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Measuring the effects of public land use change: An analysis of greenways in Raleigh, North Carolina

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ABSTRACT

From 2010–2015 Wake County, NC, and the City of Raleigh, have experienced prolific growth of outdoor amenities, primarily financed through the passage of parks and open space bond referenda. Wake County currently has over 100 miles of off-street, paved greenway trails connecting schools, parks museums and commercial areas, 65 miles of which have been added from 2010 to 2015. As a result of the expansion of the Capital Area Greenway System, several neighborhoods in Wake County now have access to new recreation and transportation opportunities. This research estimates the effects of expanding greenway infrastructure and evaluates heterogeneous demand for greenway infrastructure across households. Using a hedonic framework, I estimate the capitalization effect of greenway expansion, I find heterogeneity in capitalized values ranging from − 4–12% dependent on spatial location and highlight potential drivers of heterogeneous values.

1. Introduction

Providing environmental amenities in urban landscapes can be difficult given the trade-offs faced when choosing the location and quantity of public goods. This is especially true when considering the construction or expansion of a greenway system. A greenway is defined as a linear open space established along a natural corridor such as a stream, river, valley, scenic road, abandoned railroad corridor or other natural or man-made route (Shafer et al., 2000). The benefits of greenways, and open space more broadly, have been extensively explored in the literature with little consensus as to who benefits from living near urban parks and greenways. Some studies have shown that minority and low income populations have greater access to urban parks and greenways than high income residents, but demonstrate significantly lower utilization rates (Barbosa et al., 2007; Nicole, 2013). Moreover, differing use rates have been found when comparing urban and suburban greenways, with perceptions of crime risk along the corridor being cited as a barrier to use in urban areas (Keith et al., 2018; Nicholls and Crompton, 2005). These conflicting results leave unanswered questions of who benefits from greenway construction and expansion.

Between 2010 and 2015 Wake County, North Carolina and the city of Raleigh added 65 miles of greenway, more than doubling the size of the area's greenway system. Greenways in and around Raleigh are often constructed in flood plains or areas where local governments maintain utility easements, with the majority being built along streams and rivers. Two unique factors of the Raleigh greenway expansion help to identify how nearby residents' benefit. First, the greenway expansion took place in both high and low distress areas,[1] presenting an opportunity to evaluate the effect of greenway infrastructure expansion across heterogeneous populations. Second, most of the expansion took place in what was already undeveloped urban green space in riparian zones, resulting in significant public land use change. Through greenway construction the City of Raleigh and Wake County converted open space along rivers and streams to a recreation amenity.

Utilizing data on the timing of greenway construction and a repeated cross-section of property sales in Wake County, I estimate the capitalization effect resulting from land use change, converting open space to greenway within the hedonic framework. I find significant increases in home prices in low income areas after a greenway is constructed in previously unused open space. Furthermore, the magnitude of positive effects is largest in areas where open space was considered a disamenity prior to greenway construction. That is, undesirable areas become desirable after the greenway is completed. There is less evidence of positive capitalization effects for greenways constructed in high income

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[1] An index of distress developed by Wake County, NC is used to understand which communities are facing constraint, details of the index are discussed in Section 2.

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areas. Moreover, evidence points to greenway construction resulting in negative values for nearby properties. Impacts of greenway construction range from − 4–10% and is inversely related to some measures of distress and pre-greenway open space valuation.

Much of the existing research measures greenway values in a revealed preference framework, often using hedonic methods and a single cross section of data to evaluate WTP and capitalization effects, however, recent research has sought to uncover how these facilities are valued heterogeneously across communities (Asabere and Huffman, 2009; Campbell et al., 2007; Connolly et al., 2019; Crompton, 2001; Dill and Carr, 2003; Gotschi, 2011; Klaiber and Smith, 2013). Greenways are multi-dimensional environmental amenities that generate many benefits including conservation and recreation (Dill and Carr, 2003; Krizek et al., 2007; Lin et al., 2014). Expanding and improving environmental and recreation amenities, including parks, open space, trails and greenways is one tool used by municipalities to attract and retain residents. These amenities are increasingly cited by both businesses and individuals as central to their location decisions as cities work to fund and expand public infrastructure and recreation amenities. Additionally, urban growth models predict amenity levels to be a driver of population growth and urban parks have been found to have a direct effect on overall wellbeing (Duranton and Puga, 2014; Larson et al., 2016).

The perceived value of nearby amenities often influences the purchasing decisions of home buyers (Dill and Carr, 2003). Macy et al. (1995) find that 29% of single-family home buyers viewed access to recreational trails as an amenity, while 42% of town-home and condominium residents adjacent to a trail believed that the trail would increase their home's selling price; 17% of residents in the study were influenced by the trail to move to the area. The City of Raleigh, along with Wake County, continues to designate and develop multi-use greenways in hopes of realizing these benefits.

Other studies have found that greenways have a significant effect on surrounding properties but results have been mixed, suggesting heterogeneous effects across cities and neighborhoods (Lindsey et al., 2004; Nicholls and Crompton, 2005; Racca and Dhanju, 2006). Using an adaptive stated-preference survey coupled with a hedonic model, Krizek (2006) found that off-street cycling paths had a negative impact on home values in suburban areas but positive effects in urban areas. An Indianapolis, Indiana study using the hedonic framework found significant increases in property prices located near the Monon trail, selling for 14% more than comparable homes located further away (Lindsey et al., 2004). It is important to note that the same study found a negative, but insignificant, relationship for homes located within one-half mile of other trails, highlighting the potential for localized effects on property values. Noh (2019) finds evidence of property value increases in the period leading up to greenway construction, however the author finds a decrease in values after the greenway is constructed. Measuring the impacts of a planned greenway in Charlotte, North Carolina Campbell et al. (2007) found that there is a 0.03% premium for every one percent decrease in the distance from a planned greenway. After testing linear, exponential, and threshold spatial relationships, their model suggested a significant effect up to 5000 feet. It is important to consider that Campbell and Munroe were studying a greenway in the nascent planning stages, therefore the full value of the trail may not have capitalized into property values at the time of the study.

There is evidence of both positive and negative capitalization effects to be located near a greenway. A study of trails in Portland, Oregon found that a property located within 200 feet of a trail would, on average, sell for 6.8% less than a comparable property. The decrease was attributed to the trails in question being located in and around industrial and high crime areas, demonstrating an important econometric issue associated with hedonic price analysis, omitted variable bias (Netusil, 2005). When estimating the hedonic price surface unobserved property or neighborhood characteristics may influence property values, specifically unobserved neighborhood quality or confounding locally undesirable land use as in the Portland study.

To encourage greenway use, trails must be well maintained, easy to access and perceived as safe (Akar and Clifton, 2010; Boslaugh et al., 2004). Shafizadeh and Niemeier (1997) utilize an intercept survey to untangle the effects of trail perceptions on commuting decisions. Their research indicates that bike commuters are willing to travel farther to utilize off-street trails similar to those that make up the Capital Area Greenway System. Proper greenway design and maintenance can also encourage exercise and increase pedestrian and bike commuter mode share. Cities with a large and well-maintained greenway infrastructure experience higher rates of recreational use and commuting by bike (Dill and Carr, 2003). A study of the Burke-Gilman Trail in Seattle, Washington examined effects on property values and crime. The study found that increased crime and decreased property values were not a valid concern, in fact the opposite is true with decreases in crime happening in cases. Research to the contrary has indicated that multi-use trails help sell homes, increase property value and are perceived as an amenity (Lagerway and Puncochar, 1987; Wu and Rowe, 2022). These studies highlight how greenway design and maintenance can affect use values, given that greenways perceived as safe have higher use rates. It has been found that all greenways are not created equal and how values are capitalized depend on the design, connectivity and location of greenway infrastructure (Connolly et al., 2019).

Greenways offer an array of benefits. These can include recreation value, health benefits, improved ecosystem services and increased urban connectivity, however it is not consistently the case that individuals are willing to pay more for homes near greenways. Drawing from the literature on greenway and green space valuation I evaluate how changing land use from riparian open space to greenway affects property values. Furthermore, I estimate the heterogenous values associated with greenway construction, across income strata, in the Raleigh, NC area.

1.1. The capital area greenway system

The Capital Area Greenway System Master Plan was implemented in March 1974 with the goal of preserving open space in response to growth and urbanization in the Raleigh, NC area. The current version of the plan was adopted in 1989 and is gradually being implemented. Between 2010 and 2015 local governments added 65 miles of greenway to the Capital Area Greenway system. This expansion resulted in a system comprised of 28 individual trails with over 100 miles of greenway. The system connects parks, commercial areas, schools, museums and other areas of interest (City of Raleigh., 2017). In November 2014 voters approved a parks bond referendum, which included $15.4 million for greenway expansion and improvement and $10 million for land acquisition for parks and greenways. For the 2015 fiscal year, the City of Raleigh has earmarked $1.8 million for greenway improvements and maintenance (Mcfarlane et al., 2014).

The expansion of the Capital Area Greenway System from 2010 to 2015 offers an opportunity to apply hedonic methods in recovering the capitalization effects of an expansion across diverse neighborhoods in an attempt to understand the effects of an expanding system across several dimensions. The greenways displayed in Fig. 1 constitute the majority of the expansion of the system, accounting for over 40 of the 65 miles of trail added between 2010 and 2015. The House Creek, Neuse river, Crabtree Creek, Walnut Creek and Mingo Creek greenways, part of the Neuse River system, expanded significantly during this period.

The northernmost 6.5 miles of the Neuse River greenway were completed in November 2011, with the final one-mile stretch being completed in early 2015, connecting the southern 20 miles to the northern 6.5 miles. The most recent large greenway to be completed, Walnut Creek, was finished in February 2015 and connects areas of southeast Raleigh to downtown. Among the greenways completed since 2010, there is significant variation in the areas that they connect and heterogeneity among the populations, in both race and income, located near the trails. For the purposes of this analysis I examine the nine greenways completed between 2005 and 2010.

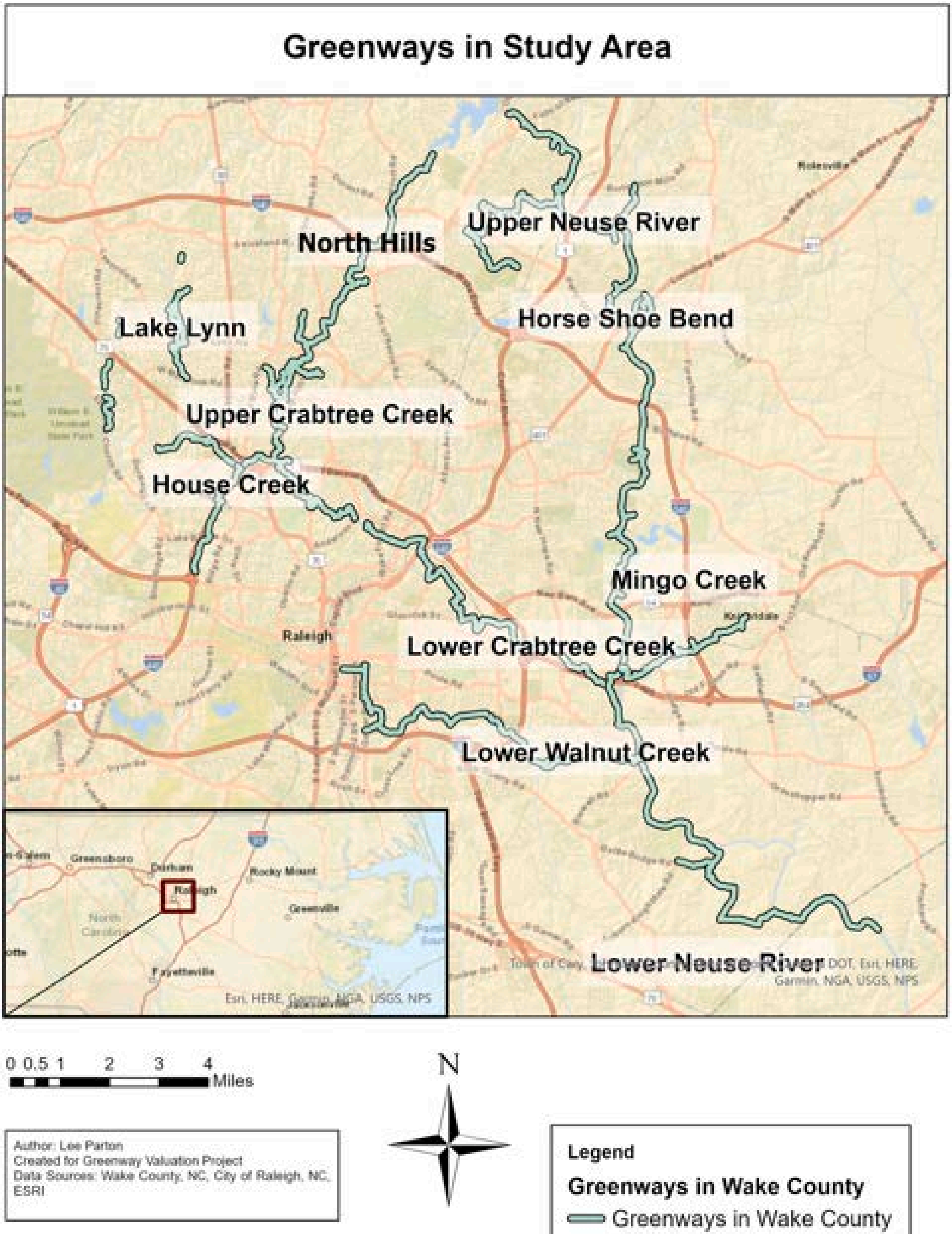

Fig. 1. Greenways In Study Area.

Fig. 2 illustrates the percentage of black resident by Census Block Group in Wake County. Block groups are U.S. Census Bureau geographies drawn to closely resemble neighborhoods and consist of 600–3000 residents. Upon completion in February 2015, the Walnut Creek Greenway established a pedestrian connection from Southeast Wake County to downtown Raleigh, serving as a connection between areas with heterogeneous populations and unemployment rates, as shown in Figs. 2, 4, 5 and 6.

The expansion of greenway system from 2010 to 2015 is shown in Fig. 3. The variation across greenway types, i.e., greenways that connect neighborhoods with downtown or other commercial areas, versus those that do not, offers the opportunity to understand how greenways are valued across space and strata.

2. Data

Data for this study have been gathered from three primary sources: The City of Raleigh, the Wake County Assessor's Office, and the U.S. Census Bureau. Property sales data from January 1st, 2006 to June 1st, 2015 have been obtained from the Wake County Assessor's Office. These data include sale price, square footage, age, assessor property grade factor,[2] construction characteristics[3] and home style. Summary statistics for Sale Price, Sqft, Bathrooms, Lot Size, Assessor Grade and Age for homes located within 5000 feet of the nine trails developed during the sample period are displayed in Tables 1 and 2. Date are screened for arm's length residential transactions.

Tables 1 and 2 include summary statistics for the 2010 ACS Distress Index utilized by Wake County to measure socioeconomic stressors in each of the 455 census block groups (BGs) located within the county. The ACS Distress score is calculated by ranking the 455 Census BGs across five dimensions, including unemployment, poverty, no high school diploma, non-working age population and housing vacancies. The five categories rankings are summed to construct the ACS Score with the lowest score indicating the least distressed block group, i.e., the best possible score is (5 *1) and the worst possible score is (5 *455). The BG index serves as a measure of "distress"' for city planners with a rank of one being the least distressed and a rank of 455 being the most distressed. As shown in Fig. 5, darker BGs represent more distressed areas, it is important to note that the ACS index applies equal weight to all five measures.

GIS data on greenways and residential parcels were downloaded as ArcGIS shape files, which describe the length, location and type of greenway along with locational property characteristics. The greenway designation can have many different interpretations. For this study, a greenway must have a trail that can be used for recreation. Trails may be paved, hard pack gravel, or dirt. Wake County defines trails and greenways as follows;

"Trails can be categorized as either park trails or connector trails. Park trails are generally contained within one park area. Connector trails serve a different purpose; they run between parks and other recreation facilities, thus connecting them and creating a system that is accessible from many different points. Similar to trails in that they connect parks, greenways normally exist parallel to other resources in the environment, such as rivers and boulevards." In keeping with this definition, analysis is performed on greenways and trails as defined above.

Data on construction timing for nine of the 28 trails in the Capital Area Greenway System have been compiled and include observations on proposal date, approval date, construction start date and completion date for several greenway segments, unfortunately completion date is the only consistent construction measure across all nine trails during the expansion. While expansion occurred with the development of nine trails during this period, I use the existing trails to control for greenway amenities across the county. In the context of my identification strategy and the timing of greenway construction, it is important to note that trail entrances generally remain closed until construction is complete. Furthermore, the greenway expansion from 2005 to 2015 follows the greenway master plan established in 1989. This information, provided by the City of Raleigh, will serve as the foundation for identifying the effects of greenway construction.

GIS data procured from Wake County also includes the location of each parcel in the county. Demographic information at the Census block group level was obtain through the U.S. Census Bureau and through data aggregated by ESRI. Demographic variables include, but are not limited to, median household income, race, employment and educational attainment.

Significant socioeconomic and demographic variation is evidenced in Fig. 4 displaying the ACS Distress Index rank of each block group Fig. 6 presents the percentage of the population living in poverty by Block Group, demonstrating heterogeneity among households located near trails. The Lower Crabtree Creek, Lower Walnut Creek and Lower Neuse River Trails traverse neighborhoods with higher poverty rates.

Combining demographic, spatial, property and greenway construction timing data, I analyze the effects of greenway construction and expansion on property values across different socioeconomic strata and geographic areas.

3. Methods

To develop an initial understanding of the relationship between property values and greenways, a hedonic analysis was undertaken. Consider the following model,

$$p_{it} = \alpha + X_{it}'\beta + \sum_{j=1}^{16} \delta_j D_{ijt} + \sum_{j=1}^{16} \zeta_{jt} D_{ijt} Post_{jt} + \phi_m BG_m + \delta_t Y_t + \epsilon_{it},$$

Equation 1: Property Value Hedonicwhere $\boldsymbol{X_{it}}$ is a vector of structural characteristics for the $\boldsymbol{i^{th}}$ sale in year $\boldsymbol{t}$, $\mathbf{D_{ijt}}$ is a measure of distance from each of the 16 greenways, existing or to be constructed during the sample period, $\boldsymbol{Post_{jt}} = 1$ for all sales occurring after a greenway $\boldsymbol{j}$ is completed, $\boldsymbol{BG}_m$ is a Census Block Group fixed effect and $\boldsymbol{Year_t}$ is an annual fixed effect. This specification serves as a starting point for analyzing a single cross section of sales in a given time period.

We are interested in the coefficients for distance ($\boldsymbol{D_{ijt}}$) and the distance-existence interaction ($\boldsymbol{D_{ijt}}$ $\boldsymbol{Post_{jt}}$). The distance variable ($\boldsymbol{D_{ijt}}$) identifies the capitalization effect of being located near public open space before the greenway is constructed. Because greenways are often constructed along streams, rivers, or in existing parks and open space, it is necessary to disentangle the effect of a greenway from existing land use. The interaction term ($\boldsymbol{D_{ijt}}$ $\boldsymbol{Post_{jt}}$) captures the greenway effect and allows us to disentangle open space and greenway values.

The effect of distance to trails can be specified in one of two ways. First, $\boldsymbol{D_{ijt}}$ can enter linearly as in Equation 1. Alternatively, the distance effect can be measured as a set of distance bins such as $\sum_{k=1}^{K-1}\sum_{j=1}^{16}\theta_{kj}d_{ijt}^k$, where $\boldsymbol{k}$ denotes a given distance range. Consider,

$$p_{it} = \alpha + X_{it}'\beta + \sum_{k=1}^{K-1}\sum_{j=1}^{16} \theta_{kj} d_{ijt}^k + \sum_{k=1}^{K-1}\sum_{j=1}^{16} \xi_{jk} d_{ijt}^k Post_{jt} + \delta_t Y_t + \phi_m BG_m + \epsilon_{it}$$

Equation 2: Distance Bin Specificationwhere,

$$d_{ijt}^1 = \begin{cases} 1 \, if \, D_{ijt} \in [0, 500] \\ 0 otherwise \end{cases}$$

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[2] The county assessor assigns a quality grade to each property, this measure is designed to estimate replacement cost of a given home and is indicative of the quality of the property.

[3] Construction characteristics include building materials such as stick built, brick, modular, etc. Home style includes a set of indicators for conventional, split level, colonial, contemporary etc. These characteristics are used for adjustments to the base assessment rate.

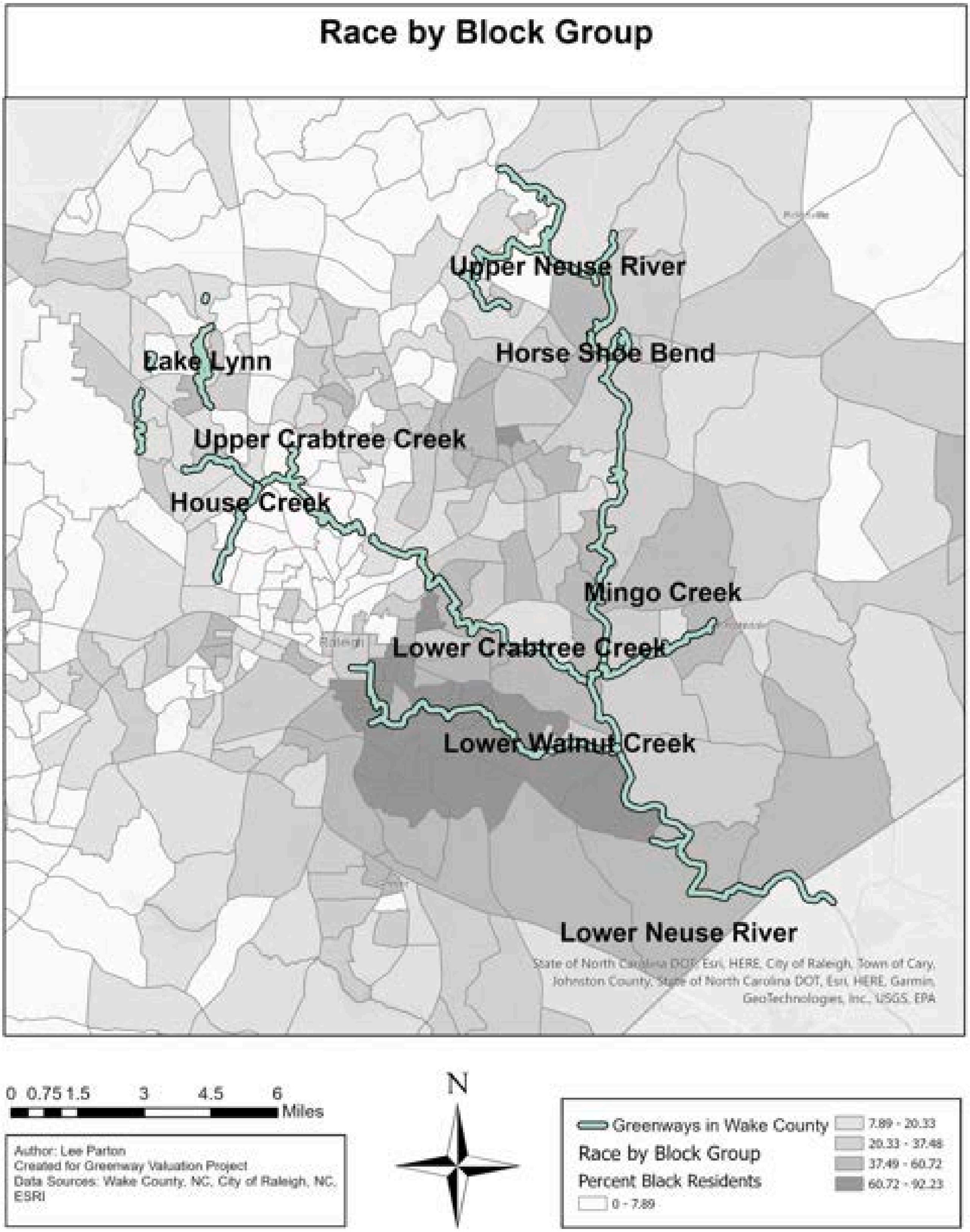

Fig. 2. Percentage of Black Residents by Block Group.

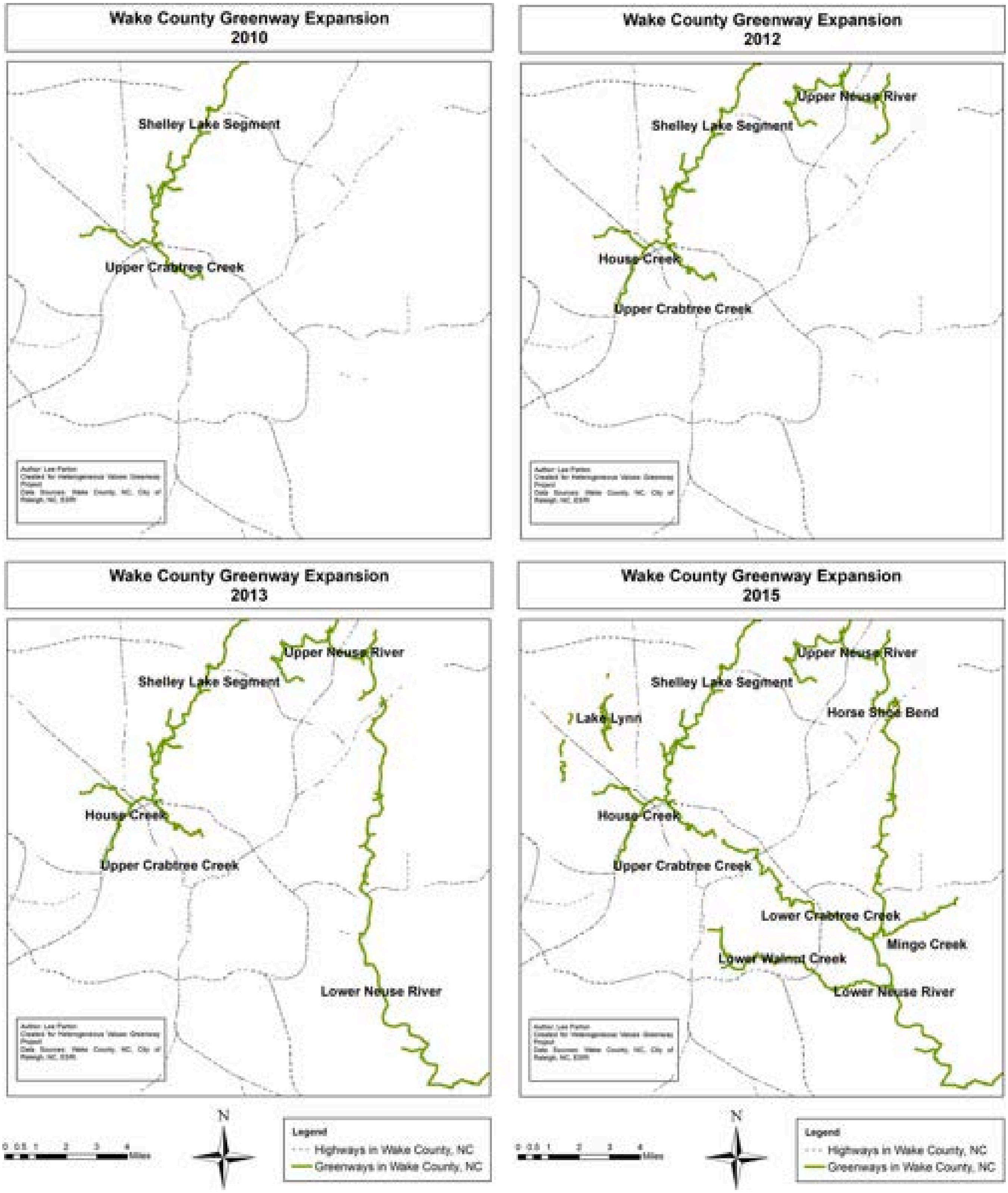

Fig. 3. Greenway Expansion.

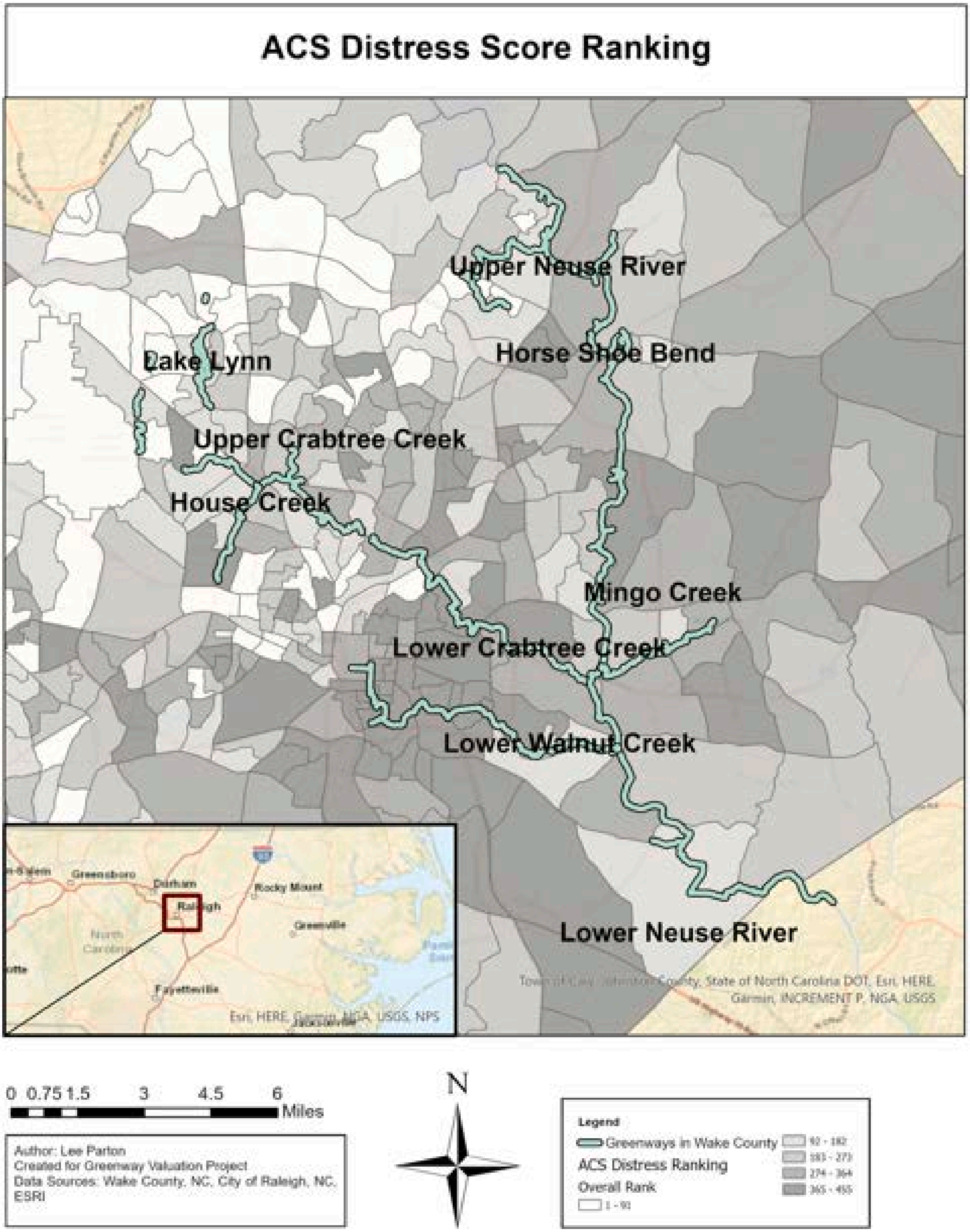

Fig. 4. ACS Distress Index Total Score by Census Block Group. Each BG was ranked from 1 to 455 across unemployment, poverty, no high school diploma, non-working age population and housing vacancies. The rankings across all five categories are then summed to construct the ACS Score, i.e., the best possible score is (5 *1) and the worst possible score is (5 *455).

Table 1
Descriptive Statistics.

Summary Statistics by Nearest Trail - Within 5000 ft	Lower Crabtree	Lower Walnut	Lower Neuse	Upper Crabtree	Upper Neuse	Lynne Rd
Sale Price	260292.7	221151.2	265493.4	372744.9	295336.9	318810.1
	(85985.4)	(95701.2)	(93754.8)	(140061.7)	(178123.2)	(125265.5)
Sqft	2187.7	1890.8	2222.9	2919.8	2318.7	2651.8
	(717.2)	(683.5)	(669.5)	(905.7)	(1131.7)	(941.4)
Bathrooms	2.523	2.340	2.561	2.946	2.570	2.804
	(0.538)	(0.453)	(0.485)	(0.719)	(0.891)	(0.660)
Lot Size (Acres)	0.255	0.348	0.270	0.537	0.282	0.329
	(0.322)	(0.154)	(0.232)	(0.621)	(0.298)	(0.618)
Assessor Grade	1.377	1.188	1.299	1.506	1.481	1.408
	(5.572)	(0.190)	(0.204)	(0.302)	(6.850)	(0.271)
Age	11.70	29.94	16.81	11.64	18.86	11.04
	(31.53)	(80.30)	(7.340)	(9.747)	(51.83)	(12.46)
ACS No Diploma Rank	124.0	177.5	130.1	179.2	158.8	142.3
	(88.10)	(84.29)	(58.44)	(86.44)	(97.34)	(35.93)
ACS Total Age Rank	301.9	200.2	203.6	236.7	177.2	159.2
	(93.82)	(105.2)	(75.36)	(51.96)	(98.98)	(44.35)
ACS Poverty Rank	102.7	147.1	112.6	159.2	155.9	155.7
	(77.99)	(73.72)	(71.25)	(78.41)	(80.94)	(23.27)
ACS Unemp Rank	252.7	179.3	159.1	246.0	195.9	214.3
	(82.78)	(58.08)	(110.3)	(109.0)	(114.3)	(46.00)
ACS Home Vacancy Rank	192.6	98.34	170.0	214.2	210.3	170.0
	(73.02)	(81.79)	(71.87)	(135.0)	(110.7)	(63.69)
Total ACS Distress Score	170.6	84.54	94.65	198.3	132.3	100.1
	(81.81)	(27.76)	(61.35)	(143.7)	(80.96)	(49.67)
Observations	4822	615	1752	1926	3194	690

Mean coefficients; standard deviation in parentheses

Table 2
Descriptive Statistics Cont.

Summary Statistics	By Nearest Trail - Within 5000 ft			All Sales
	House Creek	Horse Shoe	Mingo Creek	Wake County
Sale Price	249517.1	171051.4	326799.4	261680.2
	(135628.1)	(46758.4)	(143563.2)	(136042.4)
Sqft	2056.1	1610.3	2687.8	2255.0
	(910.9)	(450.0)	(927.4)	(907.1)
Bathrooms	2.345	2.033	2.743	2.543
	(0.556)	(0.525)	(0.647)	(0.698)
Lot Size (Acres)	0.298	0.301	0.298	0.391
	(0.321)	(0.178)	(0.235)	(0.750)
Assessor Grade	1.222	1.088	1.368	1.554
	(0.176)	(0.0655)	(0.282)	(10.40)
Age	26.07	36.65	12.18	14.89
	(79.51)	(15.40)	(12.64)	(30.86)
ACS No Diploma Rank	185.2	257.8	203.9	212.5
	(84.51)	(99.87)	(115.4)	(111.7)
ACS Total Age Rank	272.5	278.7	137.8	255.1
	(149.9)	(140.5)	(91.20)	(115.5)
ACS Poverty Rank	152.6	279.5	181.1	201.9
	(86.98)	(68.57)	(61.41)	(112.1)
ACS Unemployment Rank	129.7	231.2	296.6	229.7
	(102.0)	(127.3)	(79.05)	(119.6)
ACS Housing Vacancy Rank	235.5	201.2	52.59	221.3
	(145.9)	(108.5)	(71.47)	(115.4)
Total ACS Distress Score	163.1	270.0	111.9	222.5
	(97.93)	(122.1)	(8.694)	(116.4)
Observations	1261	726	618	153544

Mean coefficients; standard deviation in parentheses

$$d_{ijt}^{2} = \begin{cases} 1 if D_{ijt} \in [500, 1000] \\ 0 otherwise \end{cases}$$

$$\vdots$$

$$d_{ijt}^{K} = \begin{cases} 1 if D_{ijt} \in [5000, \infty] \\ 0 otherwise \end{cases}$$

where the excluded category contains properties beyond 5000 ft and $\boldsymbol{Y_t}$ is the year fixed effect.

This specification allows for non-linearities in distance from a greenway and the ability to test several distance specifications. Previous research has found that the effect of greenways and open space on property values becomes unmeasurable beyond a distance of 5000 ft (Lindsey et al., 2004). Therefore 5000 ft will serve as the cutoff for categorical distance measures. See online appendix A.1 for a data driven

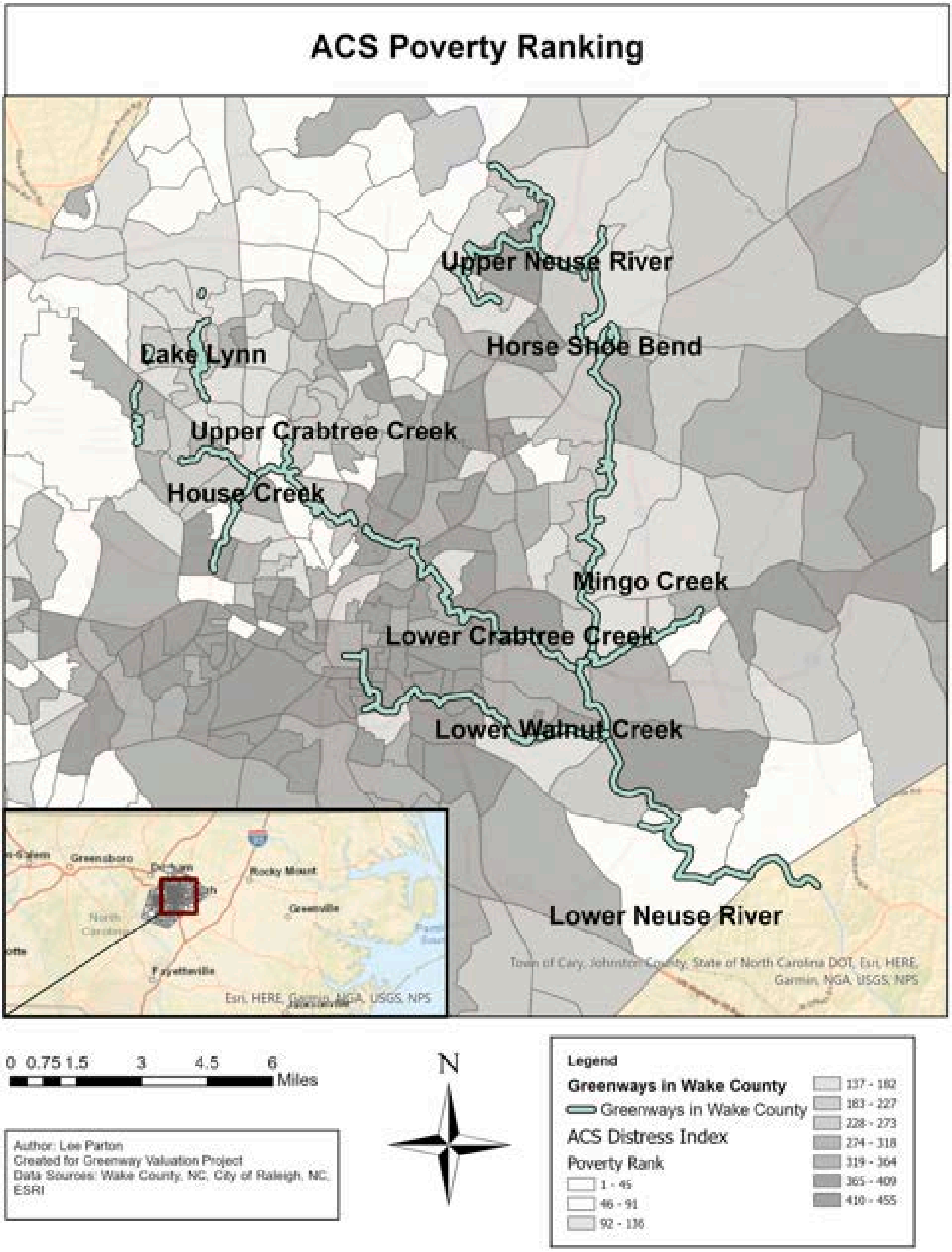

Fig. 5. ACS Distress Index – Poverty.

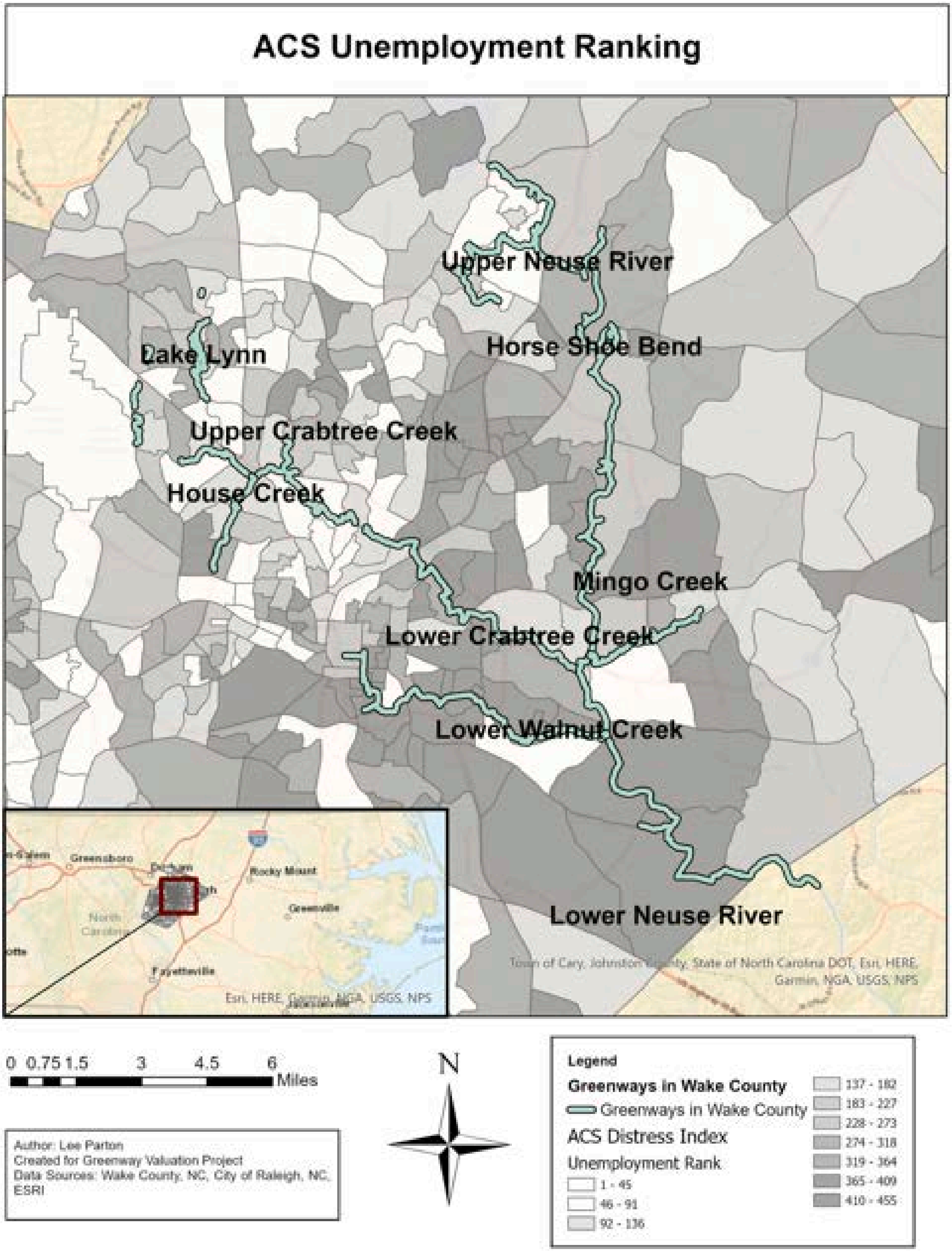

Fig. 6. ACS Distress Index - Unemployment.

Table 3
Distance Bins.

Distance Bins	
D_1	$\in [0, 500]$
D_2	$\in [501, 1000]$
D_3	$\in [1001, 2000]$
D_4	$\in [2001, 3000]$
D_5	$\in [3001, 4000]$
D_6	$\in [4001, 5000]$
D_7	≥ 5001

approach in choosing distance bins. Following previous literature and the analysis in Appendix A.1, I define distance bins as displayed in Table 3. The interaction between the distance and post trail variables is the primary vehicle through which I draw inferences about the effects of public land use change.

4. Results

Tables 4 and 5 contain the results from estimating Equation 2 using all residential transactions in Wake County, NC, with distance to greenway measured with bins as defined in Appendix A.1. *Ln (Sale Price)* is the dependent variable, allowing regression coefficients to be interpreted as semi-elasticities. Distance bin coefficients are interpreted as the approximate percent change in sale price as the result of moving a given property from beyond 5000 ft to within the given trail distance bin. As noted in Halvorsen and Palmquist (1980) dummy variable coefficients in semilogarithmic equations approximate relative effects only for small coefficient values, with the potential to overstate the magnitude of negative effects and understate the magnitude of positive effects. All coefficient estimates for distance indicators are less than 0.20, therefore are assumed to closely approximate relative effects on *Ln (Sale Price)*. Furthermore, it is important to note that while regression results

Table 4
Results by Trail.

Greenways Near Higher Distress Areas						
	Lower Crabtree		Lower Walnut		Lower Neuse	
Coefficient	Distance	(Dist)* (PostTrail)	Distance	(Dist)* (PostTrail)	Distance	(Dist)* (PostTrail)
0–500 ft	-0.0171 *	0.0310 *	-0.0571 **	0.0495 *	-0.0466 ***	0.0175
	(0.01)	(0.02)	(0.03)	(0.03)	(0.01)	(0.02)
501–1000 ft	-0.0300 ***	0.0495 **	-0.0787 ***	0.0711 **	-0.0454 ***	0.0134
	(0.01)	(0.02)	(0.03)	(0.03)	(0.01)	(0.01)
1001–2000 ft	-0.0460 ***	0.0960 ***	-0.0830 ***	-0.0049	-0.0336 ***	0.0269 **
	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)
2001–3000 ft	-0.0546 ***	0.00605	-0.0648 ***	0.0176	-0.0167 *	0.0126
	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)
3001–4000 ft	-0.0491 ***	0.0372	-0.0662 ***	-0.0166	0.00929	0.0123
	(0.01)	(0.04)	(0.01)	(0.02)	(0.01)	(0.01)
4001–5000 ft	-0.0205 ***	0.0741 ***	-0.0382 ***	-0.00984	0.0166 **	0.0242 **
	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)
Greenways Near Lower Distress Areas						
	Upper Crabtree		**Upper Neuse River**		**North Hills**	
Coefficient	**Distance**	**(Dist)* (PostTrail)**	**Distance**	**(Dist)* (PostTrail)**	**Distance**	**(Dist)* (PostTrail)**
0–500 ft	0.144 ***	-0.0426 *	-0.0113	0.00748	0.0272	-0.0737
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.07)
501–1000 ft	0.0251	0.0161	0.0109	0.00297	0.0258	-0.00979
	(0.03)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)
1001–2000 ft	0.0560 ***	-0.0375 *	-0.0162	0.00147	-0.00193	-0.012
	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)
2001–3000 ft	0.0474 ***	-0.0326 **	-0.0161	0.0331 **	-0.011	0.0300 **
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
3001–4000 ft	0.0384 ***	-0.00487	0.00785	0.0422 *	-0.00981	0.0534 ***
	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)
4001–5000 ft	0.0473 ***	0.00282	0.0263	0.0262	-0.0219 ***	0.0802 ***
	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)
Greenways Near Other Expansion Areas						
	Horse Shoe Bend		**Mingo Creek**		**House Creek**	
Coefficient	**Distance**	**(Dist)* (PostTrail)**	**Distance**	**(Dist)* (PostTrail)**	**Distance**	**(Dist)* (PostTrail)**
0–500 ft	-0.142 ***	-0.00507	0.122 ***	-0.0448	-0.141 ***	0.013
	(0.03)	(0.06)	(0.03)	(0.06)	(0.02)	(0.03)
501–1000 ft	-0.132 ***	-0.0617	-0.00773	0.0912 ***	-0.120 ***	0.0554 ***
	(0.03)	(0.04)	(0.02)	(0.03)	(0.02)	(0.02)
1001–2000 ft	-0.0151	0.123 ***	-0.115 ***	0.0325	-0.0548 **	0.0360 *
	(0.02)	(0.05)	(0.02)	(0.02)	(0.02)	(0.02)
2001–3000 ft	-0.0261 *	-0.00796	-0.0967 ***	0.00827	-0.104 ***	0.0648 ***
	(0.02)	(0.05)	(0.01)	(0.02)	(0.02)	(0.02)
3001–4000 ft	0.0118	0.0206	-0.0316 **	0.0111	-0.0121	0.0378 **
	(0.01)	(0.05)	(0.01)	(0.02)	(0.01)	(0.02)
4001–5000 ft	0.0159	0.105 ***	-0.0199 *	-0.00935	0.00519	0.0459 ***
	(0.01)	(0.04)	(0.01)	(0.02)	(0.01)	(0.01)

N = 153,455, Adjusted R-squared = 0.865
Cluster (Block Group) robust standard errors in (): * $p < 0.10$, * * $p < 0.05$, * ** $p < 0.01$

Table 5
Hedonic Regression Coefficients.

Hedonic Regression Coefficients	
Variable	Ln(SalePrice)
Sqft	0.000663 ***
	(0.0000)
Sqft^2	-5.79e-08 ***
	(0.0000)
Lot Size (Acres)	0.0578 ***
	(0.0042)
Lot Size (Acres)^2	-0.000520 *
	(0.0003)
Assessor Grade	-0.0000261
	(0.0001)
Age	-0.00540 ***
	(0.0001)
Age^2	0.00000264 ***
	(0.0000)
Construction Type Indicators	Y
Home Style Indicators	Y
Block Group Fixed Effects	Y
Year Fixed Effect	Y

N = 153455, Adjusted R-squared = 0.865
Cluster (Block Group) robust standard errors in (): *p < 0.10, * *p < 0.05, * **p < 0.01

Table 6
Linear Distance Regression.

Linear Distance Specification	
Variable	Ln(Sale Price)
Lower Crabtree Dist	-0.0000231 ***
	(0.00000183)
Post Trail 1 * Lower Crabtree Dist	-0.000000268 **
	(0.000000117)
House Creek Dist	0.00000990 **
	(0.00000469)
Post Trail 2 * House Creek Dist	0.000000355 ***
	(9.77e-08)
Upper Crabtree Dist	-0.0000157 ***
	(0.00000103)
Post Trail 3 * Upper Crabtree Dist	0.000000278 ***
	(6.94e-08)
Upper Neuse Dist	-0.00000803 ***
	(0.00000171)
Post Trail 4 * Upper Neuse Dist	-0.000000834 ***
	(9.66e-08)
Horse Shoe Dist	0.00000191
	(0.00000397)
Post Trail 5 * Horse Shoe GW	4.17e-08
	(0.000000159)
Lower Neuse Dist	-0.00000809 ***
	(0.00000227)
Post Trail 6 * Lower Neuse Dist	0.000000112
	(7.64e-08)
Lower Walnut Dist	-4.76e-08
	(0.00000566)
Post Trail 7 * Lower Walnut Dist	-0.000000205 **
	(8.49e-08)
Mingo Creek Dist	0.0000299 ***
	(0.00000506)
Post Trail 8 * Mingo Creek Dist	9.86e-09
	(7.56e-08)
Lynn Rd Dist	0.00000606 **
	(0.00000304)
Post Trail 9 * Lynn Rd Dist	-0.000000708 ***
	(6.55e-08)
Block Group FE	Y
Year FE	Y
Observations	153544
Adjusted R-squared	0.866

Cluster robust (Block Group) standard errors in ()
* p < 0.10, * * p < 0.05, * ** p < 0.0

are presented by greenway, the sample includes all transactions with distances measured from each property to each trail (Table 6).

Results across a subset of low and high distress areas are presented in Table 5 which corresponds to Figs. 7 and 8. The variable (*Distance*) is an indicator of the distance bin from each home to each greenway and where *PostTrail= 1* after the greenway is completed and opened. Coefficient estimates for other variables used in the analysis are given in Table 4. The hedonic model offers significant explanatory power with an adjusted R-squared of 0.865 and several interesting effects are observed in the model. Results presented in Table 4 and the associated figures are from a single specification (Equation 2) with distance from each transaction to each greenway in Wake County included.[4]

The effect of greenway construction along the Lower Crabtree Creek, Lower Walnut Creek and Lower Neuse River corridors is displayed in Table 5 (top panel). These trails traverse neighborhoods generally considered to be of higher distress rates as shown in Figs. 4, 5 and 6. *(Distance)* represents the capitalization effect associated with being located near the corridor before the greenway is completed, while *(Distance)* * *(PostTrail)* plots the marginal effect of the land use conversion.

Examining the Lower Crabtree Creek Trail, prior to greenway construction there is no capitalized amenity effect for homes located within 500 feet the Crabtree Creek riparian zone, with negative amenity values being found for properties located between 500 and 5000 feet from Lower Crabtree Creek. After greenway completion there is a significant increase in property values ranging from 3.1% to 9.6%. In this case the positive effect of the newly constructed greenway dominates the disamenity values in the pre-construction period. The net effect of living near the greenway can be measured as the sum of the coefficients for *(Distance)* and *(Distance)* * *(PostTrail)* shown in Table 5 (Fig. 7). While counterintuitive that the positive effect increases as distance increases, given that the greenway is an amenity, this may be indicative of residents valuing access more than proximity when a trail is constructed and is consistent with concerns of reduced privacy for properties adjacent to a trail.

A similar pattern is observed for homes very close to the Lower Walnut Creek. Disamenity values are observed for homes within 4000 feet of lower Walnut Creek before the greenway exists. After greenway construction homes very close to the trail, between zero and 1000 feet, experience a significant increase in values ranging from 3.8% to 8.3%, with trail completion having no effect on home prices beyond 1000 feet. This indicates significant capitalization for the land use conversion from open space to greenway for homes located very near the greenway. While the effect exhibits a similar pattern to the Lower Crabtree Creek trail results are insignificant results at further distances. This may be the result of adjacency conveying benefits, such as reduced crime, that do not affect the broader neighborhood. More research is required to untangle these effects. Evaluating the Lower Neuse River Trail similar patterns emerge albeit with less statistical significance. There is possible evidence access being valued with positive capitalization effects in the 1000–3000-foot range.

The Upper Crabtree Creek trail, which traverses lower distress neighborhoods, capitalization patterns are opposite of those found along the Lower Crabtree and Lower Walnut Creek trails. Capitalization estimates prior to greenway construction are positive and significant (Fig. 7 and Table 5), suggesting that homeowners value houses along the creek before the greenway is constructed. After the trail is completed significant disamenity values are realized, particularly for homes located

[4] Recent debates in the hedonic literature have questioned the ability of first stage hedonic analysis to recover marginal willingness to pay (Kuminoff and Pope, 2014), however in the context of difference-in-differences it is sufficient for recovering a lower bound on Hicksian surplus (Banzhaf, 2021). Given the limitations of this analysis I consider the estimates to be capitalization effects as per (Kuminoff and Pope, 2014).

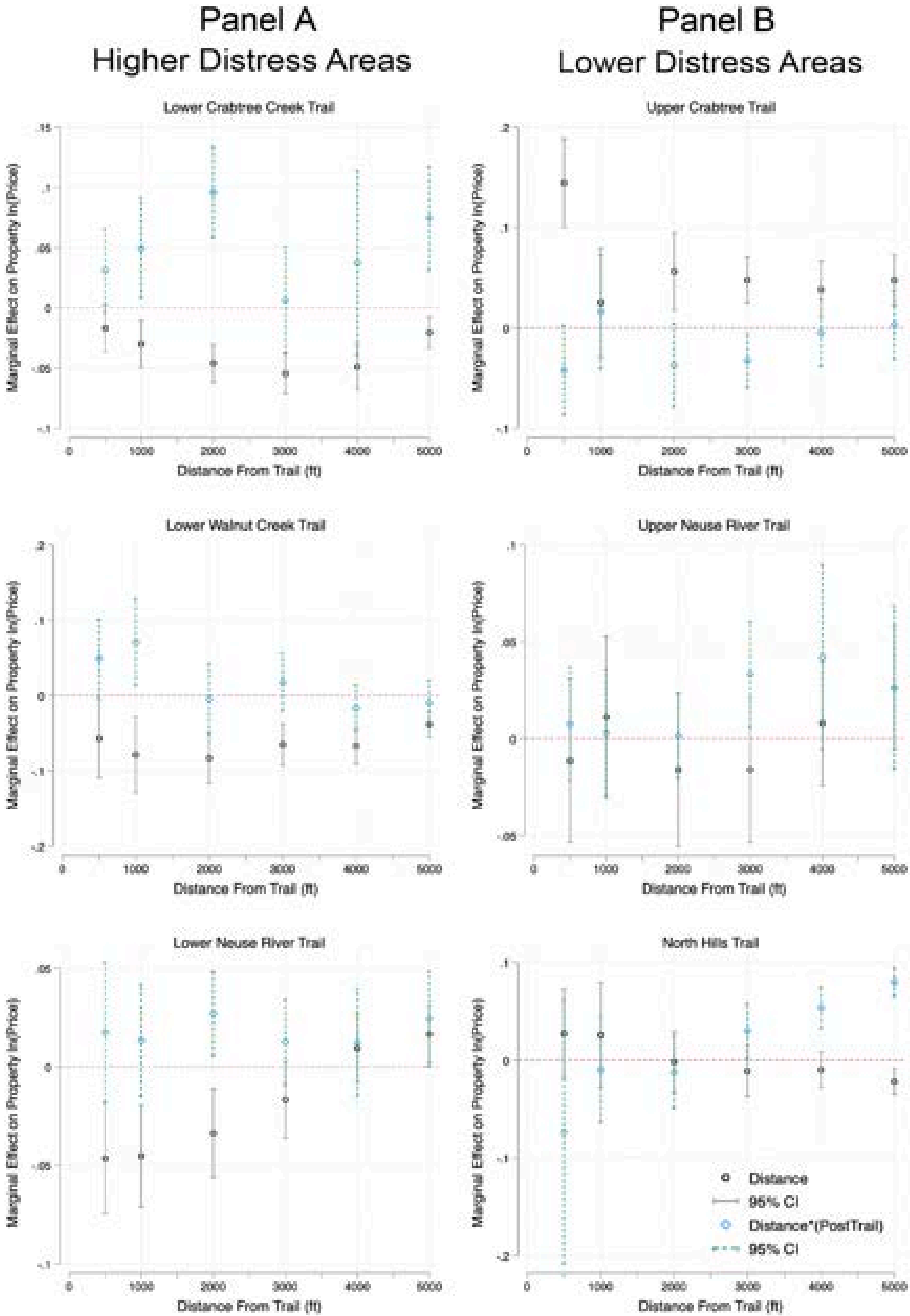

Fig. 7. Capitalization Effects Near Expansion Greenways.

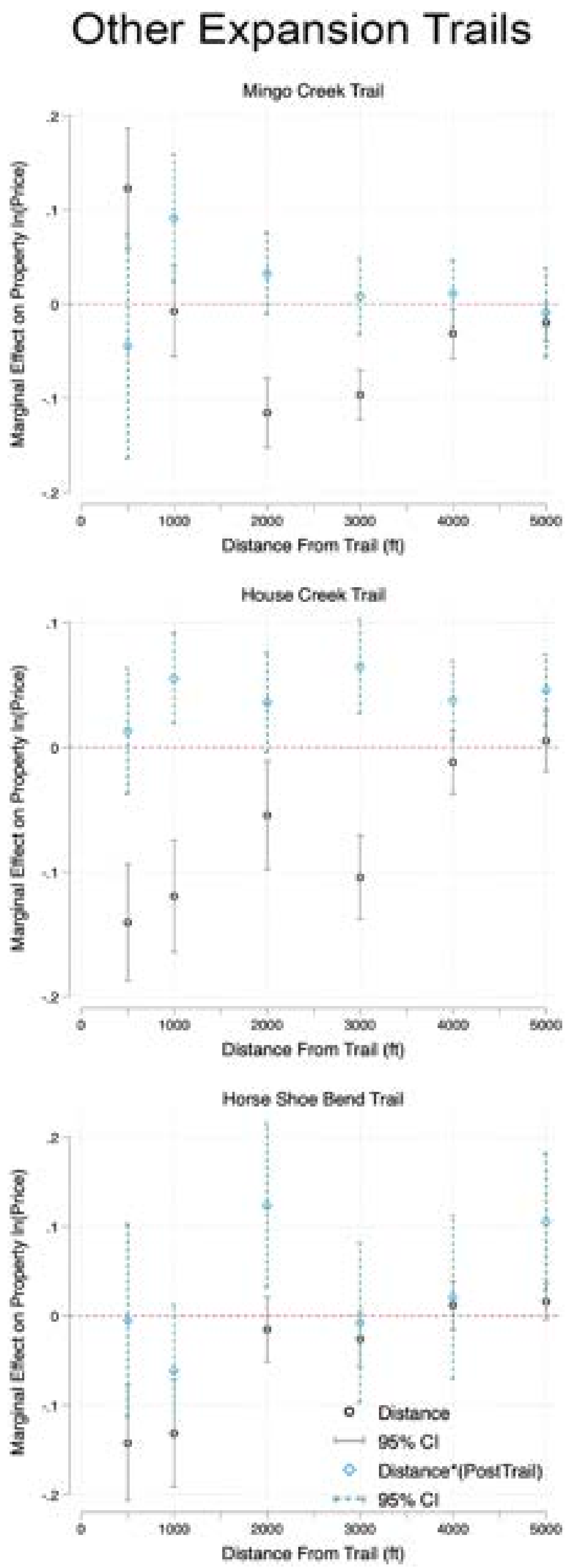

Fig. 8. Marginal Effects in Other Areas.

within 500 feet of the trail. Along the Upper Neuse River (Fig. 7 second panel) trail construction has no measurable effect for properties located within 2000 feet of the trail, with some evidence of price increases for homes located in the 3000–5000-foot zone. Lastly, the North Hills Trail estimates indicate significant amenity values are realized for homes within 1000 feet of the trail in the post-construction period, with no significant effects beyond this distance.

Differences in capitalization effects resulting from greenway construction offer evidence of heterogeneous values across space and socioeconomic status which can be highly localized. Despite the evidence presented it is unclear what mechanism is driving heterogeneity. Drawing from local market knowledge and through discussions with City and County Officials there are several potential mechanisms through which these outcomes could be realized and further research is needed to untangle these effects.

First, in distressed neighborhoods there has historically been undesirable land use along riparian corridors. These areas are largely unmaintained public land or rights of way containing streams, often with low water quality, or infrastructure easements for sewer, water and utility lines. Furthermore, these areas were unpoliced, unmaintained and unusable for recreation. Converting previously undesirable land to a linear park with connections to a larger greenway system is a significant amenity change for distressed neighborhoods. In addition to use value, greenway construction may result in a reduction in crime along the corridor, caused by an increase in foot and recreation traffic in previously distressed green space. Furthermore, increased transportation opportunities and connectivity can result in higher capitalization effects, as found by Connolly et al. (2019). Additionally, changes in neighborhood amenities could result in property value increases through gentrification or investor purchases in distressed neighborhoods. Understanding these effects requires future work, potentially with the estimation of equilibrium sorting models or the use of other structural methods in a second stage hedonic analysis. Second, low distress areas with higher baseline levels of recreation and outdoor amenities may realize smaller capitalization effects from greenways owing to diminishing marginal returns to these amenities. Additionally, anecdotal evidence suggests that riparian corridors and public spaces in low distress neighborhoods are better maintained, resulting in less value being added by greenway development.

Lastly, I find limited evidence that disamenity values may exist in low distress areas for homes very close to the greenway. This effect points to potential NIMBY effects and homeowners have anecdotally resisted greenway development when their property is adjacent to a proposed greenway, citing reduced privacy and enjoyment of their property. While the mechanisms remain unclear, this analysis presents strong evidence of heterogeneous effects and highlights the need for further investigation of how these facilities are valued.

4.1. *Robustness checks*

4.1.1. *Parallel trends*

Identification in a difference-in-differences estimation requires parallel trends of treatment and control groups in the pre-treatment period. Fig. 9 plots quality differentiated price trend for all sales that occurred within 5000 feet of a to be constructed greenway (Treated) and those beyond 5000 feet of a greenway (Control). Following (Bakkensen et al., 2019) we estimate a hedonic regression using our primary specification without the *Post Trail* interaction then plot the residuals from the regression for transactions within 5000 ft of a greenway and those beyond 5000 ft. While it is difficult to evaluate parallel trends given the varying construction timing, Fig. 9 plots trends pre and post-2010. Trends appear parallel prior to 2010 when the latest stage of greenway construction began.

4.1.2. *Alternative specification with linear distance*

To assess the robustness of the semi-parametric specification I

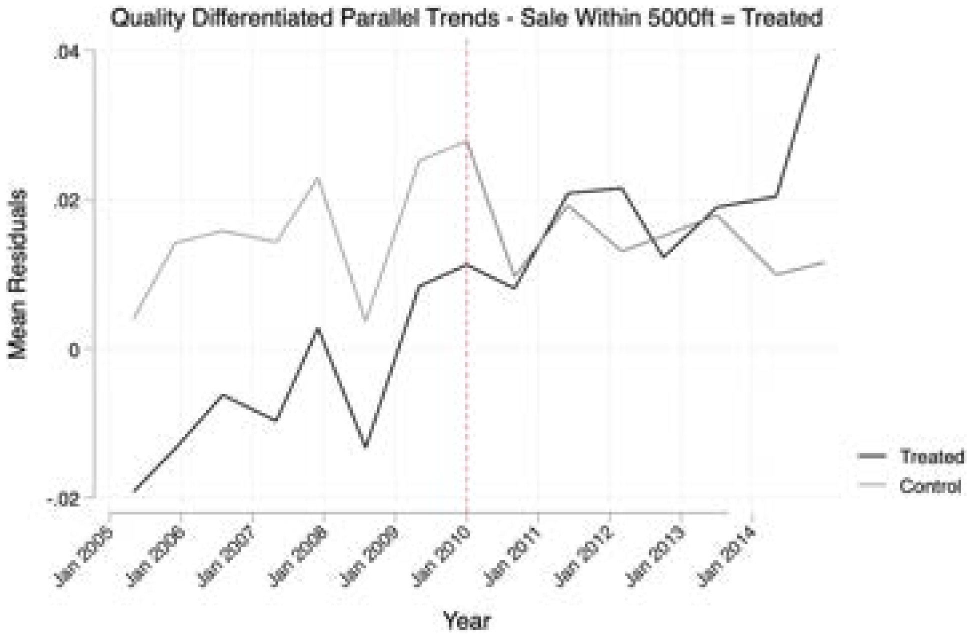

Fig. 9. Parallel Trends Graph.

Table A1
OLS Distance Bin Analysis.

Model 1		Model 2	
Ln(Sale Price)	500 ft increments	Ln(Sale Price)	1000 ft increments
log(Sale Price)	500 ft increments	log(Sale Price)	1000 ft increments
Heated Area	0.0003 ***	Heated Area	0.0003 ***
	(0.000)		0.000
Deeded Acreage	0.0268 ***	Deeded Acreage	0.0268 ***
	(0.0063)		(0.006)
Bathrooms	0.104 ***	Bathrooms	0.104 ***
	(0.003)		(0.003)
Age	-0.0007 ***	Age	-0.0007 ***
	(0.0001)		(0.000)
0–500 ft	0.0370 ***	0–500 ft	0.0345 ***
	(0.0061)		(0.006)
500–1000 ft	0.0307 ***	500–1000 ft	0.0284 ***
	(0.0061)		(0.006)
1000–1500 ft	0.0341 ***	1000–2000 ft	0.0227 ***
	(0.0061)		(0.006)
1500–2000 ft	0.0107 *	2000–3000 ft	0.002
	(0.0059)		(0.005)
2000–2500 ft	-0.0002	3000–4000 ft	0.0150 ***
	(0.0058)		(0.008)
2500–3000 ft	0.00449	4000–5000 ft	0.0150 * **
	(0.0059)		(0.005)
3000–3500 ft	0.0114 *		
	(0.006)		
3500–4500 ft	0.0180 ***		
	(0.0057)		
4000–4500 ft	0.0140 * *		
	(0.0057)		
4500–5000 ft	0.0156 ***		
	(0.0057)		

N = 153069, Adjusted R-squared = 0.841 (both models)
Robust standard errors in parentheses: * p < 0.10, * * p < 0.05, * ** p < 0.01

Table A2
Distance Bin F-Tests.

Model 1		Model 2	
Regression with 500 ft distance intervals		Regression with 1000 ft distance intervals (excl first category)	
H0:	F-stat	H0:	F-stat
500–1000 = 0	4.07 **	500–1000 = 0	3.75 *
1000–1500 = 0	0.91	1000–2000 = 0	3.22 *
1500–2000 = 0	32.31 ***	2000–3000 = 0	29.26 ***
2000–2500 = 0	5.47 ***	3000–4000 = 0	8.63 ***
2500–3000 = 0	0.69	4000–5000 = 0	0
3000–3500 = 0	1.29	> 5000 = 0	10.00 ***
3500–4000 = 0	1.16		
4000–4500 = 0	0.42		
4500–5000 = 0	0.06		
5000–5500 = 0	7.47		

Each row tests for differences in adjacent distance bins, for example row one test the hypothesis that the 0–500 ft and 501–1000 ft distance bins are equal.

estimate Equation 1 with linear distance from each greenway interacted with the Post Trail Indicator. Distance and Interaction coefficients are shown in Table 6 with the remaining coefficients presented in Appendix A.2. These estimates are consistent with the coefficient signs and significance found in Table 4.

4.1.3. *Analysis using truncated sample*

Anticipatory behavior and gentrification could be a significant driver of positive capitalization effects when a greenway is constructed. Therefore, I apply a fuzzy matching routine on the data, dropping sales where the owner address is less than an 80% match with the property address and estimate Equation 2. The results are consistent with the preferred specification using all transactions and can be found in Appendix A.3.

5. Conclusion

Given the significant expenditures earmarked for greenway construction, including $24.6 million in the 2014 Raleigh Parks and Greenway Bond (Mcfarlane et al., 2014), it is important to understand

Table A3
Linear Distance Hedonic Analysis.

Linear Distance Regression Coefficient Estimates	
	ln(Price)
Sqft	0.000663 ***
	(0.0000278)
Sqft * Sqft	-5.78e-08 ***
	(5.06e-09)
Lot Size (Acres)	0.0593 ***
	(0.00420)
Lot Size (Acres) * Lot Size (Acres)	-0.000542 *
	(0.000300)
Assessor Grade	-0.0000334
	(0.000114)
Age	-0.00542 ***
	(0.0000954)
Age * Age	0.00000265 ***
	(4.95e-08)
Block Group FE	Y
Year FE	Y
Observations	153544
Adjusted R-squared	0.866

Cluster robust (Block Group) standard errors in ()
* $p < 0.10$, * * $p < 0.05$, * ** $p < 0.0$

the aggregate and distributional effects of proposed greenways. In addition to monies allocated from Parks Bonds, the City of Raleigh budgets approximately $2.0 million per year for greenway maintenance and improvements. This does not include funds allocated by Wake County, and other municipalities within Wake County, for the construction and maintenance of greenways. Several municipalities, such as Zebulon, Garner, Knightdale, Wake Forest and Cary, all located within Wake County, are working to develop trail systems that connect to existing greenways in Raleigh and the surrounding area (Moody, 2018). When planning greenway expansion and integration, expected capitalized values may serve as a guide when evaluating alternative greenway proposals. This research demonstrates that these values are not distributed evenly across all populations within the county or city.

I find evidence that greenway values differ spatially and across demographic groups. Property values demonstrate a sensitivity to the amenity or disamenity values associated with open space before greenway construction. Evidence suggests that greenways have the potential to increase property values in areas where disamenity values were previously associated with proximity to an open space. These effects may be attributed to overall improvement in the landscape or a reduction in undesirable activities in public open spaces.

I also find evidence that converting natural open space to greenway trail has the potential to decrease property values for homes located adjacent to the area. This may be attributed to the “not in my back yard” effect, where a decrease in privacy or alteration of the natural landscape has a negative effect on property values. It is important to note that this analysis is unable to disentangle why the measured effects are occurring. While there is economic intuition and theory to support the findings, the mechanism through which greenways capitalize into property values remains unclear. The weight of the evidence in this analysis points to strong positive effects in distressed neighborhoods when previously undesirable public spaces are converted to greenways. This is consistent with other findings demonstrating significant positive effects from green infrastructure in low income neighborhoods (Wu and Rowe, 2022). Disentangling these effects will require the estimation of underlying preferences for greenway access. Future research utilizing equilibrium sorting models, state preference methods or other structural methods would further our understanding of the heterogeneous values measured here.

While the mechanism is uncertain it is important for urban planners to consider the possibility of heterogeneous effects when considering the expansion or construction of greenways. The results of this research suggest that not all greenways are valued equally. Additionally, given that a greenway system is utilized by a broader population than the individuals that reside near it, the hedonic approach should be considered a lower bound estimate of total values. This analysis is consistent with other research finding heterogenous values for public goods and highlight the need for urban planners to consider localized effects when expanding outdoor and recreation amenities and the mechanisms affecting capitalization effects for all users.

Declaration of Competing Interest

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

Data Availability

Data will be made available on request.

Appendix

See appendix Table A1. Table A2. Table A3.

Non-Linear Specification.

When choosing a non-linear specification for the distance dummies I allow the data to guide distance category width. To test categorical distance specifications, I estimate the following equation,

$$p_{it} = \alpha + X_{it}'\beta + \sum_{k=1}^{K-1}\theta_k ditk + + \delta_t Y_t + \phi_m BG_m + \epsilon_{it},$$

Equation 3: Distance Bin F-Testwhere d_{it}^{k} is distance to the nearest trail and the interaction term is omitted. Two separate models were estimated, the first model using 500 ft increments for the non-linear distance specifications and the second using a more aggregated specification for distance, i.e., distance bins are combined. The results from the OLS estimation of both models specified by Equation 3 are presented in Table 3. An F-test was then used to detect differences in the location parameter across distance indicators in each of the models, where 500 indicates $d_{it} < 500$ ft from a greenway, 1000 indicates $d_{it} \in [500 \text{ ft}, 1000 \text{ ft})$ from a greenway, etc. Results from significance tests between categories are presented in Table 4.

As per these results distance categories are constructed as follows: 0–500 ft, 500–1000 ft, 1000–2000 ft, 2000–3000 ft, 3000–4000 ft and 4000–5000 ft. While Model 2 raises questions regarding evidence of no apparent difference between the [3000 ft, 4000 ft) and [4000 ft,5000 ft), categories are constructed as stated above for simplicity.

Linear Distance Specification Results.

Analysis with Absentee Owners Removed.

Greenways Near High Distress Areas

Coefficient	Lower Crabtree Distance	Lower Crabtree (Dist)* (PostTrail)	Lower Walnut Distance	Lower Walnut (Dist)* (PostTrail)	Lower Neuse Distance	Lower Neuse (Dist)* (PostTrail)
0–500 ft	-0.0151	0.0249	-0.0716 * **	0.0509 *	-0.0538 * **	0.00753
	(0.00969)	(0.0178)	(0.0273)	(0.0281)	(0.0141)	(0.0196)
501–1000 ft	-0.0240 * *	0.0514 * *	-0.0906 * **	0.0593 *	-0.0558 * **	0.00419
	(0.00965)	(0.0209)	(0.0267)	(0.0321)	(0.0132)	(0.0148)
1001–2000 ft	-0.0397 * **	0.0879 * **	-0.0879 * **	0.00708	-0.0421 * **	0.0187 *
	(0.00784)	(0.0202)	(0.0177)	(0.0236)	(0.0114)	(0.0110)
2001–3000 ft	-0.0505 * **	-0.0139	-0.0650 * **	0.0113	-0.0211 * *	0.00818
	(0.00832)	(0.0246)	(0.0141)	(0.0201)	(0.00990)	(0.0111)
3001–4000 ft	-0.0418 * **	0.0517	-0.0687 * **	-0.0193	0.00510	0.0103
	(0.00978)	(0.0327)	(0.0122)	(0.0161)	(0.00880)	(0.0136)
4001–5000 ft	-0.0190 * **	0.0743 * **	-0.0402 * **	-0.00498	0.0156 * *	0.0243 *
	(0.00654)	(0.0155)	(0.00900)	(0.0150)	(0.00741)	(0.0130)

N = 153,455, Adjusted R-squared = 0.865
Cluster (Block Group) robust standard errors in (): * p < 0.10, * * p < 0.05, * ** p < 0.01

Greenways Near High Distress

Coefficient	Upper Crabtree Distance	Upper Crabtree (Dist)* (PostTrail)	Upper Neuse River Distance	Upper Neuse River (Dist)* (PostTrail)	North Hills Distance	North Hills (Dist)* (PostTrail)
0–500 ft	0.151 * **	-0.0549 * *	-0.0412 * *	-0.0103	0.0251	-0.123 *
	(0.0226)	(0.0230)	(0.0194)	(0.0152)	(0.0203)	(0.0665)
501–1000 ft	0.0133	0.0212	-0.0153	-0.00373	0.00628	0.00391
	(0.0280)	(0.0295)	(0.0194)	(0.0165)	(0.0224)	(0.0258)
1001–2000 ft	0.0705 * **	-0.0464 * *	-0.0479 * **	0.000813	0.00115	-0.0111
	(0.0185)	(0.0202)	(0.0173)	(0.0107)	(0.0161)	(0.0175)
2001–3000 ft	0.0520 * **	-0.0332 * *	-0.0418 * *	0.0349 * **	-0.0150	0.0337 * *
	(0.0121)	(0.0141)	(0.0178)	(0.0129)	(0.0133)	(0.0146)
3001–4000 ft	0.0362 * *	-0.00936	-0.0101	0.0726 * **	-0.00984	0.0534 * **
	(0.0144)	(0.0175)	(0.0156)	(0.0218)	(0.00989)	(0.0108)
4001–5000 ft	0.0460 * **	-0.000966	0.0158	0.00583	-0.0223 * **	0.0774 * **
	(0.0128)	(0.0177)	(0.0158)	(0.0179)	(0.00701)	(0.00801)

N = 136224, Adjusted R-squared = 0.871
Cluster (Block Group) robust standard errors in (): * p < 0.10, * * p < 0.05, * ** p < 0.01

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