Redlining's Impacts on Changes in NDVI Over Time in Ft. Wayne, Indiana

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Link to code

Abstract

The practice of redline mapping (or redlining) was adopted in the 1930's by the Homeowners Loan Corporation (HOLC) to assess the 'risk' presented by urban neighborhoods in the US, based on a racially motivated perception of safety for investment. This practice was heavily criticized and was eventually outlawed in the 1960's, but researchers in the decades since have found that the land cover in the previously redlining areas greatly differ, with decreasing land cover present as the historic risk for loans increase. Donovan Moxley and Burnell Fischer used historic redlined maps of Indianapolis, Indiana to expand on this idea, and called for more research to be conducted in several other historically redlined cities across Indiana. Due to my lack of experience with the area, I chose to investigate the impacts of redlining on Ft. Wayne, Indiana. I looked at the NDVI change from 2000 to 2019 and found that my results followed similar trends with the existing body of work, but had notable differences. The R-squared values pulled from the trendlines of NDVI over time in each zone were very low, indicating that more factors contributed to the change in NDVI over time, but found that the y-intercept of the NDVI trendline was highest for Zone A, and decreased with each zone thereafter, showing that the total vegetation land cover is higher for zones deemed least risky in the 1930's. Overall, more research needs to be done to investigate the relationship between redlined districts, NDVI, and the resulting environmental impacts.

Introduction

During the Great Depression, home foreclosures were at an all time high, resulting in the Federal implementation of the Home Owners' Loan Corporation (HOLC). The HOLC created reports for several cities across the nation to assess the risk and security of home loans across neighborhoods, assigning them a grade from A to D, with A being the least risky and D being the most. Lower grades were given to areas with high populations of African Americans, low income individuals, and older housing. The term 'redlining' was given to those areas colored red, or deemed most risky, and these redlined districts have disproportionately borne the burden of several negative externalities.

One such externality is the concentration of urban heat islands in redlined areas. The present body of research on this topic has found that across the US, historically redlined areas are correlated with a non-uniform distribution of urban heat island differentials. Notable findings include the following: 94% of urban areas examined have higher concentrations of urban heat islands in historically D-rated areas than A-rated, D-rated areas are now on average 2.6°C warmer than A-rated areas, and areas with higher ratings have less developed land cover and more greenspace. The distribution of developed land and green infrastructure are important in the discussion of urban heat islands as green infrastructure and green spaces can significantly decrease the intensity of urban heat and are considered one of the most cost effective approaches to mitigating urban heat islands.

Moxley and Fischer furthered the existing body of research by examining the impacts of HOLC grades and tree cover analysis which had previously only covered Durhan, NC, Freshco, CA, Pittsburgh, PA, and Portland, OR, and looked at the relationship between HOLC grades and tree cover in Indianapolis, IN. Through a geospatial analysis of NDVI, HOLC zones, brownfield sites, Superfund sites, mile markers, and industrial waste sites, they concluded that with higher grades under HOLC, the proportion of developed land cover decreased while the proportion of greenspace increased. They also found that historically redlined areas made up 27% of the total land areas but had the highest intensities of development, brownfield sites, Superfund sites, mile markers from I-65 and I-70 and 49.1% of industrial waste sites. After the conclusion of their paper, they recommended further research be conducted at the other historically redlined cities across Indiana, including Muncie, Gary, Ft. Wayne, and South Bend, IN.

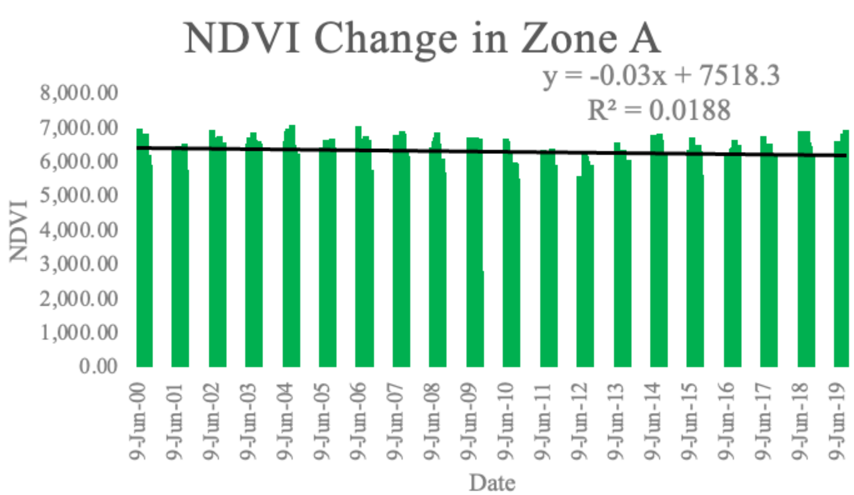
I chose to look at the redlining impacts present in Ft. Wayne, IN due to my lack of knowledge of the area, and desire to know more. Specifically, I looked at the comparison of the change over time in NDVI aggregated across each HOLC score zone, hoping to investigate the relationship between HOLC grade and NDVI scores.

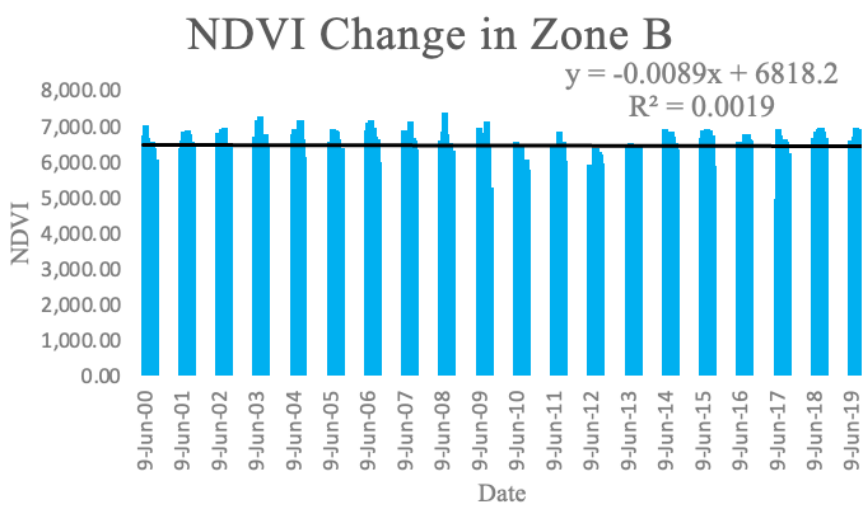
Methodology

Initiatially, the methodology specified in Moxley and Fischer was followed in ArcGIS, including the inclusion of NDVI, HOLC zones, brownfield sites, Superfund sites, mile markers, and industrial waste sites, with the intention of using ArcGIS's python window to further analyze the relationship between HOLC zones and the remaining factors, but after advisement, analysis was conducted using the Google Earth Engine (GEE). The shapefile provided by the University of Richmond was downloaded for the Ft. Wayne area and then input into GEE as an asset to then be used as a variable for analysis. HOLC grades were then given to each zone in Ft. Wayne, and stylized to resemble the historic legend for HOLC maps, with Grade A as green, Grade B as blue, Grade C as yellow and Grade D as red. To obtain NDVI data in Ft. Wayne over time, the MOD13Q1.006 Terra Vegetation Indices 16-Day Global 250m [deprecated] dataset was used. This MODIS dataset was then filtered to select the NDVI band, bounded by the HOLC shapefile, and further refined to only include data from June to September, where green land cover is most visible. The MODIS dataset provided data from 2000 to 2019 for each zone for further analysis, with the intention to examine the slope of the trendline over time, the R-squared value, and y-intercepts of the graphs generated for each HOLC zone. The graphs generated for each zone were then extracted as a .csv file for further manipulation.

Results

Using Microsoft Excel, graphs were generated for each dataset, including the equation of the trendline and R-squared values. Results are as follows:





NDVI Change in Zone B
y = -0.0089x + 6818.2
R² = 0.0019
8,000.00
7,000.00
6,000.00
5,000.00
4,000.00
3,000.00
2,000.00
1,000.00
0.00
NDVI
9-Jun-00
9-Jun-01
9-Jun-02
9-Jun-03
9-Jun-04
9-Jun-05
9-Jun-06
9-Jun-07
9-Jun-08
9-Jun-09
9-Jun-10
9-Jun-11
9-Jun-12
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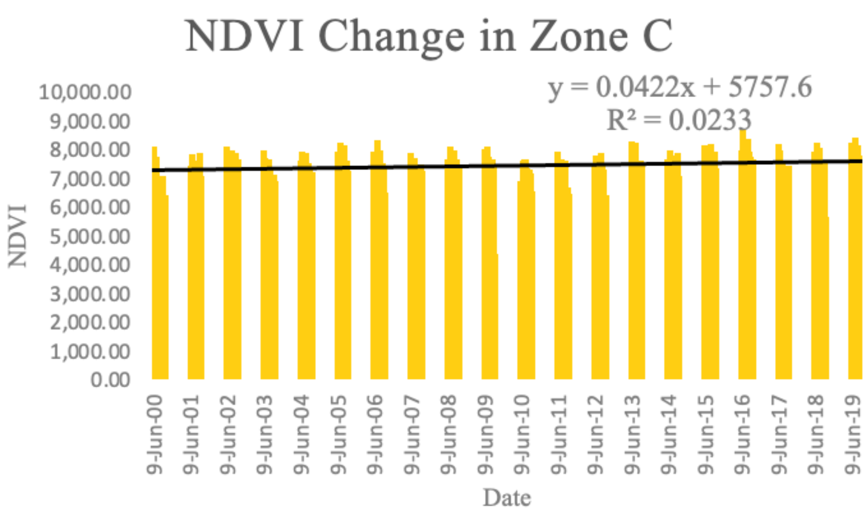
9-Jun-15
9-Jun-16
9-Jun-17
9-Jun-18
9-Jun-19
Date



NDVI Change in Zone C
y = 0.0422x + 5757.6
R² = 0.0233
10,000.00
9,000.00
8,000.00
7,000.00
6,000.00
5,000.00
4,000.00
3,000.00
2,000.00
1,000.00
0.00
NDVI
9-Jun-00
9-Jun-01
9-Jun-02
9-Jun-03
9-Jun-04
9-Jun-05
9-Jun-06
9-Jun-07
9-Jun-08
9-Jun-09
9-Jun-10
9-Jun-11
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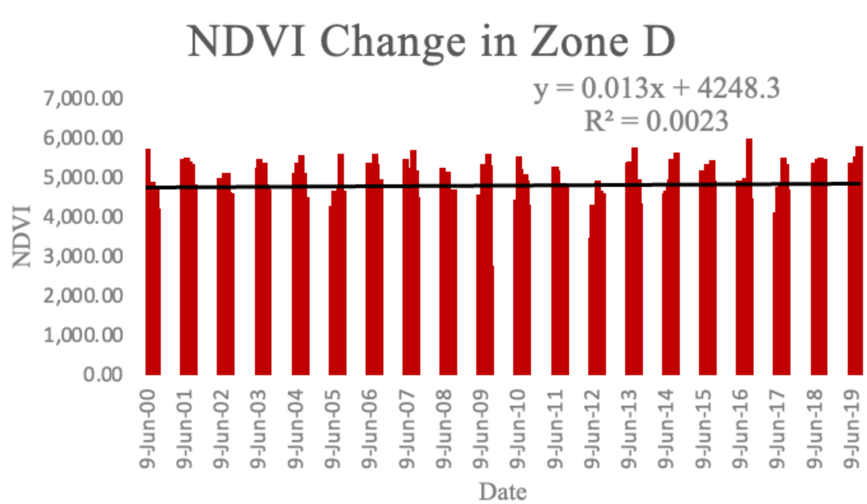
9-Jun-18
9-Jun-19
Date



NDVI Change in Zone D
y = 0.013x + 4248.3
R² = 0.0023
7,000.00
6,000.00
5,000.00
4,000.00
3,000.00
2,000.00
1,000.00
0.00
NDVI
9-Jun-00
9-Jun-01
9-Jun-02
9-Jun-03
9-Jun-04
9-Jun-05
9-Jun-06
9-Jun-07
9-Jun-08
9-Jun-09
9-Jun-10
9-Jun-11
9-Jun-12
9-Jun-13
9-Jun-14
9-Jun-15
9-Jun-16
9-Jun-17
9-Jun-18
9-Jun-19
Date

The most notable result are the differences in y-intercept values. The lowest y-intercept value was present in the aggregation of Zone D polygons, valued at 4248.3, followed by Zone C at 5757.6, Zone B at 6818.2, and Zone A at 7518.3. This is consistent with the existing body of work studying NDVI and HOLC scores. Examining the slopes of the trendlines, there was not a similar increase or decrease as HOLC scores changed, with Zone A's trendline having a slope of -0.03, Zone B at -0.0089, Zone C at 0.0422, and Zone D at 0.013. Each zone also had low R-squared values, with no clear trend across changes in HOLC scores.

Discussion

The displayed trend of y-intercepts decreasing while moving from low risk to high risk zones indicates that NDVI is lowest in the most redlined areas of the city, meaning these neighborhoods consist of the least greenspaces and have the highest vulnerabilities to urban heat islands. This high vulnerability to urban heat islands then in turn leaves these communities more vulnerable to exacerbated air pollution, storm events, and energy injustices due to the increased need for mechanical air conditioning in these areas. The slightly positive value of the slope of the trendlines for Zones C and D could possibly be attributed to industrial abandonment, rather than an increase in community green infrastructure over time, as mentioned in Moxley and Fischer. There are also most definitely other factors contributing to the change in NDVI scores over time besides HOLC scores, which could also be a contributing factor to the very low R-squared values.

Changes in NDVI over time could be impacted by a plethora of factors, not limited to the brownfield and Superfund locations, industrial waste sites, and mile markers examined by Moxley and Fischer. By only looking at NDVI and HOLC zones, this research lacks the opportunity to investigate the multitude of factors that might have contributed to these results.

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