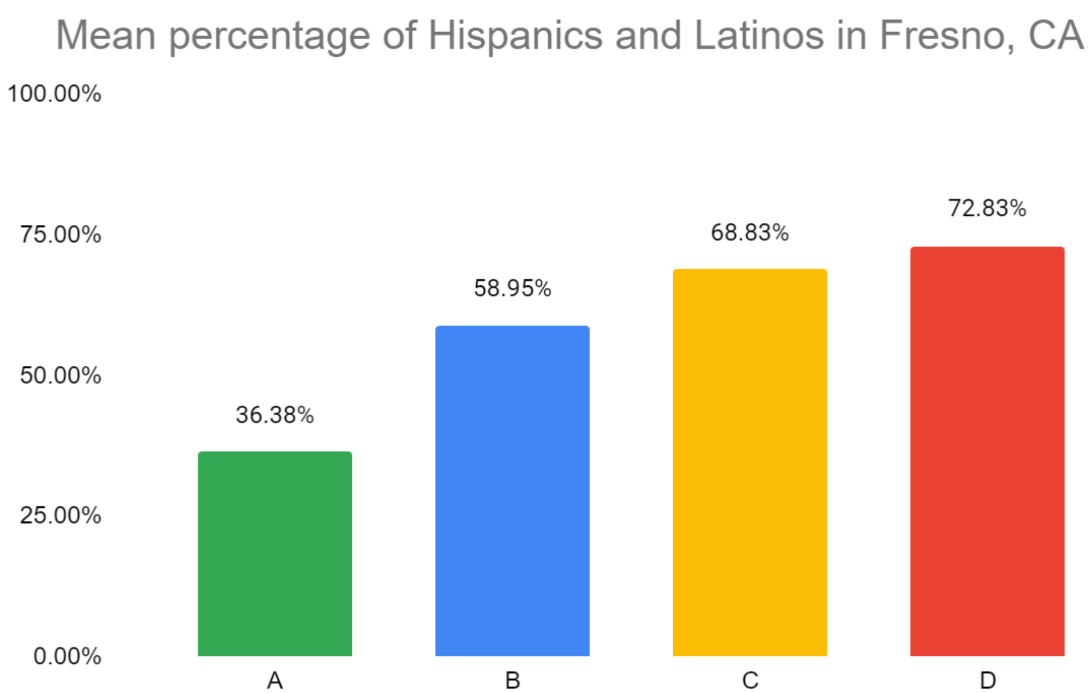


Figure 23. The percentage of Hispanics and Latinos obtained by averaging the four study blocks of HOLC graded Fresno, CA.

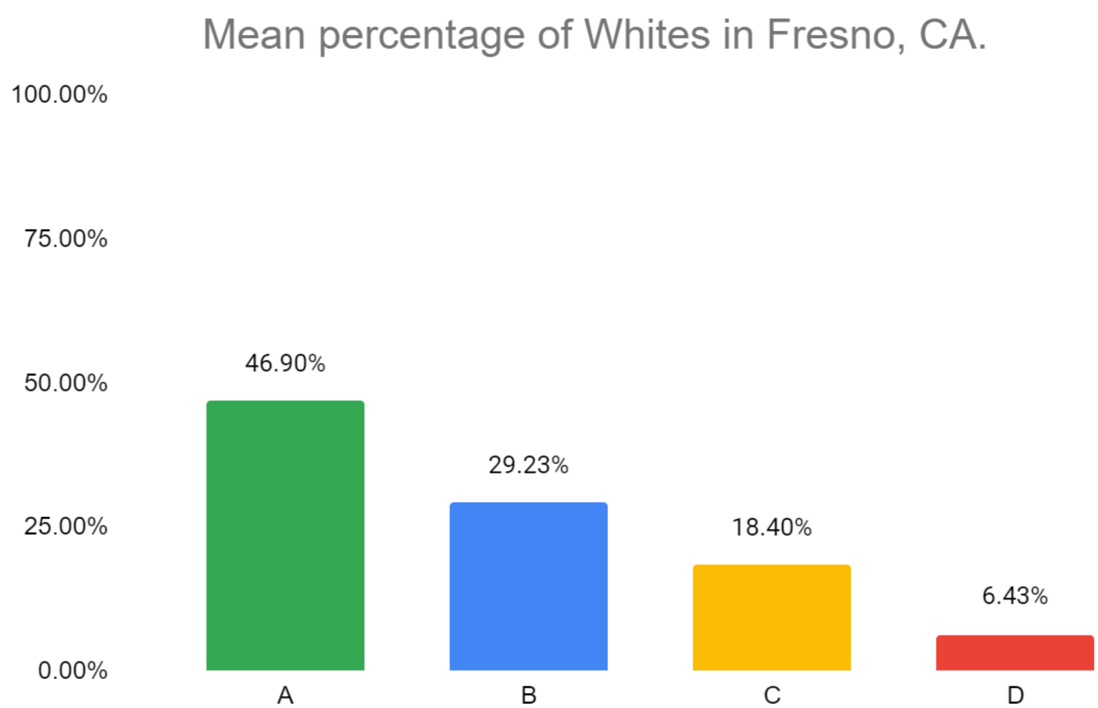


Figure 24. The percentage of Whites obtained by averaging the four study blocks of HOLC graded Fresno, CA

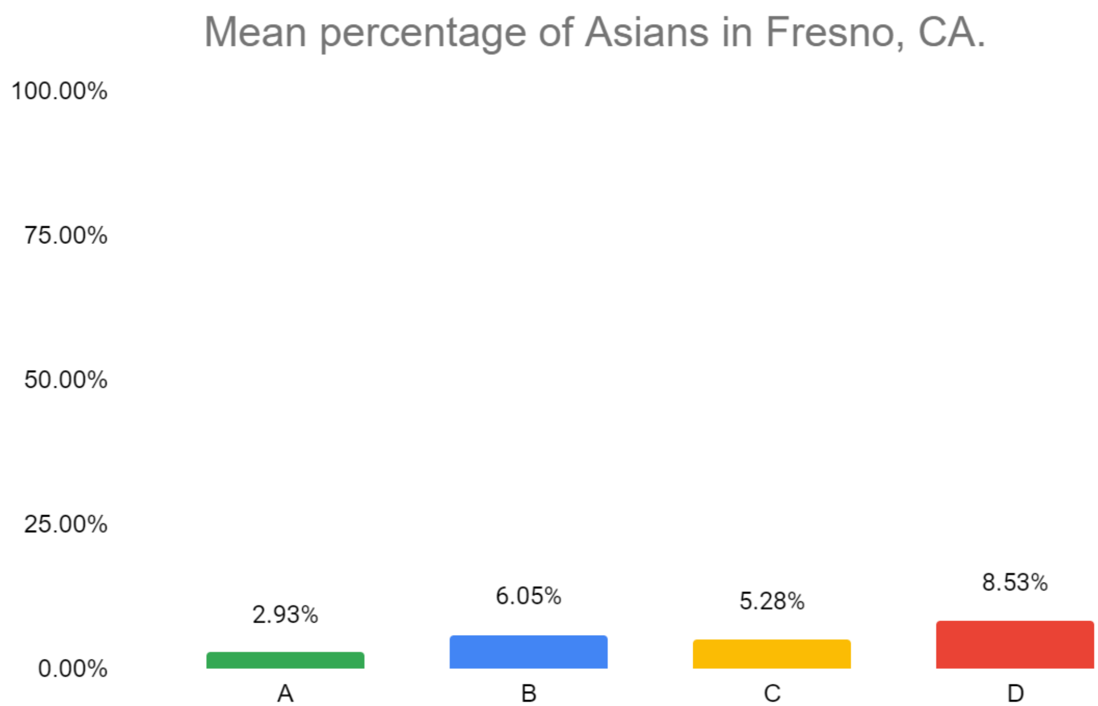
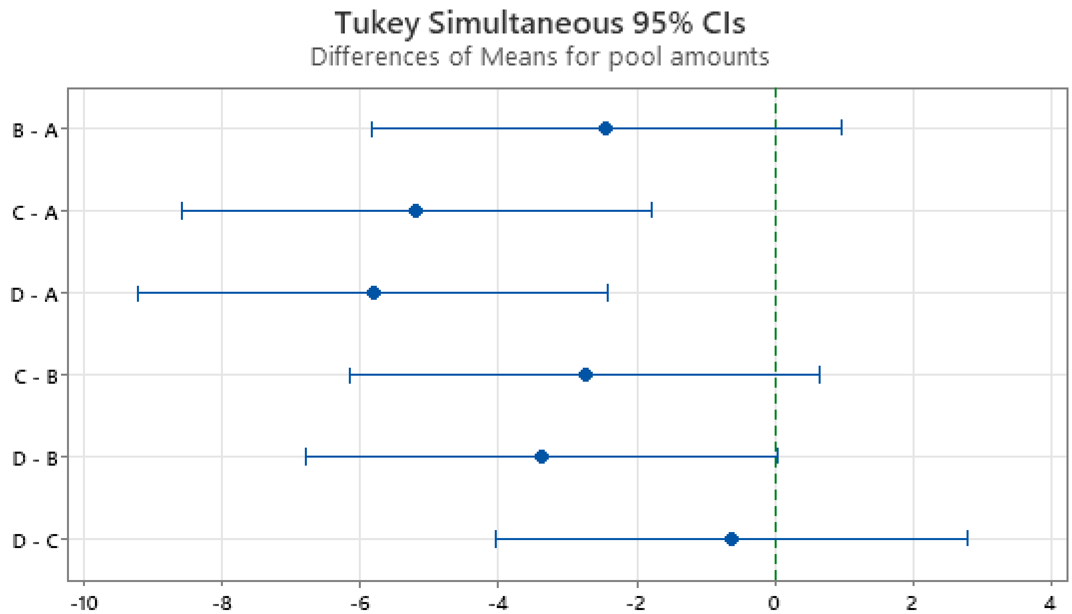


Figure 25. The percentage of Asians obtained by averaging the four study blocks of HOLC graded Fresno, CA.

4.6 Statistical Analyses

1. *One-way ANOVA of Residential Outdoor Water Features and HOLC Grades*

The numbers of outdoor water features were totaled for each HOLC grade. A one-way ANOVA was then performed to determine if the means of each HOLC grade were different from one another using Minitab for analysis (Fig. 26). A p-value of 0.0001 was returned, rejecting the null hypothesis that the mean values of outdoor water features in the selected study cities are the same for each HOLC grade. To further investigate the difference of means between HOLC grades, A Tukey test was performed (Fig. 27). The HOLC grades of A and D, as well as A and C were considered statistically different from one another when comparing the number of outdoor water features. All other grade-to-grade comparisons of means using the Tukey test were considered not statistically different. Furthermore, the Tukey interval between grades C and D was nearly centered over 0, suggesting that these grades are statistically similar to one another. This result is similar to a study conducted by The US Federal Reserve, which states that C grades, or "yellowlined" areas, are often as bad or worse than redlined areas (Aaronson et al., 2021).



Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Group	3	343.9	114.64	8.66	0.000
Error	60	794.1	13.23		
Total	63	1138.0			

Figure 26. One-way ANOVA used to determine a difference in mean water feature amounts between HOLC grades in this study

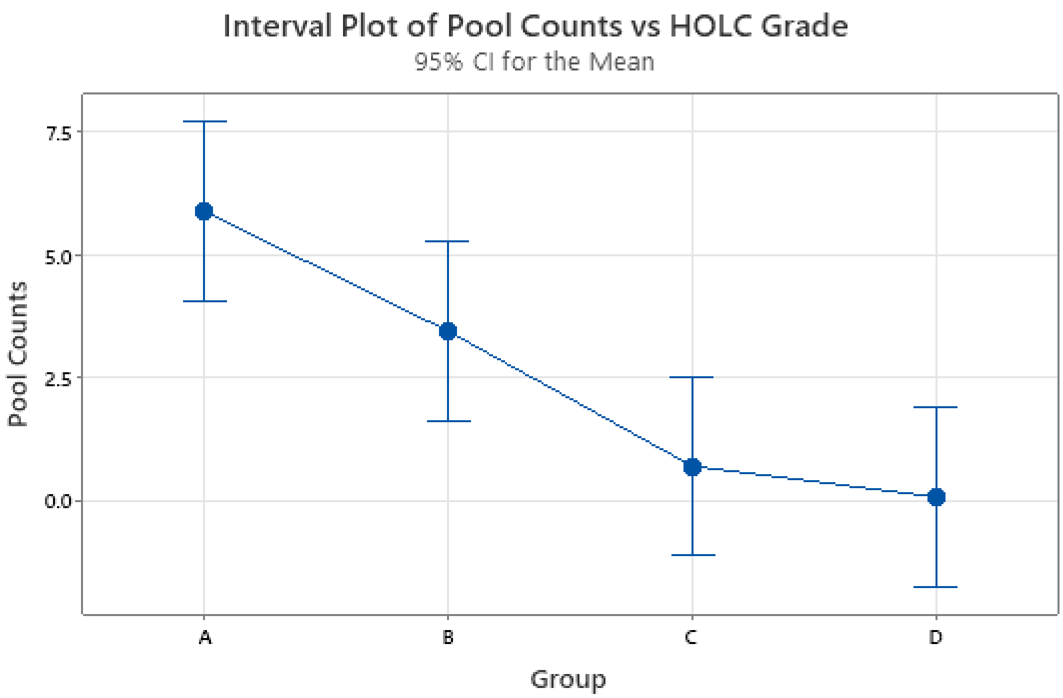
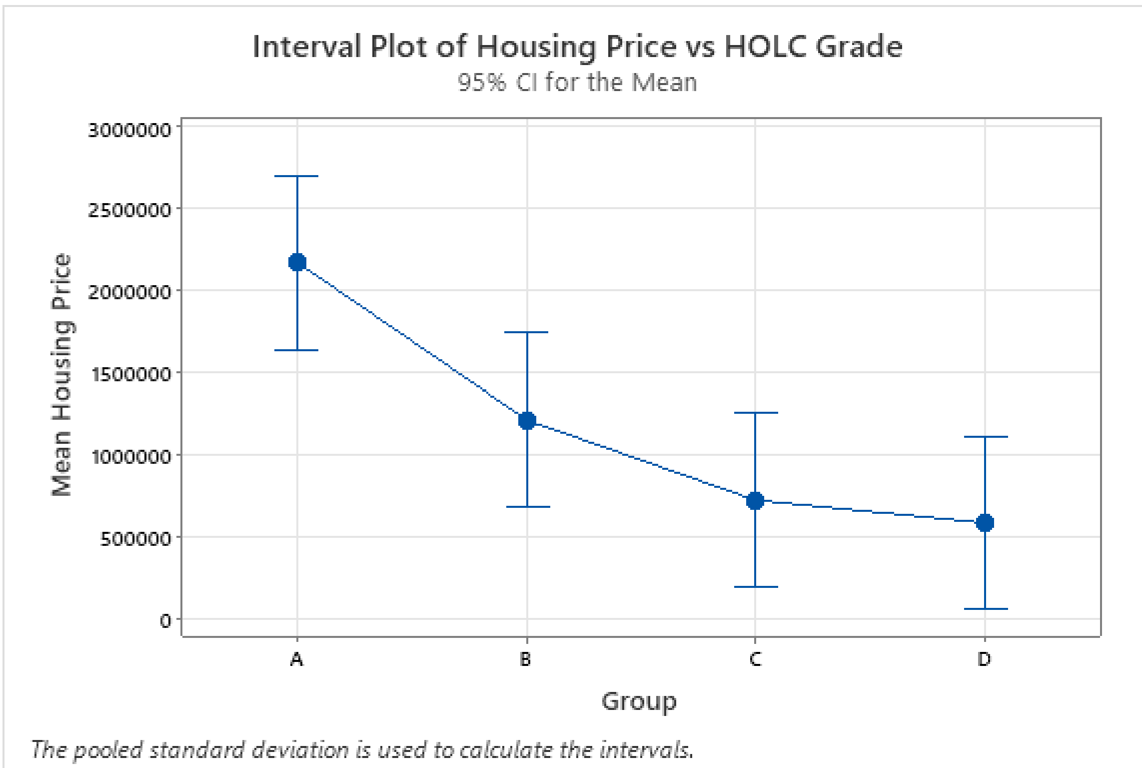


Figure 27. Tukey test of mean water features by HOLC grade. Intervals over zero are considered to be not statistically different from one another.

2. *One-way ANOVA of Housing Prices and HOLC Grades*

A one-way ANOVA was also performed on mean housing values totaled by HOLC grade (Fig. 28). Similar to the previous ANOVA, the means of the house values (as Zestimates) were considered statistically different from one another, with a *p*-value of 0. As such, the null hypothesis was rejected, which conditionally allowed for a Tukey test (Fig. 29). As before, grades A and C, and A and D were statistically different from one another, with all other grade-to-grade interactions being statistically similar. Additionally, the interval between C and D was once again nearly zero, suggesting a similarity between the two grades.



Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	1.11619E+13	1.11619E+13	13.12	0.003
Error	14	1.19103E+13	8.50738E+11		
Total	15	2.30722E+13			

Figure 28. One-way ANOVA of housing prices by HOLC grade.

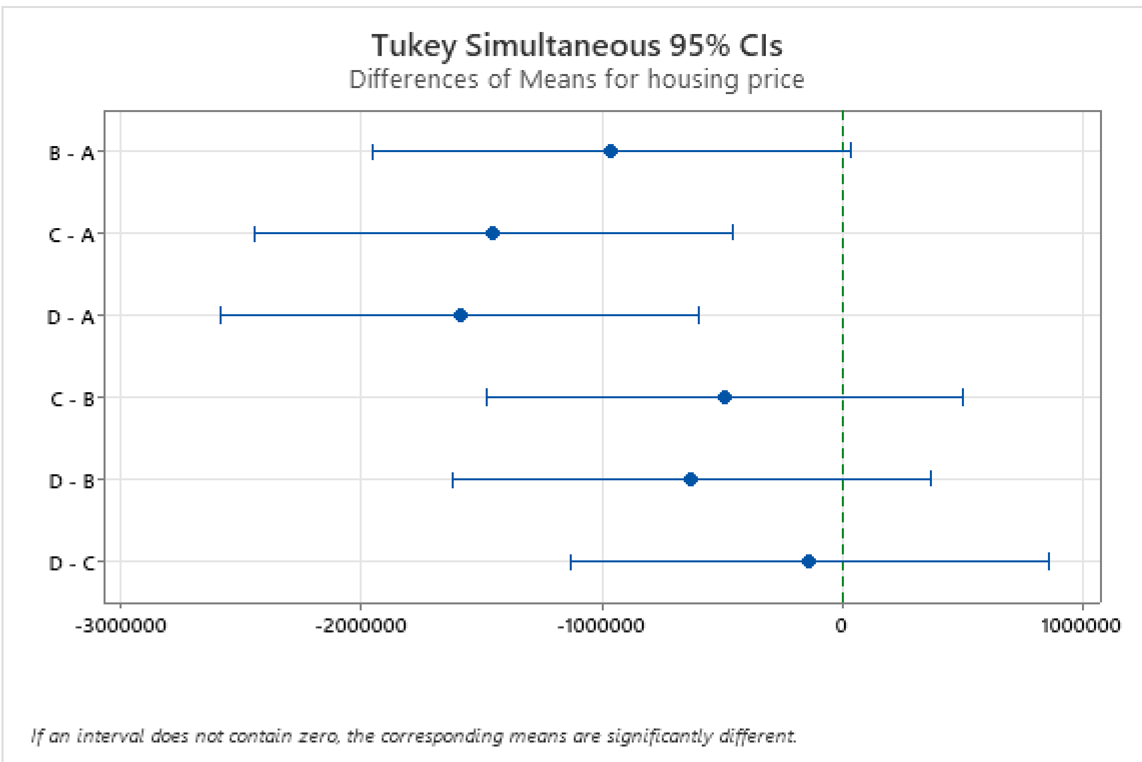
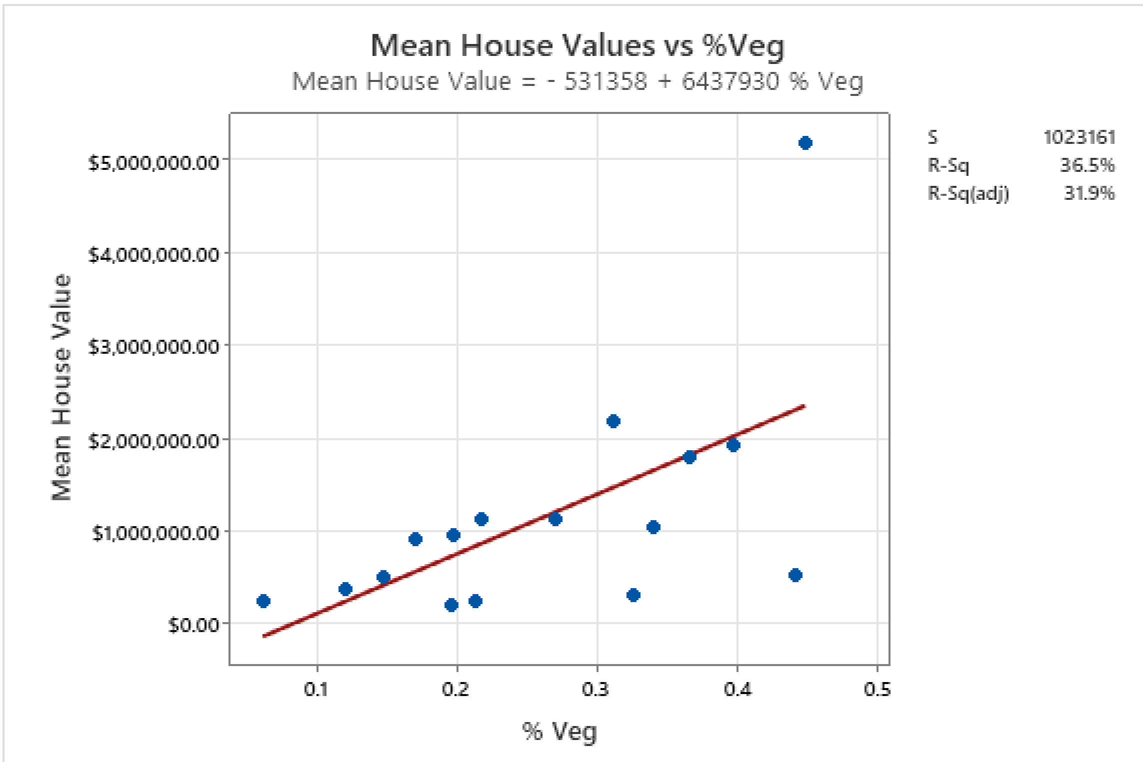


Figure 29. A Tukey test of housing prices by HOLC grade. Intervals over zero are considered not statistically different from one another.

3. Linear Regressions of Housing Values versus Vegetation Intensity and Residential Water Features

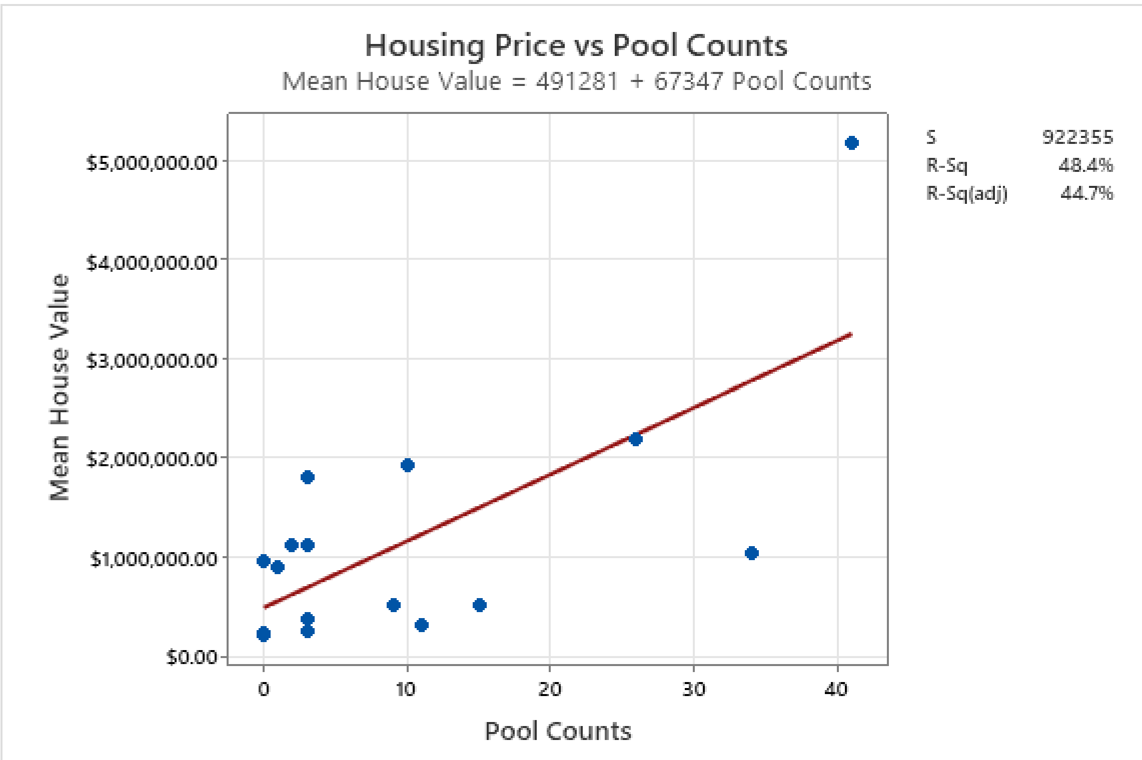
Two linear regressions were conducted in Minitab to assess the statistical relationships between mean housing prices and the environmental indicators of vegetation intensity and outdoor water features. In both regressions, mean house value was used as the response variable. The first regression (Fig. 30) was significant at the 95% level ($p = 0.013$) and yielded a positive relationship ($y = 6{,}437{,}930x - 531{,}358$) between vegetation intensity and housing values ($r^2 = 36.5\%$). The second regression between housing prices and pool counts (Fig. 31) was significant at the 95% and 99% levels ($p = 0.003$). This regression demonstrated a positive relationship ($y = 67{,}347x + 491{,}281$) between pool ownership and home values ($r^2 = 48.4\%$). In both regressions, the A grade of Los Angeles was identified as an outlier for pool counts and vegetation range. The A grade data were greater than 1.5 times the interquartile range.



Coefficients

Term	Coef	SE Coef	T-Value	P-Value
Constant	-531358	651951	-0.82	0.429
% Veg	6437930	2270562	2.84	0.013

Figure 30. Linear regression of housing values (as Zestimates) and Vegetation intensity.



Coefficients

Term	Coef	SE Coef	T-Value	P-Value
Constant	491281	296942	1.65	0.120
Pool Counts	67347	18593	3.62	0.003

Figure 31. Linear regression of housing values (as Zestimates) and Pool Counts.

Chapter 5: Discussion

5.1 Summary

Although redlining is now illegal in America, the results of this study show that it continues to perpetuate unequal distribution and consumption of water outdoors in the Southwest United States. Every D grade in this study, except in Los Angeles, did not have a single water feature. Furthermore, the D grades for every study city had the least amount of pools in comparison to the other respective grades of each city. The C grades of each city had the next smallest amount of pools in comparison to other grades. These findings are consistent with other studies, like Napieralski et al. (2022) and Harlan et al. (2006), which link pool ownership to wealth and affluence. The notion of communities without pools and water features may not seem consequential, however, communities with pools are better protected against the urban heat island effect, and have higher housing values (Vidal et al., 2011). Communities graded A contain the greatest amount of water features, meaning they benefit from the cooling effects, higher housing values and also create a bigger demand on the already taxed water systems of the American Southwest. In Phoenix, homes with pools use more than two times the water than homes without (Wentz and Gober, 2007). Outdoor water features such as pools in arid environments are one such example of a “Tragedy of the Commons" scenario, where those with greater amounts of surface water are individually benefitting from an essential resource needed by all.

Vegetation density is crucial for understanding how much water a residence uses outdoors in arid and semi-arid environments, like those found in the Sunbelt. In the American Southwest, green landscapes require near-constant irrigation. As such, the vegetation density of a community is an ideal metric to assess outdoor water use. For each of the four cities in this study, both mean and percentage of vegetation were highest in the A graded areas. Furthermore, as HOLC grades descended from A to D, so too did both the mean NDVI and percentage of vegetation. For every city in this study, the A grades had two times or greater the amount of vegetation than their respective D grades. Simply put, the better graded a neighborhood was by the HOLC, the more water it uses to tend to its landscapes. When taken into account with the distribution of outdoor water features in HOLC graded areas, better graded areas use more water outdoors than those graded as lesser.

The practice of redlining likely helped to bolster the finances of those living in A graded areas. The Zillow average value for a home in Phoenix, AZ is $413k, yet the average Zillow price in the A graded areas of this study is just over 1 million dollars. The average price of a home in Phoenix is a stark contrast to the redlined areas in the same city, where the average Zillow value is $239k, exemplifying disparities in wealth (Zillow, 2022). The interplay between blue space and property values is not fully understood, however, research has shown that properties with a pool are more valuable than those without (Fisher-Jeffes et al., 2015). Although causation cannot be determined from this study, it is a notable finding that home value trends mirror that of outdoor water usage within the context of formerly redlined neighborhoods, which is to say, better graded areas contain more residential wealth and use more water outdoors.

The distributions of industrial and residential zoning types reflect the results of previous research questions examined in this study. The A grades of each study city contain the greatest percentages of residential zoning (Table 3). Inversely, the amount of industrial zoning is greatest in the D graded areas of each city (Table 4). Fresno, San Jose, and Phoenix did not possess any industrial zones in areas with A and B grades. In Los Angeles, the amount of industrial zoning in A and B graded areas combined (1.29%) still comprises less than half of the industrial zoning of the D grade (7.92%). These findings are consistent with a study by Lane et. al. (2022), which found redlined communities have higher rates of exposure to air pollution as a result of greater numbers of factories being built and expanded in redlined areas. The pollutants analyzed in the study (NO_2 and $PM_{2.5}$) by Lane et. al. are considered “short-lived”, lingering only hours and days in the atmosphere, yet their increased amounts in redlined areas show that segregatory policies have repercussions that span generations.

Racial sorting, or the separation of racial groups, is still evident in many of the study cities. The more favorable A and B grades of every city in this study had the highest percentages of white residents. When compared with Hispanic and Latino residents, where rates were highest in the D grade for every city, a segregatory trend is apparent. Additionally, African Americans in Fresno still reside in D graded areas in greater numbers compared to more favorable grades. Although the “stepwise” trend is not apparent for every BIPOC population living within the D graded areas of this study, many residents, namely Hispanics and Latinos, are found in greater percentages within redlined communities.

5.2 Study Limitations

There are multiple limitations within this study. First, only four blocks were used to obtain a picture of the outdoor water features for each HOLC grade. Shadows, vegetation and satellite artifacts made some water feature identifications difficult, so to remedy this, Google Earth was used as a second source. These same four blocks were also used to calculate the racial demographics for the HOLC grades. Additionally, the racial demographics used in this study were calculated via aggregation of block groups, and are thus a mathematical approximation. Second, NDVI was used for the years of 2014 and 2017 due to the need for a 1 m resolution. Third, Zillow Zestimates were used to calculate single-family home values. Zillow is a for-profit company that uses historical tax and property records to calculate values, as such, Zestimates are only as accurate as these data. Zillow states their median error for Zestimates is 1.9% for homes on the market, and 6.9% for homes off market (Zillow, 2021). Single family residences were chosen to link a family's water usage and wealth via home prices, as such, the interplay between other forms of housing and water usage is not investigated in this study. Lastly, undercounting of populations during the 2020 Census also compromise the integrity of the racial data collected in this study. The 2020 Census reports that undercounting occurred for Latinos by 4.99%, and African Americans at 3.30% (US Census Post-Enumeration Survey Estimation Report, 2022). Overcounting was also reported by the 2020 census in both White (1.64%) and Asian (2.62%) populations (US Census Post-Enumeration Survey Estimation Report, 2022).

5.3 Conclusion

As determined by Q3 and Q5, many areas graded as D by the HOLC within this study are still inhabited by a larger proportion of BIPOC residents with lower incomes. Although the

HOLC maps were created almost a century ago, the legacy of federally supported racism they enforced is still apparent today. Research has only recently begun to investigate the breadth of the effects of redlining, and furthermore, few studies have investigated the effects of yellowlining within formerly HOLC graded communities. Each of the five research questions in this study leads to a result that redlined areas negatively impact: the greater rates of industrial zoning and reduced residential spaces, the lesser home values, and by proxy, income, the lower amounts of vegetation and residential water features, and consequently, water usage. Although segregation is now illegal in America, a new generational segregation can be witnessed. Bygone policies like redlining have locked residents and generations of their children into neighborhoods where they experience the effects of climate change in greater intensities than other areas. More work is needed both in investigational work to determine the links between water usage and racial justice, as well as proactive research and policy changes to rectify and prevent further injustices. The findings from this study can be used to inform both residents at the individual level, as well as government officials at the state and federal level. These data are fine-scale, collected at the individual parcel or neighborhood, and as such, can be used by government officials as a targeted map for the curtailment of excess outdoor water usage. Furthermore, the high-resolution NDVI data can be used as a guide for replacing the water-intensive lush green lawns of residents with a native xeric (or desert vegetation) landscape.

This study addressed the literature gap between the socioeconomic and environmental legacies of redlining by linking a single-family home's water usage to their income. Future work in this area is needed to investigate correlations between other types of housing and public pools. Additionally, this study is the first of its kind to examine types of zoning in formerly redlined cities. There is a need in the current body of literature to explore what zoning types occur in *all* formerly redlined cities instead of just the four selected for this study, as well investigate how this zoning impacts the environment, health and wellness of residents who live in these areas.

Water does not have an innate shape or form, it simply obeys the restrictions placed upon it by those in positions of power. Therefore, the inequitable distribution of residential water features is a reflection of the restrictions we place on each other. Water is essential for life, even more so in the drought-stricken areas of the Sunbelt. The scenario of eco-apartheid is already apparent in the United States, where pollutants, heat islands, and lack of green spaces pervade communities of color. If attempts are not made to rectify the past laws, which are charging the current inequities, climate change will certainly widen the gap between disparate communities and those that are more affluent.

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