

VALUATION OF AESTHETIC AMENITIES WITH LANDSAT DATA

by

Jack Andrew Purvis

Under the Direction of Elizabeth Kramer

ABSTRACT

Using landsat data provided from three Georgia counties, hedonic modeling was performed to determine the monetary contribution to property values by land cover. The focus of analysis is directed toward Canopy and Impervious categories. Focal means are calculated at different ranges for immediate and neighborhood-wide assessment of surrounding cover. Layout variables designed to describe neighborhood composition are included. Neighbor Size, the measure of average size and Nearest Neighbor, the average distance between nearby homes, are calculated at same neighborhood ranges as Focal means. Regressors also include distances to Schools, Hospitals, Airports, and Highways.

Pooled Ordinary Least Squares performed with data normalized by log-transformation yields practical, statistically significant results. Consistency of estimates among counties provides assurance of model viability, while variety is still strong between all counties.

INDEX WORDS: environmental economics, spatial statistics, land cover, landsat data, neighborhood, Georgia, county

VALUATION OF AESTHETIC AMENITIES WITH LANDSAT DATA

By

JACK ANDREW PURVIS

B.S., The University of Georgia, 2008

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment
of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2011

© 2011

Jack Andrew Purvis

All Rights Reserved

VALUATION OF AESTHETIC AMENITIES WITH LANDSAT DATA

by

JACK ANDREW PURVIS

Major Professor: Elizabeth Kramer

Committee: Jeffrey Dorfman
Rebecca Moore

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
August 2011

TABLE OF CONTENTS

<u>Chapter 1: Introduction</u>	1
<u>Chapter 2: Hedonic Pricing Methods (HPMs) Analysis</u>	3
2.1 Spatial Applications	5
Sales Prices	9
Assessed Land Values	11
Objectives	12
2.2 Methodology	14
Data Description	15
Data Analysis	22
Panel Modeling & Transformation	24
2.3 Hedonic Model Results	27
<u>Chapter 3: Ecosystem Services Literature Review</u>	32
3.1 Air	33
3.2 Stormwater	37
3.3 Energy Reduction	40
<u>Chapter 4: Conclusions</u>	45
4.1 Statistical Analysis	45
4.2 Canopy Cover Monetary Discovery	49

4.3 Concerns	50
<u>Bibliography</u>	53
<u>Appendix</u>	58

LIST OF TABLES

Table 1: Land use and land cover by county in percentages 16

Table 2: Terms 21

Table 3: Summary Statistics by County 22

Table 4: Pooled Ordinary Least Squares, 750 meter radius 28

Table 5: Air Pollutant Removal & Monetary Contribution 35

Table 6: Energy Savings in \$/yr 43

LIST OF FIGURES

Figure 1: Quarterly GA HPI 1999-2010 13

Figure 2: Aerial image of Clarke County neighborhood 17

Figure 3: Landsat Data - Satellite spectrometry of % Canopy cover 18

Figure 4: Focal means calculation, 9x9 pixel = 3 meter radius (local) 19

Figure 5: Focal means of % Canopy cover 19

Figure 6: Neighborhood ranges (250, 500, 750, and 1000 meter radii) 20

Figure 7: Residual vs. Fitted Values – Clarke, 750 meter radius 26

Figure 8: QQ Plots – Clarke, 750 meter radius26

CHAPTER 1

INTRODUCTION

There are many studies that describe how to value the benefits of trees to a neighborhood or community. Generally, these benefits fall into two categories those that provide benefits to communities (public) and those that benefit the individual (private).. Private valuation will be analyzed with the use of a hedonic pricing method. Here, I will assess what a homeowner is willing to pay for additional trees on their property when purchasing a home. This reveals how an individual's interest in curb appeal translates to buying decisions. Economic impact of ecosystem services provided by canopy cover is the best way to describe public benefit contribution. Many of the services provided by natural features must be replaced when a landscape is developed. Landowners, typically pay for these services through local government taxes, which must use engineer solutions to provide these services. Land use information is often used to determine monetary effects by using property prices, usually sales prices of buildings, as dependent variables in regression models. This is a great example reflecting the analysis of private goods, as sales prices are immediately pertinent to home buyers. However that is not to say this information is completely divorced of useful public-benefits analysis. This is most relevant when considering the effects infrastructural growth has on the environment due to changing property prices. Any growth in impervious cover can have potential adverse environmental effects, the costs of which are usually burdened by taxpayers in the form of repair

and maintenance. Interestingly, many public environmental benefits can also be correlated with private ones. This is particularly true when considering the energy expenditure reduction potential by urban trees. Beyond energy, there is also the issue of the monetary costs of pollution in terms of both the price of healthcare and mitigation. Ultimately, there is a great deal of overlap in terms of private and public benefit contributed by forests. However in this study, private benefits will be presented in chapter 2 when reviewing econometric analysis with hedonic pricing methods. Chapter 3 will follow with a literature review outlining monetary discovery of ecosystem services provided by canopy cover, with the intent of conveying public benefits.

CHAPTER 2

Hedonic Pricing Methods (HPMs) Analysis

The general format used in most aesthetic valuation studies is known as hedonic pricing. Hedonic pricing methods are tools that allow for economic estimation of environmental aspects not already assigned monetary value. Simply put, HPMs regress prices by these aspects, yielding coefficients in terms of dollar amounts. As in the case of this study, HPM techniques usually quantifies the private good values of the regressors of interest. Typically, HPM regressors are quantifiable and easy to record; on the other hand the complex nature of aesthetic contribution by different overlapping features makes modeling difficult and heavily debated. To avoid over-complicating matters we will open with a study that uses tree count in an HPM model.

An article published in 1988 explained that landscaping with trees resulted in a 3.5% to 4.5% increase in sales price for homes in Athens, Georgia. These findings, presented in *Influence of Trees on Residential Property Values in Athens, Georgia: A Survey based on Actual Sales Prices* by USDA Forest Service researchers Anderson and Cordel (1988), came from data that was observed from photographs of each individual property in the study. Sales prices were regressed by building characteristics and number of nearby trees using two different stepwise models. The first model found that each tree located in the front yard added \$343 to the sales price. The estimates were statistically significant at the 5% level and an R^2 of 0.77 was

achieved. The authors then went on to generalize the model by adding additional regressors and changing the variable “total number of trees in front yard” to “number of trees on the lot.” The tree value coefficient added an additional \$290, all estimates remained significant, and the R^2 grew to 0.79. (Anderson and Cordel, 1988)

Though this study manages to determine generic tree values with high degrees of statistical and practical viability, it is limited to the study area in question. If the modeling system can be performed in other areas and yield location-specific estimates, the true benefit of this research can be realized. In order for that to be possible, the data from each area of interest must be recorded in the same fashion. The entire dataset came from a “Final Sales Catalog” published by the Athens-Clarke County Board of Realtors. It was estimated that more than 90% of all residential property sales were included in this report along with photographs of most of the homes, which were used to count the number of trees per property. Then the data was narrowed to include only single family homes that had records for all building characteristic variables. As most of this information, besides the photos, is available in many counties this system of analysis shows great promise for future application. With this research, developers can more effectively determine the quantity and type of trees to include in residential neighborhoods, thereby allowing them to delineate market segments by relating buyer aesthetic preferences to respective income class.

2.1 Spatial Applications

Much of the data used in the previous study are also available from county tax digests, which requires that home-owners self-report interior updates and therefore are often incorrect. Tree count data for individual properties can be collected separately from tax records. There are a number of options for collecting this data ranging from field data collection or the use of aerial photographs. Due to the inconvenient expense and the length needed to perform on-site data collection, many researchers have turned to spatial statistic evaluation of larger-range land cover data. Today, land cover information comes from aerial photos or satellite imagery such as landsat datasets, these sources provide consistent datasets for large areas which can be used in the analysis of local and neighborhood characteristics. *The amenity value of the urban forest: an application of the hedonic pricing method* by Liisa Tyrväinen from the University of Joensuu in Finland opens our exploration of spatial analysis (1997). Similar to studies done in the U.S., tax offices were consulted for building characteristic data. Land use types were categorized using aerial photographs of the study area. Building characteristics and distances to each land use category are regressed on price/acre in first-stage hedonic price models. The effect of the number of rooms was factored by including dummy variables for each different total numbers of rooms, ranging from two to five. Percentage of greenspace, age of property, and the size of the lot were also included. Results indicate that homeowners valued 1% of greenspace within their

lot at \$7.36/acre. Distance from forested areas was preferred while proximity to natural waterways was valued at about \$154/acre for every 100 meters (Tyrväinen, 1997).

HPMs can accommodate a diverse array of data sources. In the last two reviewed articles data was collected from photographs. The first required a count of the number of trees in each property and the second utilized aerial imagery digitized for land use classification. In the past, the primary constraints of aerial imagery are lack of geographical and temporal coverage. These images aren't as hard to find or as expensive as property pictures, but they are much more difficult to attain if the subject area of interest hasn't already been photographed. Avenues of contracting or requesting for regular aerial surveying of a specified fly-path are seldom available to the average researcher. These limitations stress the necessity of an alternate data source, one that allows large-scale evaluation at low cost. These data are becoming easier to access through government data sites as well as site such as Google Maps, but often require the user to have some experience with Geographic Information Systems.

An article from England seems to do this, though the source is somewhat unexpected. *Using a geographic information system to estimate an hedonic price model of the benefits of woodland access* by Powe, Garrod, Brunsdon, and Willis (1997), as its name suggests, takes advantage of geospatial software. From the University of Newcastle upon Tyne in England, this study was designed with the intent of utilizing a "broader approach" than previous literature. Sales prices and building characteristics were attained from mortgage records while land cover data was derived by digitized Bartholomew maps. Bartholomew maps are the popular standard in England; some varieties describe land cover with impressively vivid detail. Using ArcMap

software, spatial variables were calculated with focus towards forest cover access. To address correlation issues, an index was constructed by summing values that were calculated by dividing the area of the nearest forest by the respective distance-squared for each property. With both the dependent variable, sales price, and the forest index being log-transformed the output coefficient resembles a positive elasticity of 0.0461, or 4.6%. All estimates were statistically significant and an R^2 of 0.81 was achieved. (Powe et al., 1997)

Probably the most important concept the reader should take away from these works is the practicality of land cover data manipulation for HPM models. There is no universally accepted type of land cover data among researchers. The only shared “standard,” if there is one, is that with reasonable intuition there exists some direct causal link with property prices. This unspoken rule is the result of successful studies that utilize direct observation of existing land cover, rather than coincidental correlations between ambiguous and unrelated features. However the idea of finding regressors by observing unobservable effects is an abstract one. It is possible that all of these sources reflect the same effects; perhaps mathematical information hidden within property photos, aerial imagery, and common geography maps, all describe the same aesthetic benefit. If this is the case, it is evidence that supports the inclusion of most of these environmental variables, giving researchers plenty of freedom in modeling strong HPM models. However, applicability is made easy with uniformity. Colin Price of the University of Wales drove this point with his 2003 publication, *Quantifying the aesthetic benefits of urban forestry*. In it, Price reviewed the diverse approaches used in aesthetic valuation of forest cover by many researchers. Price argues that the wide scope of these differences indicates that there are many

failures in estimation reliability. Price's corrective proposal of uniformity sits well with anyone interested in application of findings, stating: "The more explicit we make it, the more likely it is that a proper consensus can be achieved on the aesthetic value of urban trees." (Price, 1997) Further inadequacies of methods that regress sales prices will be discussed in the following section, followed by a proposed alternative.

2.1.1 Sales Prices

Often in sales price HPMs, the inclusion of an environmental variable seems to provide more convenience than statistical reliability. Regressing sales price by number of rooms, size of house, etc. seems quite reasonable, but in most of these models researchers simply add proxy variables that are environmental in nature to describe aesthetic benefits. Typically these variables are distances and layout of natural amenities such as forest or wetlands, though as this study has shown, land cover intensities have been considered as well. Output coefficients of building characteristic variables serve as benchmarks; as long as these estimates are reasonable and expected then so should be those of the environmental proxies. However, since most of these studies fall within somewhat low goodness-of-fit measures and often have high standard errors, adding an unrelated variable often boosts R^2 values with little effect on standard errors of pre-existing variables. Since supporting statistical test results can't be considered damaging, the benchmark ideology presents a potential problem with interpretation. Statistical test output can confuse readers by seeming to support the inclusion of these environmental variables. It is these low standards and general acceptance of many environmental variables that has contributed to their overestimation in previous models, a concern which was voiced by Price in the previously discussed article. (Price, 1997)

Additionally, sales prices may not be quite as correlated with aesthetic benefits of environmental features as one may think; most often a narrow scope is needed for impressive

output to be achieved. Though impressions are relative to which reader observes the literature, statistical tests seem to be a popular standard. However, relying on these tests can be risky, especially when one considers that the study areas used are limited in both size and scope. This is primarily due to incongruities between the researcher and the consumer. Subconsciously, a seller may waiver on the value he or she assigns aesthetic benefits before doing so on the value of the number of bedrooms or the size of the house. As a result, aesthetic contribution to price could vary greatly among properties with similar design. As data collection is expensive, this variation in sales prices encourages researchers to limit study areas to convenient sizes such as single subdivisions or neighborhoods, thereby constraining building characteristic ranges. As these ranges are tightened, property homogeneity focuses unrelated explanatory power into land cover estimates. Such an incentive for homogeneity promotes systems that require expensive and difficult on-sight data collection while limiting the potential areas of application as well as the viability of output coefficients. Similarly, this limitation is presented with effects from changes in economic status over time. Values assigned to building characteristics are subject to huge variability due to the growing volatility in the housing market between 2001 and 2008. Research that fails to consider changes over time effectively isolates application of findings to the year(s) in which the study was performed.

Probably the most imperative inefficiency of using sales prices is the general lack of data reliability. Sales prices are heavily reliant on owner provided building characteristics; regression without these variables would result in missing variable error. The most convenient source of building characteristic data comes from tax digests. Constructed by county appraisers, prices

and values are regularly updated, and considered accurate; this cannot be said about specific attributes of the house recorded in these same datasets. Often the recorded size, number of bathrooms or bedrooms, etc. are maintained for long periods of time in tax records regardless of change by new owners. Without first-hand annual surveying of all properties, which is rarely performed by assessors, any remodeling activity by homeowners is overlooked. This is a huge oversight, rendering this source for these variables lacking in reliability. Unless remodeling requires a permit or certificate of occupancy and the homeowner obtains these the information about the house is not updated in the tax records. Though tax digests are a poor source for building characteristics, that doesn't mean reliable sources don't exist; the literature reviewed in the hedonic modeling section illustrates this. However, most sources beyond tax digests are expensive and require difficult collection techniques, problems this study hopes to avoid.

2.1.2 Assessed Land Values

The best way to conceptualize the limitations of sales price HPMs is in the valuation of properties without constructed buildings. However, using building characteristics to describe lots without buildings could result in bias; for this reason empty lot observations are usually dropped from most HPM models. As the sale of empty lots can only be valued by location-specific features, such as aesthetic ones, their exclusion comes with an extensive loss in useful explanatory power. In order to overcome this obstacle, this study will use land values in lieu of sales prices.

Land values, like sales prices, are derived from market information by tax assessors. Remember that the reliability of market value data recorded by assessors isn't under debate, but accurate records of building characteristics are. Any uniform measure of market values that excludes the necessity of building characteristic regressors would make an ideal dependent variable for this study. Conveniently, land values meet these criteria, as they are updated as often as sales prices and allow the inclusion of empty lot observations during analysis.

2.1.3 Objectives

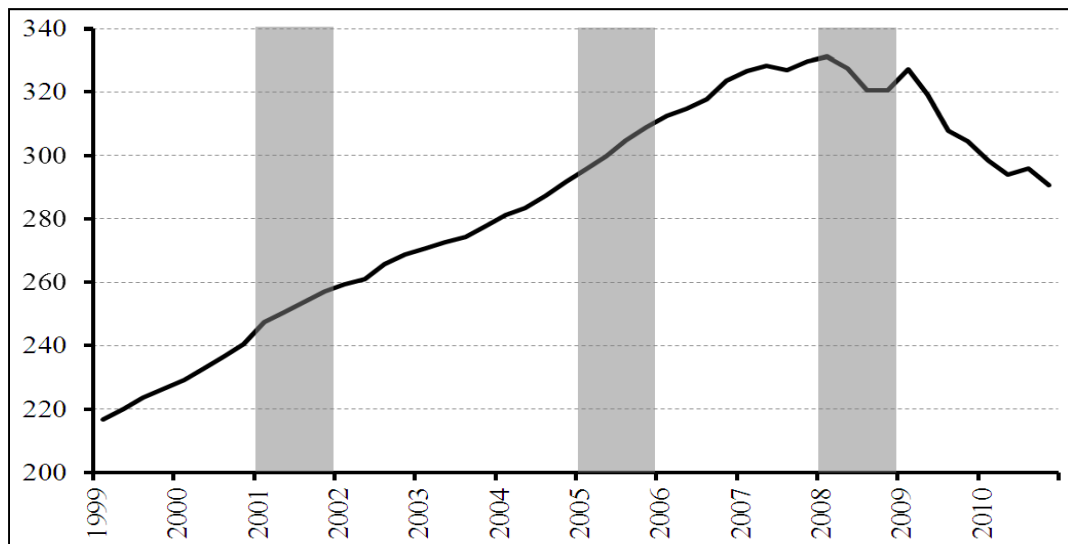
The proposed system regresses land value per acre by an array of spatial variables designed to describe aesthetic and environmental features of residential areas. Land values do not include the value of the residential buildings, therefore, existing homes and empty parcels can be evaluated together. This paper will use variables derived from Landsat satellite imagery, land cover, tree canopy, and impervious surfaces. Since building characteristics are omitted, benchmark variables are lost. Without these variables, the best way to measure the reliability of output estimates is through repeated performance, which is illustrated by comparing output estimates for the three different Georgia counties.

Canopy cover estimates are expected to be positive, as the reviewed preceding literature suggested. Impervious cover is harder to predict, as approval/disapproval is almost entirely dependent on the culture and infrastructure of the subject area in question. Since Georgia has had a steady history of favoring urbanization, impervious cover should also have positive

estimates. Differences in magnitude between canopy and impervious cover should be inferred by the reader carefully. These two land cover categories are independent and measured in percentages, therefore estimates aren't complimentary and relevant only to current levels of respective category. The differences between the output land cover estimates will be described in greater detail in section 4.1.

As mentioned before, greater model reliability will be achieved if attention is paid to changes in economic status between subject years. Though this study is not analyzing sales prices, market activity has a direct impact on land value calculation. The results of this analysis should reflect the Georgia Housing Price Index, illustrated in figure 1. It is expected that the yearly coefficients should rise from 2001 to 2008 to reflect the Georgia HPI.

Figure 1: Quarterly GA HPI 1999-2010



*Shaded regions represent study years

*Data Source: FRED, Federal Reserve Economic Data, Federal Reserve Bank of St. Louis; House Price Index for Georgia (GASTHPI); Federal Housing Finance Agency;

<http://research.stlouisfed.org/fred2/series/GASTHPI>

Further, the volatility in 2008 suggests less estimation reliability, which should be indicated by a higher standard error. However, it is not expected that a statistically insignificant estimate will be formulated. This is also expected of the layout variables Neighbor Size and Nearest Neighbor. These fixed variables will be defined with greater detail in chapter 2.

2.2 Methodology

This study evaluates the effects of land cover, as described by two components, tree canopy cover density and impervious surface cover density. Both of these variables were derived from Landsat Satellite imagery (Homer et al., 2004). Both represent the percentage of either tree canopy or impervious surfaces included in an individual 30 meter pixel. Canopy cover is all tree canopy found in the pixel and impervious surface represents built areas where rainfall cannot infiltrate. They represent greenspace and built features, respectively. Canopy is made up of the explicit aggregated intensity of all trees within the measured area, while imperviousness is a composite of hard covers such as roofs, sidewalks, parking lots, roads, severely impacted soil, etc. In urban areas, overlap, though limited, is common and as a result the two aren't direct compliments of each other. These amounts and distribution of canopy and impervious surface represent the differences in neighborhood styles. For example, more dense mixed in-town neighborhoods will have higher impervious surfaces and medium to low tree

canopy, while suburban residential neighborhoods might have lower impervious surfaces and higher tree canopy measures.

In addition, other neighborhood attributes are as popular for analysis as they are pertinent. Therefore distance variables are included in order to that consumer interest in long-range neighborhood features is considered. This paper considers public schools, hospitals, airports, and highways, each having their own importance, while also potentially serving as proxies for distance to business districts. In addition to traditional neighborhood regressors, we have introduced new layout variables to account for neighborhood design. Neighbor Size refers to the average size of surrounding buildings, while Nearest Neighbor reveals the average distance between each property, both within specified neighborhood ranges. If formatted correctly, these variables should value the overall aesthetic and environmental benefits of land cover, location, and neighborhood layout.

2.2.1 Data Description

Property data from Athens-Clarke, Henry, and Augusta-Richmond counties, respectively from the Athens, Atlanta, and Augusta metropolitan districts, were obtained from county tax assessor and commissioner offices. Land cover (canopy and impervious surface) came from the Natural Resources Spatial Analysis Laboratory (NARSAL) at University of Georgia. Land use and cover by county is presented in the following table in percentages.

The overlap of available data yielded land cover and tax digest data only for the years 2001, 2005, and 2008; datasets were constructed in panels, with the subject of each panel being a residential unit.

Table 1: Land use and land cover by county in percentages

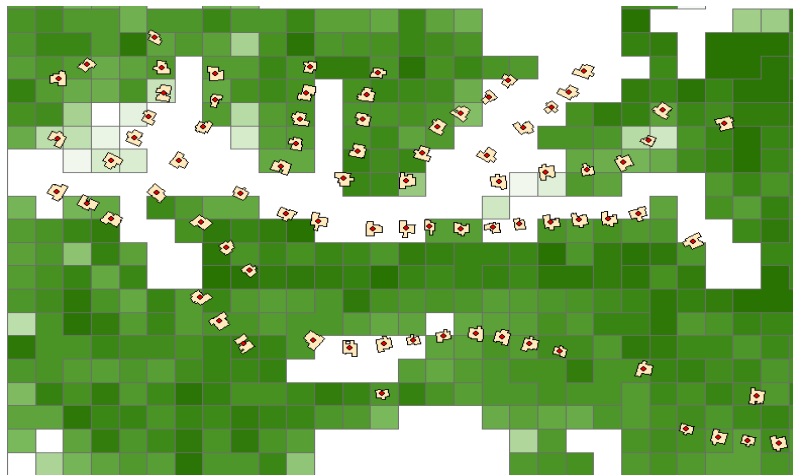
	Clarke	Henry	Richmond
Urban	22.0	21.7	21.3
Agriculture	12.1	20.3	14.5
Forestland	37.2	35.3	33.2
Canopy			
2001	68.9	68.9	65.1
2005	70.6	70.8	69.4
2008	74.5	76.5	68.1
Impervious			
2001	25.0	23.9	31.8
2005	28.6	27.7	34.7
2008	30.9	31.6	37.8

Figure 2: Aerial photograph of Clarke County neighborhood



Tree canopy density was derived from Landsat Satellite imagery using a process described by Homer, et al 2004. The neighborhood aerial image in figure 2 corresponds to the tree canopy density data shown in figure 3, where white represents no canopy and the canopy percentage is represented as a gradient of percentage from light to dark. Each pixel defines a 30 x 30 meter plot of land, the values of which are scaled as percentages.

Figure 3: Canopy cover as a percentage of the individual pixels, derived from Landsat satellite imagery



Property locations were detailed by respective polygons constructed by tax appraisers or commissioners of each county. The centroid of each polygon was determined in order to assign the most spatially appropriate pixel value to each residential unit. Since the property rarely sat in the center of a single pixel, local cover values were also determined using focal means calculation. This is done by averaging the value of a single cell and the values of the eight adjacent cells around it. Figure 4 illustrates the process in which focal means are calculated.

Figure 4: Focal means calculation, 3x3 pixels = 30 meter radius (local)

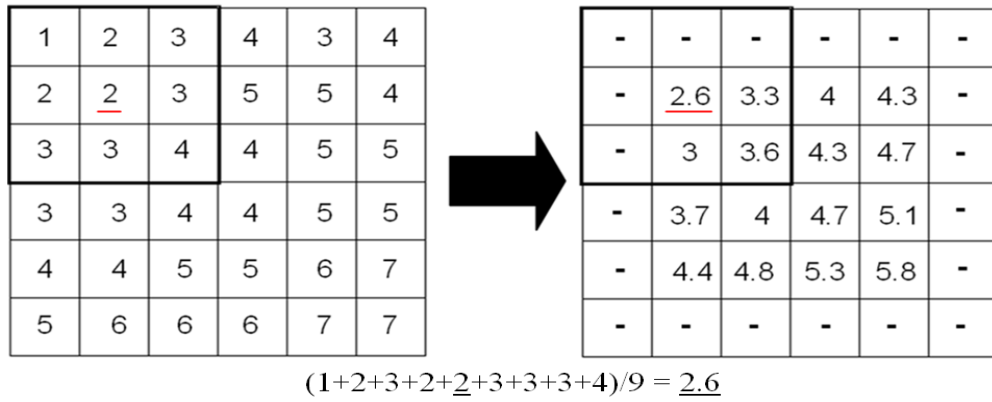
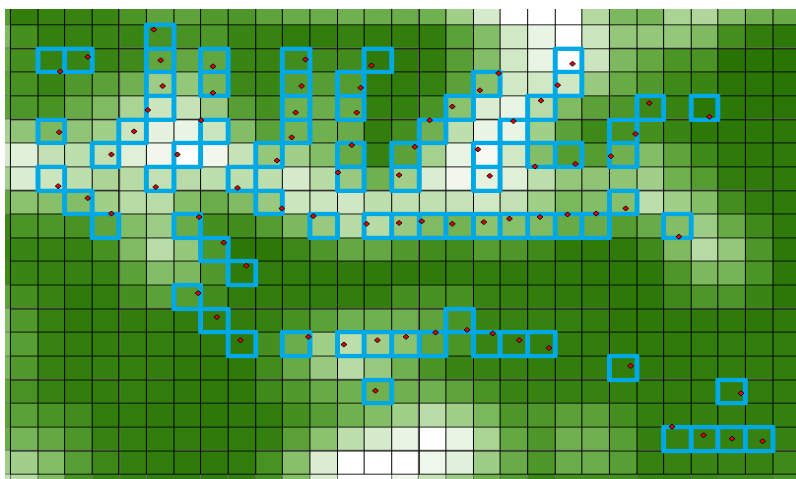


Figure 5: Focal means of % Canopy cover



Each property centroid was then assigned the value of the pixel in which it resided while overlaying the focal means layer, figure 5.

This same process was applied to larger ranges, described in this study as neighborhood ranges. Every variable subject to customizable buffer ranges was calculated with varying emphasis on neighborhood sizes, while the viewable area around each house is considered an explicit “neighborhood.” Varying the distance of the radius (eye-line) from the building centroid yields multiple neighborhoods for each property. Radii of 100, 250, 500, 750, 1000, 1250, and 1500 meters were considered for this study to thoroughly and confidently describe a minimum practical range that yields statistically significant estimates.

Layout variables were also computed using these ranges. Neighbor size details the average size of all buildings within each neighborhood, while nearest neighbor does the same but for average distance between building centroids.

Figure 6: Neighborhood ranges (250, 500, 750, and 1000 meter radii)



To clarify, all range variables are described by function and distance; each property has four neighborhood variables, Canopy, Impervious, Neighbor Size, and Nearest Neighbor, each calculated separately for seven different ranges. As a result, each property ID is assigned 28 potential neighborhood variables. There is no intention to illustrate the effects of all seven ranges; one range will be selected for the final dataset after preliminary analysis. See table 2 for clarification of discussed variables.

Table 2: variables used in the analysis

Variables	Units	Type	Description
Range	Meters	Definition	Radial distance of area around property
Land Value	Acres	Response	Land value/acre of property parcel
Neighbor Size	Square Feet	Regressor	Average size of neighboring properties
Nearest Neighbor	Feet	Regressor	Average distance between properties
Distance	Miles	Regressor	Distance between property and nearest feature

It is important to recognize the nature of this data such that one does not get hung up on the strict quantitative measurements of land cover value. The interaction of stereotypes implied by these variables can reveal neighborhood ambiance. To illustrate, imagine the aesthetics of a low-canopy, high-impervious housing subdivision with small average distances between large houses. Though everyone may conceive an entirely different landscape, a distribution curve should exist within which most individuals share reasonably similar design features. Finding and functionalizing that distribution will allow researchers to effectively determine consumer monetary assessment of qualitative features, in this case, neighborhood aesthetics.

2.2.2 Data Analysis

To find the most appropriate range for neighborhood and community analysis, regressions were performed at each radius; the results of each can be found in the appendix, while model format is explained in section 2.3. A radius of 750 meters was chosen for final analysis, as it is the smallest of ranges that maintains good statistical significance. Table 3 shows summary statistics for the final dataset, followed by brief discussion.

Table 3: Summary Statistics by County

	Mean (Standard Deviation) / Min – Max			Units
	Clarke	Henry	Richmond	
Land Value (thousands)	110.65 (165.19)	73.15 (71.68)	58.73 (65.72)	acres
	1.44 - 4671	0.18 - 966	1.51 - 1540	
Canopy	42 (30)	20 (28)	27 (27)	%
	0 - 100	0 - 100	0 - 100	
Impervious	18 (16)	24 (21)	32 (19)	%
	0 - 90	0 - 100	0 - 100	
Local Canopy	43 (24)	23 (22)	27 (22)	%
	0 - 95	0 - 95	0 - 88	
Local Impervious	17 (12)	22 (16)	30 (15)	%
	0 - 90	0 - 81	0 - 99	
Neighbor Canopy	47 (13)	34 (15)	29 (16)	%
	6 - 90	0 - 89	0 - 76	
Neighbor Impervious	18 (11)	20 (13)	30 (14)	%
	0 - 74	0 - 71	0 - 85	

Table 3 cont.: Summary Statistics by County

Neighbor Size (thousands)	2.50 (0.85)	2.25 (1.08)	1.86 (0.73)	feet ²
	1.16 - 17.02	0.83 - 37	0.80 - 12.46	
Nearest Neighbor	113 (35)	103 (28)	67 (14)	feet
	58 - 509	0 - 438	44 - 217	
Schools	0.88 (0.54)	4.23 (2.79)	4.68 (3.94)	miles
	0.02 - 4.19	0.14 - 20.56	0.02 - 21.22	
Hospitals	2.96 (2.04)	17.56 (8.74)	6.71 (4.23)	miles
	0.10 - 9.68	0.26 - 39.47	0.16 - 36.23	
Airports	4.7 (2.21)	9.29 (3.85)	10.68 (4.55)	miles
	0.43 - 11.98	0.05 - 24.50	0.43 - 29.35	
Highways	0.82 (0.74)	3.29 (2.59)	1.29 (1.25)	miles
	0.01 - 5.11	0.03 - 12.52	0 - 10.73	
No. of Observations	26,529	99,432	75,620	

The range of data was altered such that properties with land values of less than \$1000 were excluded in hopes of minimizing properties with recording errors, inherited land, etc. This table reveals clear implications about the balance of land cover; while Clarke County has the lowest impervious cover it also maintains the highest canopy. Henry and Richmond both fall in the middle ground, but are still comparable. It seems that neighborhood cover is somewhat consistent among all three counties, though they still reflect the behavior of non-focal cover. Layout variables, with the exception of Richmond's nearest neighbor, are consistent as well. This suggests that general layouts of common residential subdivisions of each county are similar to one another.

2.2.3 Panel Modeling & Transformation

The final dataset is in panel format while the analysis utilizes spatial statistic techniques. Panel data analysis typically begins with Pooled Ordinary Least Squares (POLS) regressions, and then is compared with other Fixed Effects methods. Omitted from this report are the other fixed effects results, as they proved to be less reliable or practical. With these methods being removed from consideration, most other advanced panel data analysis methods, particularly Random Effects, were overlooked. The POLS model performed here is described as:

$$y_t = x_{it}\beta_1 + z_i\beta_2 + D_t\beta_3 + \varepsilon_{it}$$

where,

y = Land Value per acre of observed property

x = Observed, Local, and Neighborhood values of Canopy and Impervious cover

z = Neighbor Size, Nearest Neighbor, and distance to Schools, Hospitals, Airports, and Highways

D = Year Dummy variables; {= 1 if true, 0 if not}

Year-2001, Year-2005, Year-2008

i = Property ID

t = Time (year)

ε = Error

POLS, along with nearly all panel analysis methods, often includes some sort of classification system whereby the bulk of explanatory power of output estimates are described in the changes or differences among multiple records of the same observation. These concerns are addressed in this study only with the exclusion of single-observation panels. On the other hand, classification by yearly dummy variables, D , addresses the previously discussed changes in economic status. As a result, each property observation is one of either two or three subjects within its respective panel. This method was also chosen for a few additional reasons: first, little statistical reliability was found in methods using other classification systems during preliminary analysis; second, as discussed in the data description, dataset construction was limited by data availability of every type, narrowing the scope by year and county; and finally, by excluding single-panel observations, bias due to increased purchases during 2008 can be avoided without having to remove all 2008 records from the sample.

Residual analysis was performed in response to many sources suggesting potential problems with heteroscedasticity in HPM models. Though White tests indicate homoscedasticity, the traditional and more reliable method of visual inspection should be considered. This approach requires residual vs. fitted value plots; after construction, these figures proved to be more difficult to interpret than anticipated. Figure 7 illustrates this for Clarke County at the 750 meter range; however this behavior was not limited to Clarke alone, Henry and Richmond shared similar patterns.

Figure 7: Residual vs. Fitted Values – Clarke, 750 meter radius

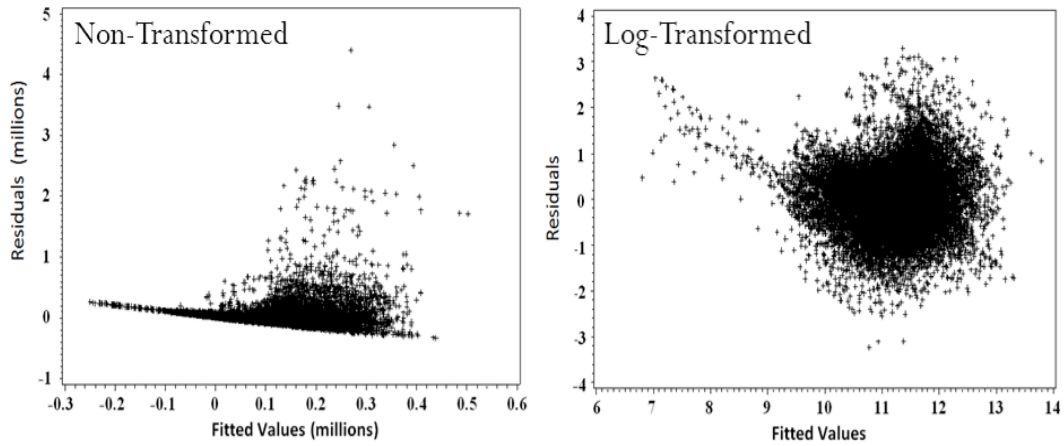
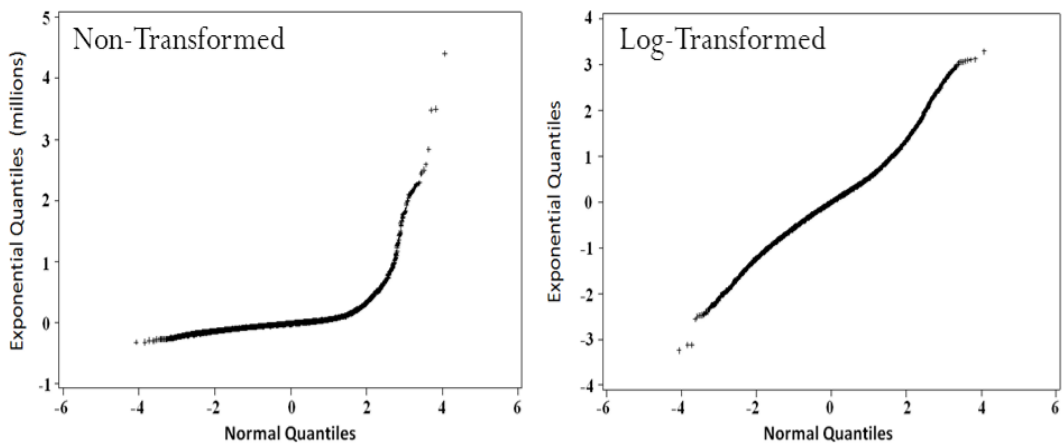


Figure 8: QQ Plots – Clarke, 750 meter radius



QQ plots, presented in Figure 8, suggested potential problems with normality. To correct for these issues, a natural log transformation of the response variable Land Value was used. Plots from the log-transformed POLS model show that the data was successfully normalized while maintaining general homoscedasticity. White test results and plots for Henry and Richmond at the 750 meter range are available in the appendix. Residual plots for models at other ranges aren't included.

2.3 Hedonic Model Results

Table 4 shows the POLS estimates, the respective standard errors, implicit contribution, and R^2 for the log-transformed model. Implicit contribution was calculated by determining the coefficients as percentages, which were taken from the average per acre land value. This chapter will discuss land cover output estimates for the immediate, local, and 750 meter ranges in detail. POLS results for each range are available in the appendix.

Of the immediate land cover estimates only Richmond canopy is statistically significant. According to these coefficients, one percent of canopy cover in Clarke County contributes about 0.07% or \$77.46 to per acre land values. As for the other counties, one percent of canopy cover in Henry and Richmond contributes 0.08% or \$58.52 and 0.14% or \$82.22 to per acre land value, respectively. At the immediate range, one percent of impervious cover decreases per acre land value by 0.15% or \$165.98 in Clarke County, has no practical effect on per acre land value in Henry, but increases per acre land value by 0.03% or \$17.62 in Richmond.

Table 4: Pooled Ordinary Least Squares, 750 meter radius; log-transformed coefficients and implicit (*average property value) \$ contribution.

	Coefficients / (Standard Error) by County					
	Clarke		Henry		Richmond	
	Log	Implicit	Log	Implicit	Log	Implicit
Canopy	0.0007 (0.0002)	77.46	0.0008 (0.0001)	58.52	0.0014* (0.0002)	82.22
Impervious	-0.0015 (0.0004)	-165.98	0.0000 (0.0001)	0.00	0.0003 (0.0002)	17.62
Local Canopy	-0.0008* (0.0003)	-88.52	-0.0020* (0.0001)	-146.30	0.0013* (0.0003)	76.35
Local Impervious	0.0242* (0.0006)	2,677.73	0.0240* (0.0002)	1,755.60	0.0185* (0.0003)	1,086.51
Neighbor Canopy	0.0047* (0.0004)	520.06	-0.0001 (0.0002)	-7.32	0.0101* (0.0003)	593.17
Neighbor Impervious	0.0058* (0.0007)	641.77	0.0136* (0.0003)	994.84	-0.0105* (0.0004)	-616.67
Neighbor Size	0.0001* (0.0000)	11.07	0.0000* (0.0000)	0.00	0.0003* (0.0000)	17.62
Nearest Neighbor	-0.0083* (0.0002)	-918.40	-0.0066* (0.0001)	-482.79	0.0059* (0.0003)	346.51
Schools	0.0465* 0.0087	5,145.23	-0.0090* 0.0007	-658.35	0.0015* 0.0009	88.10
Hospitals	-0.1267* 0.0033	-14,019.36	-0.0092* 0.0002	-672.98	-0.0404* 0.0008	-2,372.69
Airports	-0.0648* 0.0022	-7,170.12	-0.0068 0.0004	-497.42	0.0004* 0.0006	23.49
Highways	0.1345* 0.0070	14882.42	0.0021 0.0007*	153.62	0.0149* 0.0023	875.08

Table 4 cont.: Pooled Ordinary Least Squares, 750 meter radius; log-transformed coefficients and implicit (*average property value) \$ contribution.

Year-01	11.45* (0.04)	93,957	10.89* (0.01)	53,938	9.09* (0.0267)	8,917
Year-05	11.62* (0.03)	112,027	11.05* (0.01)	63,538	9.26* (0.03)	10,586
Year-08	11.75* (0.04)	128,014	10.87* (0.02)	52,696	9.55* (0.03)	14,124
R²	0.4988		0.662		0.3576	

* = statistically significant at the 5% level

At the neighborhood range, or 750 meter radius range, Henry County was the only to fail to meet significance at the 5% level. At this range, one percent of canopy cover contributes about 0.47% or \$520.06 to per acre land value in Clarke County and 1.01% or \$593.17 in Richmond, but decreases per acre land value in Henry by 0.01% or \$7.32. At this range one percent of impervious cover provides 0.58% or \$641.77 to Clarke County land value per acre and 1.36% or \$994.84 to per acre land value in Henry County, but decreases per acre land value by 1.05% or \$616.67 in Richmond.

Fixed Variables: Neighborhood Layout & Distance Features

All layout estimates are statistically significant at the 5% level. The Henry County neighbor size coefficient is too small for interpretation, though we see that a single square foot of building area in nearby homes is worth 0.01% or \$11.07 and 0.03% or \$17.62 to per acre land value in Clarke and Richmond, respectively. Nearest neighbor estimates are a bit more diverse. An additional foot in the average distance between buildings diminishes per acre land values by about 0.83% or \$918.40 in Clarke and 0.66% or \$482.79 in Henry, but contributes to per acre land value in Richmond properties by 0.59% or \$346.51.

With the exception of the airport coefficient in Henry County, all distance estimates are statistically significant at the 5% level. As the airport in Henry County is privately owned, this comes as no surprise. These estimates are also quite large in comparison to others, but one must keep in mind that they describe a mile, while the largest average distance (see table 3) from any of these features was a little more than 17 miles. In Clarke County a single mile between a home and the nearest school contributes 4.65% or \$5145.23 to per acre land values. This same distance (one mile) from the nearest school decreases per acre land values by 0.9% or \$658.35 in Henry while increasing per acre land values by 0.15% or \$88.10 in Richmond. For every one additional mile between homes and the nearest hospitals, per acre land values decrease by 12.6% or \$14,882.42 in Clarke, 0.92% or \$497.42 in Henry, and 4.04% or \$2,372.69 in Richmond. Each mile between homes and the nearest airport decreases per acre land values by 6.48% or

7,170.12 in Clarke and 0.92% or \$497.42 in Henry, while it increases per acre land value by 0.04% or \$23.49 in Richmond. Every mile between homes and the nearest highway increases per acre land values by 13.45% or \$14,882.42 in Clarke, 0.21% or \$153.62 in Henry, and 1.49% or \$875.08 in Richmond.

Changes by Year

Yearly estimates are all statistically significant. The log-transformed model provides a great deal of consistency, as discovered during residual analysis. This is an expected benefit of working with transformed data, and is useful when comparing different study areas, such as three individual counties. Ranging from 11.45 to 11.75 in Clarke, 10.87 to 11.06 in Henry, and 9.09 and 9.55 in Richmond, we see that the yearly estimates in all counties have similar size and maintain the same direction. However, by taking the exponentials of these values we find that the implicit dollar contribution varies greatly, ranging from \$8,900 in 2001 for Richmond to \$128,000 in 2008 for Clarke. Yet the values are consistent through the years, with Clarke ranging from \$93,000 to \$128,000, Henry from \$53,000 to \$63,000, and Richmond from \$8,000 to \$14,000.

CHAPTER 3

Ecosystem Services Literature Review

The nature of ecosystem services is diverse and interconnected. Though categorization of these services may overlook spatial correlation, it is a necessary step in revealing the monetary benefits they provide. The Millennium Ecosystem Assessment report indicated that some national assessments include up to 100 unique categories of forest services, due to high reliance on resources and externalities. (Millennium Ecosystem Assessment, 2005) This report went on to review various research sources that outlined monetary values provided by forest systems. Simply put, an ecosystem service is one that originates from an ecological source and provides benefits to a society as a whole. As forests themselves can be considered parent ecosystems of many smaller individual ecosystems, quantifying canopy cover can be quite useful in an attempt to detail its contribution to societal benefits. These benefits can be valued monetarily in terms of the private or public market sectors, though they aren't always easily distinguishable.

Chapter 2 delivers an analytical valuation of some private sector benefits, yet it is incomplete. Forestland can provide recreational income in the form of parks and other public utilities, as well as directly contributing to prices of properties they are adjacent to. Though following discussion presents benefits in a public context, it is important to remember these relationships in all aspects. In doing so, the reader should be able to realize that monetary valuation of ecosystem services is not only possible, but by reviewing the following references,

has already been done. One source in particular, though mentioned as controversial, placed the annual contribution by forest ecosystems at \$4.7 trillion, or 15% of the global GNP. (Costanza et al., 1987) Without strict valuation of these public services, researchers fail to make them relevant in the eyes of economists, a necessary achievement for project development and approval. In the following sections, the functions of forestland ecosystem services are discussed in the categories: air quality, stormwater, and energy reduction. Each discussion includes monetary explanation, which will be further summarized in the conclusions chapter.

3.1 Air

These include nitrogen and sulfur oxides (NO_x & SO_x), carbon monoxide (CO), and ozone (O_3). Not only problematic in gas form, oxides can also be transferred to water via precipitation. Ozone is unusual in that it is produced by all plant-life during photosynthesis, though many species are net-absorbers. Particulate matter (PM) is another problematic pollutant. Particulates are best described by the forms in which they manifest, which include dusts, salts, aerosols, sand, and large molecular compounds. Sometimes their presence alone can aggravate or impede health conditions, while the most detrimental effects come from their breakdown within ecosystems or by resident organisms.

The unconstrained and uncontrollable scope of Earth's atmosphere and waterways magnify problems for researchers investigating the effects of relationships between gas pollutants as well as airborne and waterborne particulates. Tide, temperature, wind-patterns,

pressure, and a variety of other factors come into play when attempting to predict flow patterns, let alone the effect of the pollutants that they host. However it is well known that many of these pollutants are connected with increased risks of asthma and heart attacks in humans as well as ecosystem damages such as loss in plant production. Since trees absorb gasses indiscriminately, all of the aforementioned oxygen-based pollutants can be mitigated in the same way or at least similarly to carbon dioxide. Airborne PM can be captured by the mass of canopies and the bushy area, growth of which immobilizes PM by incasing it within its plant stock. 1% canopy cover has been shown to save from roughly \$39,000 to \$206,000 in annual NO₂ prevention or removal costs. This range lands around \$14,000 to \$67,000 for SO₂, \$9,000 to \$57,000 for O₃, and \$28,000 to \$139,000 for PM. A project in Fresno, California, using efficient landscapes, estimated that CO was the least affected air pollutant while the 16,500 trees in the study reduced annual reduction and removal expenses by roughly \$13,000.

Carbon Sequestration

Carbon sequestration is the act of removing carbon from the atmosphere. Sinks are physical mediums that absorb, bind and store carbon; long-term storage is referred to as sequestration. During photosynthesis carbon is stored within root systems, soil, foliage, and plant tissue. The process isn't perfect however, as some carbon is released during the process or the decay of plants; for this reason carbon storage is often measured commensurately before sequestration programs are developed. Much research provides credible reason to conclude that rates of carbon storage by trees aren't random or subject to an immeasurable amount of variation.

It also further supports the commonly-accepted notion that higher canopy cover is correlated with greater storage potential. On average 1% canopy cover can store about 1 to 11 tons of atmospheric carbon annually, depending on location. This translates to savings ranging roughly from \$1,000 to \$12,000 in annual CO₂ reduction or non-forestation removal efforts. Putting carbon storage in monetary terms allows researchers the convenience of valuing pollution mitigation efforts. This is particularly relevant for those efforts that are at the center of the commonly debated effects of climate change from greenhouse gas emissions, as CO₂ is the leading culprit.

Table 5: Air Pollutant Removal & Monetary Contribution. Removal by 1% canopy cover in kg/ha/d, value in \$(thousands)/yr

<u>Pollutant</u>	<u>Removal</u>	<u>Value</u>	<u>Location</u>	<u>Source</u>
CO ₂	0.70	12	Study Area, Chicago, IL	Nowak (1994)
CO ₂	0.30	1	Chicago, IL	Nowak (1994)
CO ₂	0.80	6	Cook County, IL	Nowak (1994)
CO ₂	0.70	3	DuPage County, IL	Nowak (1994)
SO ₂	0.59 [†]	-	Long Island, NY	Murphy et al. (1977)
SO ₂	0.20 ^{††}	-	Argonne National Lab., IL	Wesely & Lesht (1988)
SO ₂	0.15 [†]	-	Savannah River Plant, SC	Murphy et al. (1977)
SO ₂	0.04 [†]	-	Savannah River Plant, SC	Lorenz & Murphy (1985)
SO ₂	0.03 [†]	-	Alamance County, NC	Hicks et al. (1982)
SO ₂	0.03 ^{††}	-	Argonne National Lab., IL	Wesely & Lesht (1988)
SO ₂	2.10	67	Study Area, Chicago, IL	Nowak (1994)
SO ₂	1.40	14	Chicago, IL	Nowak (1994)
SO ₂	2.80	41	Cook County, IL	Nowak (1994)
SO ₂	1.20	10	DuPage County, IL	Nowak (1994)
NO ₂	0.18	-	Salt Lake Valley, UT	Heggestad (1972)

Table 5 cont.: Air Pollutant Removal & Monetary Contribution. Removal by 1% canopy cover

in kg/ha/d, value in \$(thousands)/yr

NO2	0.04	-	Salt Lake Valley, UT	Heggestad (1972)
NO2	2.40	206	Study Area, Chicago, IL	Nowak (1994)
NO ₂	1.50	39	Chicago, IL	Nowak (1994)
NO ₂	2.50	99	Cook County, IL	Nowak (1994)
NO ₂	2.90	63	DuPage County, IL	Nowak (1994)
O ₃	6.00	57	Study Area, Chicago, IL	Nowak (1994)
O ₃	3.10	9	Chicago, IL	Nowak (1994)
O ₃	7.10	31	Cook County, IL	Nowak (1994)
O ₃	5.60	14	DuPage County, IL	Nowak (1994)
PM	5.50	139	Study Area, Chicago, IL	Nowak (1994)
PM	3.50	28	Chicago, IL	Nowak (1994)
PM	6.30	74	Cook County, IL	Nowak (1994)
PM	5.20	34	DuPage County, IL	Nowak (1994)

[†] = assumed heavy cover at 75%

^{††} = assumed grass effects were irrelevant; 50% cover

Table 5.2.: Air Pollutant Removal & Monetary Contribution. Removal by t/yr, value in \$/tree

<u>Pollutant</u>	<u>Removal</u>	<u>Value</u>	<u>Location</u>	<u>Source</u>
CO ₂	304,000 ^{†††}	0.55	Sacramento, CA	McPherson (1998)
Total*	13,741	20.75	Modesto, CA	McPherson et al. (1999)

^{†††} = assumed 31% average canopy cover

* = CO₂, O₃, NO₂, PM, and Volatile Organic Compounds

3.2 Stormwater

As water flows across landscapes, it accumulates various chemicals and particulates found along the path it travels. These substances are then deposited along and at the end of flow paths. Pervious lands allow for water to infiltrate, like soil or sand. Impervious surfaces like sidewalks and streets prevent infiltration, thereby forcing water to transfer over rather than through. While neither surface type completely eliminates runoff, pervious surfaces provide the benefit of infiltration, which allows pollutant absorption by vegetative root systems and the soil itself. Although percolation limits the ability of soft paths to direct water flow, properly integrated design of soil topography and vegetation can focus stormwater through root systems that serve as filters before reaching water bodies. Further, large forest systems provide retention benefits, without which runoff pollution would be greatly exacerbated.

Impervious Runoff Prevention

Engineering allows water to be effectively channeled with desired direction, but can also increase the amounts of runoff which flow into neighboring environments and ecosystems. Unlike agricultural and residential ground cover, urban impervious cover often accumulates chemicals unintentionally. Most of these chemicals are byproducts or leaks from automobile activity like oil, gasoline, transmission fluid, or engine coolant. Imperviousness designed for runoff pollution prevention requires some sort of intermediary filtering mechanism along flow

paths. The expense of such mechanisms may outweigh its preservation benefit, at least in monetary terms. Of course, it is difficult to assign monetary value to ecosystems; as a result, designers are often faced with the troublesome process of weighing public pressure of environmental conservation with construction costs. Of the alternative approaches, strategic tree-planting is unique in that it encourages the substitution or even removal of impervious cover. Further, this approach implements prevention and passive pollution removal without great expense.

Flooding

Though impervious cover may not be directly correlated with reduced canopy cover, there is plenty of evidence to support a loose negative relationship, particularly when observing the after-effects of urbanization. An infrastructure without adequate means of addressing the loss of water retention benefits due to conversion of forestland will experience flooding and the negative externalities associated with it. To further complicate matters, these effects are almost impossible to predict and extremely difficult to remedy.

While serving as another source of non-point pollution, flooding also carries a variety of other impacts, which often require more immediate action. While stormwater runoff effects are isolated to neighboring landscape and water discharge points, floods can actually worsen non-point pollution by increasing flow area and rate. This can undermine the effectiveness of pollutant absorption by bypassing and even degrading soil foundations of natural or man-made vegetative systems. Ecosystems can experience harsh damage to biodiversity which can remain

long after the initial impact, as flow paths are often altered due to flood erosion. Further, floods are aesthetically unpleasing and often spill into nearby operations that require land-use resources. Since 1995, flood damage costs in the U.S. have ranged roughly from \$1.12 billion in 2002 to \$8.93 billion in 1997; per capita costs being \$3.88 to \$33.37 respectively. (Pielke, Jr., 2002)

Any measure to avoid such expense is an opportunity that should not be taken lightly. In 2003, American Forests published the findings of a study that analyzed the effects of land cover change over a 17 year period between 1984 and 2001 in Mecklenburg County, North Carolina. The study, *Urban Ecological Analysis, Mecklenburg County, North Carolina*, used landsat imagery to derive canopy and impervious cover. (2003) The 184,935 acres of forestland was estimated to account for 935 million cubic feet of annual water retention benefits; a man-made water retention system of this magnitude was estimated to cost as much as \$1.87 billion to manage. (American Forests, 2003)

Allowing conversion of large forestlands will inevitably require corrective action. If conversion is at the hand of private enterprises, which it most often is, a vast majority of taxpayers will burden the reparative costs while sharing none of the monetary benefit. From both liberal and conservative viewpoints, this is an unfair allocation of fiscal responsibility. As seen with a variety of existing programs, this can be avoided with simple environmental protection practices, thereby serving both the environmentalist as well as the economist.

3.3 Energy Reduction

The variability in energy reduction benefits provided by residential trees is vast. The simple existence of trees around properties can alter temperature conditions with surprising efficiency. These alterations can have great impacts on energy use of respective home-owners, which can then translate to pollution mitigation by decreasing power plant workloads. Such benefits function by way of their layout and density, and directly affect climatological behavior of the environment in which they reside. Table 6 details the location of research performed and includes references as well as additional sources.

Layout: Tree Shade & Wind Block

The most popular of energy savings methods from trees is shading. Mitigating direct sunlight can decrease the workload of air conditioning units, thereby lowering energy bills. This drop in energy expenditure alleviates output quotas for supplying power plants. In effect, tree shade can lower living expenses and simultaneously mitigate byproduct pollution. However, tree placement does require strategic analysis; it must consider both sun angle at different times of the year as well as the potential interaction of trees with wind. Wind reduction benefits are as conceptually simple as those presented with tree shade; blocking cooling winds during colder seasons limits energy expenditure for heating systems.

All in all, the layout of trees around residential units, if done correctly, has huge potential in saving energy. Research shows that proper placement can decrease annual expenditure via tree shade by \$1 to \$28 per tree per house, while wind block provides savings of roughly \$1 to \$11. However, though the layout of landscape design has on the surface the effects of shade and wind reduction by trees, there are many inherent attributes that can easily be overlooked.

Heat Transfer and Evapotranspirational Cooling

Heat conduction is, at its most basic level, the introduction of energy. All that is introduced is quickly disbursed among surrounding materials. Therefore a constant source of heat energy is needed in order to maintain any temperature above absolute zero. Our primary source, and our only for this discussion, is the Sun. In essence, any attempt to manipulate temperature is an attempt to disrupt the natural flow of the Sun's heat. Much of the energy that enters the atmosphere is quickly scattered and reflected by clouds and air patterns. What remains is then either transferred into water vapor and gasses, or reflected or absorbed by Earth's surfaces.

Absorbed heat is then radiated among other nearby surfaces, watersheds, and atmosphere. When reflected, heat radiation can remain in the atmosphere, trapped by winds, ozone, and other gasses. The overall heating as a result of this process is most commonly known as the "greenhouse effect."

During photosynthesis, plants release water through their stomata. The evaporation of this water, known as transpiration, along with the evaporation of water from surrounding land

surfaces is called evapotranspiration (ET). For a liquid to evaporate, it must draw latent heat, thereby cooling surrounding objects, liquids, and atmosphere. ET cooling is an attribute that all plant-life provide and can prove to be a powerful source of heat-reduction in urban forestation projects. ET cooling has been shown to decrease energy expenditure by about \$1 to \$15 per house for every nearby tree.

Table 6: Energy Savings in \$/year

<u>Type</u>	<u>Value</u>	<u>Cover</u>	<u>Location</u>	<u>Source</u>
Shade	12.00	25' tree	Atlanta, GA	McPherson (1993)a ¹
Shade	0.44	25' tree	Boston, MA	McPherson (1993)a ¹
Shade	11.57	25' tree	Dallas, TX	McPherson (1993)a ¹
Shade	8.95	25' tree	Denver, CO	McPherson (1993)a ¹
Shade	28.81	25' tree	Fresno, CA	McPherson (1993)a ¹
Shade	20.30	25' tree	L.A., CA	McPherson (1993)a ¹
Shade	25.75	25' tree	Miami, FL	McPherson (1993)a ¹
Shade	4.15	25' tree	Minneapolis, MN	McPherson (1993)a ¹
Shade	2.40	25' tree	Portland, OR	McPherson (1993)a ¹
Shade	5.67	25' tree	Rocky Valley, TN	McPherson (1993)a ¹
Shade	21.61	25' tree	Tuscon, AZ	McPherson (1993)a ¹
Shade	4.58	25' tree	Washington DC	McPherson (1993)a ¹
Shade	239.3 [†]	avg. tree	Fresno, CA	McPherson (1993)a
Shade	34	18' tree	Tuscon, AZ	McPherson & Dougherty (1989)
Shade	10	3.1 avg. trees	Sacramento, CA	Simpson & McPherson (1995)
Wind	3.93	25' tree	Atlanta, GA	McPherson (1993)a ¹
Wind	14.19	25' tree	Boston, MA	McPherson (1993)a ¹
Wind	1.75	25' tree	Dallas, TX	McPherson (1993)a ¹
Wind	4.80	25' tree	Denver, CO	McPherson (1993)a ¹
Wind	1.96	25' tree	Fresno, CA	McPherson (1993)a ¹
Wind	0.87	25' tree	L.A., CA	McPherson (1993)a ¹
Wind	0.65	25' tree	Miami, FL	McPherson (1993)a ¹
Wind	10.48	25' tree	Minneapolis, MN	McPherson (1993)a ¹
Wind	3.27	25' tree	Portland, OR	McPherson (1993)a ¹
Wind	6.11	25' tree	Rocky Valley, TN	McPherson (1993)a ¹
Wind	1.96	25' tree	Tuscon, AZ	McPherson (1993)a ¹
Wind	5.46	25' tree	Washington DC	McPherson (1993)a ¹
Wind	18.36 [†]	avg. tree	Fresno, CA	McPherson (1993)a
Wind	2.56; 0.54 ^{††}	40' tree	Minot, ND	Heisler (1991) ¹
Wind	2.26; 0.80 ^{††}	40' tree	Huron, SD	Heisler (1991) ¹

Table 6 cont.: Energy Savings

Wind	1.61; 0.40 ^{††}	40' tree	Minneapolis, MN	Heisler (1991) 1
Wind	1.58; 0.46 ^{††}	40' tree	Grand Island, NE	Heisler (1991) 1
Wind	1.17; - ^{††}	40' tree	Harrisburg, PE	Heisler (1991) 1
Wind	1.22; 0.44 ^{††}	40' tree	Topeka, KS	Heisler (1991) 1
Wind	1.02; 0.68 ^{††}	40' tree	Wichita Falls, TX	Heisler (1991) 1
ET	8.95	25' tree	Atlanta, GA	McPherson (1993) ^{a1}
ET	0.87	25' tree	Boston, MA	McPherson (1993) ^{a1}
ET	6.33	25' tree	Dallas, TX	McPherson (1993) ^{a1}
ET	6.11	25' tree	Denver, CO	McPherson (1993) ^{a1}
ET	11.79	25' tree	Fresno, CA	McPherson (1993) ^{a1}
ET	5.46	25' tree	L.A., CA	McPherson (1993) ^{a1}
ET	23.35	25' tree	Miami, FL	McPherson (1993) ^{a1}
ET	5.46	25' tree	Minneapolis, MN	McPherson (1993) ^{a1}
ET	1.31	25' tree	Portland, OR	McPherson (1993) ^{a1}
ET	5.24	25' tree	Rocky Valley, TN	McPherson (1993) ^{a1}
ET	8.95	25' tree	Tucson, AZ	McPherson (1993) ^{a1}
ET	4.80	25' tree	Washington DC	McPherson (1993) ^{a1}
ET	89.93 [†]	avg. tree	Fresno, CA	McPherson (1993) ^a
Total*	1 mil.	31%, city	Modesto, CA	McPherson et al. (1999)
Total**	1.62	dense shrubs	Tucson, AZ	McPherson et al. (1989) ²

¹ = McPherson (1993)a and Heisler (1991) values were speculated from bar graphs

² = McPherson et al. (1989) values are not annual; 2 week study period in August and October

[†] = Shade Tree Program of Fresno, CA; application of energy efficient landscapes

^{††} = Wind blocks designed to emulate 40 ft trees: N & W block; S block

* = Shade and Climate

** = ET and Shade

CHAPTER 4
CONCLUSIONS

To conclude, the benefits of canopy cover, though often overlooked, are not incalculable. The system derived in this paper details a simple and effective method in deriving reliable prediction coefficients from large study areas with varying location at reasonable expense. Though no approach is without flaws, the method utilized in this paper was constructed with the intent of avoiding inefficiencies of other research. In the following sections, discussions on the nature of this analysis will reveal the utility of its function in practice, followed by concerns for future research.

4.1 Statistical Analysis

Beyond Richmond County, immediate land cover estimates fail to meet statistical significance, thereby revealing the necessity for evaluating land covers at larger ranges. Though the local estimates are for the most part statistically significant, they do come with a few shortcomings. The biggest concern involves the unexpected negative sign. Although an analyst must remain unbiased when interpreting empirical estimates, it is difficult to concede that canopy cover, on average, would decrease land values. On the other hand, the directional consistency among counties encourages confidence in the local range. As stated before, the absence of

benchmark variables requires sturdy criterion for the acceptance of any land cover regressor, which local estimates don't seem to meet. With all of their merit, local cover variables shouldn't be disregarded, instead the reader should keep in mind that strict measures of statistical viability aren't indicative of economic reliability.

Where the other ranges fall short, neighborhood estimates seem to excel. The Henry canopy estimate is the only contradiction, having an unexpected negative sign. Beyond this, the neighbor estimates appear superior, as they more often meet expectations and maintain better consistency.

Before discussing other variables, the issue of differing sizes between canopy and impervious estimates should be addressed. As table 4 illustrates, impervious cover always maintains a greater effect on land values, in magnitude anyways, than canopy cover. It's important for the reader to remember the nature of these regressors, in that both canopy and imperviousness are valued as percentages. Recalling the data analysis in section 2.2.1, we see the effective growth of impervious cover is considerably less pressing than that of canopy cover. In numerical terms, a percentage growth in the 2008 Clarke County average imperviousness of 30.9% doesn't equate to a percentage growth in the canopy cover average of 74.5%. This is reflected in all of the counties, and is an important supporting detail of canopy cover conservation.

Layout and Distances

If preference of neighborhood makeup can be assumed subject to location, these findings indicate that residents of all three counties have little interest in the general size of neighboring buildings. However, these low neighbor size estimates could also indicate an appreciation for diversity among communities in building size and type. As for neighborhood crowding, there seems to be strong implication by the nearest neighbor estimates that residents in both Clarke County and Henry County prefer more condensed communities, while those in Richmond county prefer distance from their neighbors.

Distance variables seem to account for a good deal of information as well. Interestingly, residents from both Clarke County seem to prefer distance from the nearest schools. This can almost be said for Richmond, except that the estimate is so small by comparison, it is practically insignificant. Henry County residents are the only to appreciate proximity to the nearest school. In all counties, nearness to hospitals is desired, with all estimates being large (based in miles) and have a negative sign. Airport proximity is preferred in Clarke and Henry counties, while Richmond county citizens seem uninterested with a small, yet positive sign. Finally, increased distance from the nearest highway is uniformly popular, with estimates for each county having a positive coefficient.

In actuality, inference of layout and distance variables is limited. The monetary benefit provided by layout specification may very easily fail to overcome construction costs. Distances are more useful when thought of as proxies to various demographic and geographic features, without which could cause missing variable bias. The true worth of these regressors is

mathematical. Their inclusion helps prevent over-estimation of land cover coefficients by correctly designating large partitions of correlative information. At the same time these estimates serve, in a sense, as benchmarks; as long as they don't reach absurd or counter-intuitive size or sign, their being statistically significant is evidence for model viability.

Intercepts by Year

Yearly coefficients closely reflect the expectations asserted in the objectives section. For all three counties, the 2008 intercept estimates consistently have higher standard errors. For the most part all estimates grew in size as expected. One potential incongruity would be with Henry, as the yearly estimates maintain high consistency between 2001 and 2008, though this hardly warrants any concern of model failure.

Yearly effects act differently between model type, while the log-transformed estimates efficiently reflect the expected changes due to economic activity. Further, these estimates aid the casual reader's inference of results, as they all have a positive sign. In actuality, the log-transformed model receives its greatest support from the practicality of the output yearly coefficients. That is not to say a non-transformed model would be unreliable, but only that it falls short in convenient interpretation of yearly effects by comparison.

4.2 Canopy Cover Monetary Values

There is a great deal of expense that can be avoided by maintaining pre-existing forests and encouraging tree placement design during and after development. In a sense, urban forests are cost-minimizing economic systems with passive and noninvasive techniques. From another perspective, canopy cover incentivizes more environment-friendly housing with the prospect of increased property values. By considering previous findings as well as those of this study, it can be stated that 1% canopy cover has the potential to annually contribute roughly \$260 to \$570 to individual property values while saving the homeowner roughly \$7 to \$50 in energy expenditure. Further, air quality improvement can be valued from \$91,000 to \$481,000 to respective towns/counties. Indirectly, these measurements could encourage the postponing of a new power plant installation, serving an optimal utility for the economy as well as the environment. Beyond the strict value of canopy cover, the inherent water-retention benefits alone, by some, provide more than enough evidence to explore more stringent conservation techniques. Though these are difficult to summarize, they really don't even need to be measured if avoidable.

Though it is important to consider the full spectrum of benefits in monetary terms, it may be helpful to adopt a naturalistic perception. The best way to do this is to imagine the economy of a personified forest ecosystem. Just by the management of assets and resources alone, this system dominates practically every other known economic system in terms of both efficiency and equity. On paper, this economy has the longest track record of consistent achievement of

net benefits, with the highest yields. With constant and nearly perfect recycling efficiency, this system has somehow managed to escape the umbrella of anthropogenic accomplishment. It should come as no surprise that natural ecosystems are superior environmental conservationists. Quantifying and categorizing the benefits they provide is the first step in developing a fashionable and realistic program. Omitting any of the discussed contributions, even by conservative estimates, may be just enough to have a project proposal thrown out.

4.3 Concerns

Like all infrastructure projects, design must be implemented carefully. Aggressive programs could overlook negative impacts to energy-savings if location-specific aspects aren't considered. Many of the previously discussed conservation features of tree-planting strategies have the potential of being, for a lack of better words, too effective. Further, there are ecological and economic impacts that should be considered before large-scale installation or reinstatement of any kind of land cover.

Although tree shade may provide great energy savings benefits by cooling residential units, this cooling effect can backfire during colder months and actually increase energy use through heating expenditures. For this reason, clear distinctions between evergreen and deciduous trees are made when considering the efficiency of urban forestation projects. For example, McPherson and Simpson's Sacramento simulations considered this effect when including the condition that newly planted trees would be deciduous. It was assumed that even

though the trees would be leafless during the colder months, their structural remains would block 30% of winter sunlight. It was concluded that average annual heating use increased by 0.85 GJ per property per tree after the addition of new trees. (Simpson and McPherson, 1997) In his multiregional simulations, McPherson found that tree-shade alone actually increased energy use in Boston, Minneapolis, and Portland, because more energy was being spent heating the residences during the colder months than there was being saved during the warmer ones. (McPherson, 1993) These effects foreshadow monetary project failures when planning is practiced carelessly.

Statistical Limitations

While our findings appear reasonably reliable by low R^2 spatial statistics modeling, the format and nature of the data calls into question the appropriateness of allowing this model to be considered a spatial one. The primary area of concern is that of the neighborhood estimates. Our results indicated relatively consistent findings, but a second glance at all ranges may shake our confidence. A steady increase in statistical significance and consistency in the neighborhood estimates can be correlated with the rise of range radius. In other words, as the analytical area around each property grows, so does the explanatory power of the model. This is risky; a larger range could swallow a greater deal of information, in-effect creating large estimates of irrelevant parameters. As land covers are somewhat negatively correlated, statistical significance could also grow at the same rate of correlation. As an R^2 cannot be heavily relied upon for these models, perhaps the most appropriate goodness-of-fit measure is one referenced in all fields of

scientific analysis, repetition of findings. In the same spirit, known theories should be considered when observing model behavior, which can be done by residual analysis.

Having yet to publish/present (or find) articles utilizing methods similar to those in this paper, the only form of repetition we have is that of consistency among counties. This consistency is discussed in the results chapter in regards to the neighborhood land cover estimates. As for residual analysis, plots detailed in the appendix and reviewed in the results chapter support the log-transformation method and also indicate data reliability, narrow though it may be. Without preceding literature or a better goodness-of-fit measure, the limited explanation of these indirect measures will have to suffice for now.

BIBLIOGROPHY

American Forests. 2003. Urban ecosystem analysis, Mecklenburg County, North Carolina.

www.americanforests.org.

Anderson, L.M.; Cordell H.K. 1988. Influence of trees on residential property values in Athens, Georgia: A survey based on actual sales prices. *Landscape and Urban Planning*. 15: 153-164.

Booth, D.B.; Hartley, D.; Jackson, R. 2002. Forest cover, impervious-surface area, and the mitigation of stormwater Impacts. *Journal of the American Water Resource Association*. 38(3): 835-845.

Costanza, R.; d'Arge, R.; de Groot, R.; Farber, S; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'Neill, R.V.; Paruelo, J.; Raskin, R.G.; Sutton, P.; van den Belt, M. 1987. The value of the world's ecosystem services and natural capital. *Nature*. 387: 253-260

DeWalle, D.R.; Heisler, G.M.; Jacobs, R.E. 1983. Forest home sites influence heating and cooling energy. *Journal of Forestry*. 81(2): 84-88.

Heggestad, H. E. 1972. How plants fight "man-made" pollution. *The Science Teacher*. (April): 21-24.

Heisler, G.M. 1990. Mean wind speed below building height in residential neighborhoods with different tree densities. *ASHRAE Transactions*. 96(1): 1389-1396.

- Heisler, G.M. 1991. Computer simulation for optimizing windbreak placement to save energy for heating and cooling buildings. In: Proc. of Symp. on Trees and Sustainable Development 2-7 June; Ridgetown College, Ridgetown, Ont., Canada. pp. 100-104.
- Homer, C.; Huang, C.; Yang, L.; Wylie, B.; Coan, M. 2004. Development of a 2001 national landcover database for the United States, Photogrammetric Engineering and Remote Sensing. 70: 829-840.
- Hicks, B. B.; Wesely, M. L.; Durham, J. L.; Brown, M. A. 1982. Some direct measurements of atmospheric sulfur fluxes over a pine plantation. Atmospheric Environment. 16(12): 2899-2903.
- Huang, Y.J.; Akbari, H.; Taha, H.; Rosenfeld, A.H. 1987. The potential of vegetation in reducing summer cooling loads in residential buildings. Journal of Climate and Applied Meteorology. 26: 1103-1116.
- Jo, H.K.; McPherson, E.G. 1995. Carbon storage and flux in residential greenspace. Journal of Environmental Management. 45: 109-133.
- Loren, R.; Murphy, C. E. 1985. The dry deposition of sulfur oxide on a loblolly plantation. Atmospheric Environment. 19(5): 797-802.
- McPherson, E. G. 1990. Modeling residential landscape water and energy use to evaluate water conservation policies. Landscape Journal 9(2): 122-34.
- McPherson, E. G. 1991. Economic modeling for large-scale urban tree plantings. In Energy Efficiency and the Environment: Forging the link. Washington: American Council for an Energy Efficient Economy.

- McPherson, E.G. 1993. Evaluating the cost effectiveness of shade trees for demand-side management. *The Electricity Journal*. 6(9): 57-65.
- McPherson, E.G. 1994. Cooling urban heat islands with sustainable landscapes. *The Ecological City: Preserving and Restoring Urban Biodiversity*. 151-171.
- McPherson, E.G.; Dougherty, E. 1989. Selecting trees for shade in the southwest. *Journal of Arboriculture*. 15(2): 35-43.
- McPherson, E.G.; Simpson, J.R.; Livingston, M. 1989b. Effects of three landscape treatments on residential energy and water use in Tuscon, Arizona. *Energy and Buildings* 16: 127-138.
- McPherson, E. G.; Sacamano, P. L.; Wensman, S. 1993. Modeling benefits and costs of community tree plantings. USDA Forest Service, Western Center for Urban Forest Research, technical report.
- McPherson, E.G.; Simpson, J.R. 1995. Shade trees as a demand side resource. *Home Energy Magazine*. 12: 11-17.
- Millennium Ecosystem Assessment. 2005. *Ecosystems and human well-being*. Washington, DC: Island Press.
- Murphy, C. E.; Sinclair, T. R.; Knoerr, K. R. 1977. An assessment of the use of forests as sinks for the removal of atmospheric sulfur dioxide. *Journal of Environmental Quality*. 6(4): 388-396.
- Nowak, D.J. 1993. Atmospheric carbon reduction by urban trees. *Journal of Environmental Management*. 37: 207-217.

- Nowak, D.J. 1994a. Air pollution removal by Chicago's urban forest. In: McPherson, E.G., Nowak, D.J., Rowntree, R.A (Eds.), Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project (NE-186). Forest Service, US Dept. of Agriculture, Department of Agriculture, Radnor, PA., pp. 63-81.
- Nowak, D.J. 1994b. Atmospheric carbon dioxide reduction by Chicago's urban forest. In: McPherson, E.G., Nowak, D.J., Rowntree, R.A (Eds.), Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project (NE-186). Forest Service, US Dept. of Agriculture, Department of Agriculture, Radnor, PA., pp. 83-94.
- Pielke, Jr., R.A.; Downton, M.W.; Barnard Miller, J.Z. 2002. Flood damage in the United States, 1926-2000: A reanalysis of national weather service estimates. Boulder, CO: UCAR.
- Powe, N.A.; Garrod, G.D.; Brunsdon, C.F.; Willis, K.G. 1997. Using a geographic information system to estimate an hedonic price model of the benefits of woodland access. *Forestry*. 70(2): 139-149.
- Price, C. 2003. Quantifying the aesthetic benefits of urban forestry. *Urban Forestry & Urban Greening*. 1: 123-133.
- Rowntree, R. A.; Nowak, D.J. 1991. Quantifying the role of urban forests in removing atmospheric carbon dioxide. *Journal of Arboriculture*. 17: 269-275.
- Simpson, J.R. 2002. Improved estimates of tree-shade effects on residential energy use. *Energy and Buildings*. 34(10): 1067-1076
- Simpson, J.R.; McPherson, E.G. 1997. Simulation of tree shade impacts on residential energy use for space conditioning in Sacramento. *Atmospheric Environment*. 32(1): 69-74.

- Tyrväinen, L. 1997. The amenity value of the urban forest: an application of the hedonic pricing method. *Landscape and Urban Planning*. 37: 211-222.
- Wesely, M. L.; Lesht, B. M. 1988. Comparison of the RADM dry deposition module with side-specific routines for inferring dry deposition. EPA/600/54-88/027. Research Triangle Park, NC: U.S. Environmental Protection Agency. 101 p.
- Wissmar, R. C.; R. K. Timm; M. G. Logsdon. 2004. Effects of changing forest and impervious land covers on discharge characteristics of watersheds. *Environmental Management* 34: 91-98.

APPENDIX

1. Pooled Ordinary Least Squares Results

1.1 Non-Transformed

Clarke	Coefficients (Std.Error) by radial range (m ²)						
	100	250	500	750	1000	1250	1500
Canopy	24.23 (61.50)	31.21 (57.21)	34.58 (56.81)	47.50 (56.85)	54.27 (56.88)	56.53 (56.84)	54.92 (56.81)
Impervious	-184.00 (95.93)	-98.53 (93.65)	-106.72 (93.20)	-153.09 (93.28)	-177.03 (93.32)	-191.26 (93.27)	-205.10 (93.21)
Local Canopy	33.09 (178.65)	267.45 (103.55)	224.41 (84.84)	172.81 (81.45)	162.41 (80.06)	158.94 (79.16)	165.05 (78.51)
Local Impervious	4263.67 (201.60)	3124.91 (168.66)	3318.18 (150.29)	3684.37 (145.71)	3862.98 (143.69)	3963.15 (142.50)	4037.38 (141.65)
Neighbor Canopy	267.65 (193.60)	274.30 (105.82)	513.33 (99.20)	575.64 (106.33)	546.15 (118.00)	506.79 (126.52)	390.29 (134.61)
Neighbor Impervious	-37.28 (198.35)	1902.62 (171.00)	2365.11 (165.40)	2008.29 (168.89)	1864.72 (175.77)	1563.65 (180.59)	1247.18 (185.36)
Neighbor Size	17.98 (1.43)	12.95 (1.43)	5.89 (1.28)	4.42 (1.32)	2.81 (1.38)	5.51 (1.47)	7.91 (1.56)
Nearest Neighbor	-260.21 (18.80)	-322.05 (24.67)	-470.74 (36.60)	-533.26 (42.49)	-565.29 (47.38)	-755.65 (54.46)	-947.43 (61.68)
Schools	-3929.18 (1982.50)	-476.73 (1989.99)	4110.83 (2034.50)	4611.27 (2057.39)	4215.97 (2066.10)	4993.75 (2061.64)	4837.14 (2053.01)
Hospitals	-16523.05 (733.42)	-14861.47 (747.71)	-13097.56 (765.90)	-12717.32 (781.80)	-12250.36 (805.96)	-11022.79 (832.95)	-9821.15 (863.50)
Airports	-12141.91 (493.94)	-11094.68 (497.50)	-9645.55 (508.54)	-9272.69 (520.09)	-8842.55 (534.91)	-7942.31 (554.15)	-7035.68 (574.65)
Highways	3578.03 (1611.87)	5841.86 (1605.97)	10347.96 (1633.70)	11175.26 (1659.41)	11262.00 (1675.44)	12446.51 (1689.72)	13398.18 (1701.13)
Year 2001	110365.79 (6653.72)	91932.50 (7448.46)	87129.48 (8157.95)	91761.35 (8772.63)	97314.70 (9396.08)	105862.15 (9826.98)	119918.91 (10311.99)
Year 2005	114847.71 (5768.29)	94367.84 (6727.54)	88986.33 (7533.87)	94131.26 (8208.82)	99507.94 (8865.24)	108409.47 (9326.21)	122861.68 (9838.97)
Year 2008	141421.94 (6280.36)	106223.04 (7623.83)	92146.52 (8790.55)	98450.33 (9699.32)	103957.87 (10567.40)	115521.28 (11164.78)	133447.61 (11807.49)
R-Squared	0.2089	0.2133	0.2171	0.2141	0.2123	0.2126	0.2129

Henry	Coefficients (Std.Error) by radial range (m²)					
	100	250	500	750	1000	1250
Canopy	-36.24 (10.62)	-30.43 (9.67)	-21.21 (9.75)	-19.13 (9.80)	-21.71 (9.80)	-23.38 (9.81)
Impervious	-109.36 (14.85)	69.79 (14.29)	24.96 (14.41)	15.97 (14.50)	13.97 (14.50)	10.88 (14.52)
Local Canopy	-51.14 (29.68)	-23.21 (16.83)	-29.54 (14.49)	-14.47 (13.94)	1.67 (13.63)	15.76 (13.48)
Local Impervious	1795.38 (32.01)	1528.07 (26.34)	1982.09 (24.00)	2132.01 (23.29)	2180.40 (22.81)	2233.41 (22.57)
Neighbor Canopy	178.71 (32.24)	239.41 (15.83)	280.04 (14.86)	262.84 (15.76)	217.39 (17.11)	143.91 (18.43)
Neighbor Impervious	1094.39 (32.09)	1687.63 (27.19)	1282.81 (29.23)	1359.84 (30.58)	1584.02 (31.87)	1628.45 (33.03)
Neighbor Size	-7.13 (0.26)	-4.66 (0.26)	1.12 (0.21)	0.77 (0.16)	0.13 (0.11)	0.03 (0.08)
Nearest Neighbor	-126.19 (3.40)	-254.26 (5.09)	-384.61 (7.11)	-317.21 (7.82)	-245.56 (8.32)	-204.41 (8.86)
Schools	-1566.86 (64.11)	-1036.54 (63.41)	-852.48 (64.74)	-941.89 (65.32)	-951.56 (65.54)	-966.58 (65.81)
Hospitals	-427.13 (20.72)	-240.25 (20.64)	-135.36 (21.28)	-145.65 (21.71)	-142.04 (21.99)	-142.36 (22.32)
Airports	-137.20 (42.07)	-68.09 (41.33)	26.25 (41.81)	15.23 (42.09)	-34.92 (42.08)	-74.58 (42.14)
Highways	-1237.12 (67.73)	-656.73 (67.13)	-617.99 (68.67)	-558.84 (69.87)	-424.77 (70.54)	-351.63 (71.09)
Year 2001	54230.35 (1009.08)	46259.33 (1103.58)	42994.18 (1242.61)	34950.12 (1329.37)	28082.22 (1401.21)	26046.09 (1477.99)
Year 2005	60617.84 (1053.68)	50421.41 (1153.24)	47704.98 (1296.72)	39165.20 (1381.74)	31549.25 (1450.32)	29142.37 (1524.67)
Year 2008	52301.77 (1150.10)	31982.35 (1321.82)	28923.92 (1571.07)	16783.58 (1728.60)	3727.28 (1865.55)	-507.32 (1991.57)
R-Squared	0.5192	0.5377	0.5269	0.5202	0.5195	0.5182

Richmond	Coefficients (Std.Error) by radial range (m²)						
	100	250	500	750	1000	1250	1500
Canopy	-5.77 (15.91)	80.39 (15.68)	69.75 (14.91)	56.50 (14.77)	54.78 (14.93)	52.66 (15.14)	53.37 (15.30)
Impervious	98.86 (19.90)	60.58 (19.48)	44.56 (18.60)	42.14 (18.44)	45.74 (18.64)	46.07 (18.91)	44.33 (19.11)
Local Canopy	57.52 (54.69)	-34.85 (30.32)	33.54 (25.12)	63.22 (23.96)	81.94 (23.75)	115.89 (23.87)	124.32 (24.00)
Local Impervious	177.57 (49.17)	1000.45 (36.90)	990.01 (31.32)	956.53 (30.20)	986.49 (30.07)	1035.84 (30.27)	1055.60 (30.47)
Neighbor Canopy	331.93 (58.54)	642.20 (30.45)	376.91 (26.73)	353.55 (26.50)	397.18 (27.37)	391.54 (28.43)	408.60 (29.52)
Neighbor Impervious	290.85 (53.63)	-142.82 (39.25)	-826.32 (36.91)	-830.54 (37.00)	-757.27 (37.90)	-692.34 (38.72)	-771.72 (39.44)
Neighbor Size	39.10 (0.33)	21.62 (0.34)	37.20 (0.47)	34.62 (0.50)	29.15 (0.54)	23.36 (0.59)	22.74 (0.63)
Nearest Neighbor	-278.25 (10.05)	280.74 (18.26)	70.36 (25.26)	354.38 (29.26)	676.20 (32.35)	1015.02 (35.31)	1028.81 (37.72)
Schools	-290.30 (72.64)	-376.56 (76.72)	-120.61 (74.76)	-168.79 (75.01)	-466.18 (76.33)	-748.92 (77.88)	-810.53 (79.31)
Hospitals	-1128.48 (65.33)	-1378.23 (67.77)	-1632.77 (65.79)	-1723.91 (66.16)	-1841.04 (68.21)	-1969.46 (70.58)	-1940.82 (72.48)
Airports	-421.12 (57.92)	-330.94 (59.62)	-159.89 (57.21)	-270.97 (56.84)	-193.15 (57.61)	-165.11 (58.69)	-254.38 (59.61)
Highways	156.27 (202.46)	387.66 (210.09)	84.19 (204.69)	-532.14 (205.69)	-1376.79 (210.31)	-2160.67 (215.01)	-2439.98 (218.81)
Year 2001	-13529.37 (1468.49)	-40884.67 (1927.14)	-34170.29 (2189.04)	-47852.04 (2352.89)	-63363.00 (2496.37)	-76635.31 (2611.35)	-74834.85 (2701.74)
Year 2005	-2284.66 (1519.95)	-29948.35 (1990.04)	-21662.43 (2260.26)	-35122.58 (2426.78)	-50675.75 (2571.36)	-64178.92 (2686.45)	-62114.74 (2776.68)
Year 2008	11621.84 (1666.98)	-17118.06 (2227.12)	-1236.28 (2576.02)	-13425.91 (2791.34)	-29253.87 (2982.63)	-43371.68 (3128.60)	-39942.71 (3243.88)
R-Squared	0.2648	0.2253	0.2888	0.2991	0.2828	0.2620	0.2460

1.2 Log-Transformed

Clarke	Coefficients (Std.Error) by radial range (m ²)						
	100	250	500	750	1000	1250	1500
Canopy	0.0006 (0.0003)	0.0005 (0.0002)	0.0006 (0.0002)	0.0007 (0.0002)	0.0008 (0.0002)	0.0008 (0.0002)	0.0008 (0.0002)
Impervious	-0.0015 (0.0004)	-0.0011 (0.0004)	-0.0013 (0.0004)	-0.0015 (0.0004)	-0.0016 (0.0004)	-0.0017 (0.0004)	-0.0017 (0.0004)
Local Canopy	0.0015 (0.0007)	0.0003 (0.0004)	-0.0004 (0.0004)	-0.0008 (0.0003)	-0.0009 (0.0003)	-0.0008 (0.0003)	-0.0008 (0.0003)
Local Impervious	0.0244 (0.0008)	0.0206 (0.0007)	0.0229 (0.0006)	0.0242 (0.0006)	0.0251 (0.0006)	0.0257 (0.0006)	0.0261 (0.0006)
Neighbor Canopy	-0.0007 (0.0008)	0.0018 (0.0004)	0.0039 (0.0004)	0.0047 (0.0004)	0.0049 (0.0005)	0.0047 (0.0005)	0.0042 (0.0006)
Neighbor Impervious	-0.0002 (0.0008)	0.0081 (0.0007)	0.0064 (0.0007)	0.0058 (0.0007)	0.0060 (0.0007)	0.0048 (0.0008)	0.0038 (0.0008)
Neighbor Size	0.0001 (0.0000)	0.0001 (0.0000)	0.0001 (0.0000)	0.0001 (0.0000)	0.0001 (0.0000)	0.0001 (0.0000)	0.0001 (0.0000)
Nearest Neighbor	-0.0043 (0.0001)	-0.0049 (0.0001)	-0.0075 (0.0002)	-0.0083 (0.0002)	-0.0086 (0.0002)	-0.0099 (0.0002)	-0.0111 (0.0003)
Schools	-0.0101 (0.0082)	-0.0033 (0.0084)	0.0412 (0.0086)	0.0465 (0.0087)	0.0404 (0.0088)	0.0366 (0.0087)	0.0275 (0.0087)
Hospitals	-0.1580 (0.0030)	-0.1492 (0.0031)	-0.1334 (0.0032)	-0.1267 (0.0033)	-0.1193 (0.0034)	-0.1089 (0.0035)	-0.0999 (0.0037)
Airports	-0.0839 (0.0021)	-0.0787 (0.0021)	-0.0692 (0.0021)	-0.0648 (0.0022)	-0.0605 (0.0023)	-0.0529 (0.0023)	-0.0467 (0.0024)
Highways	0.0983 (0.0067)	0.0976 (0.0068)	0.1290 (0.0069)	0.1345 (0.0070)	0.1332 (0.0071)	0.1420 (0.0072)	0.1493 (0.0072)
Year 2001	11.5653 (0.0277)	11.4691 (0.0313)	11.4567 (0.0343)	11.4506 (0.0370)	11.4385 (0.0398)	11.4811 (0.0417)	11.5441 (0.0438)
Year 2005	11.7410 (0.0240)	11.6328 (0.0283)	11.6304 (0.0317)	11.6265 (0.0346)	11.6100 (0.0376)	11.6512 (0.0395)	11.7142 (0.0418)
Year 2008	11.9478 (0.0261)	11.7742 (0.0321)	11.7662 (0.0369)	11.7599 (0.0409)	11.7368 (0.0448)	11.7892 (0.0473)	11.8645 (0.0501)
R-Squared	0.5096	0.5007	0.5041	0.4988	0.4929	0.4922	0.4910

Henry	Coefficients (Std.Error) by radial range (m²)					
	100	250	500	750	1000	1250
Canopy	0.0009 (0.0001)	0.0005 (0.0001)	0.0008 (0.0001)	0.0008 (0.0001)	0.0009 (0.0001)	0.0009 (0.0001)
Impervious	-0.0016 (0.0001)	0.0006 (0.0001)	0.0002 (0.0001)	0.0000 (0.0001)	-0.0001 (0.0001)	-0.0001 (0.0001)
Local Canopy	-0.0010 (0.0003)	-0.0003 (0.0002)	-0.0017 (0.0001)	-0.0020 (0.0001)	-0.0022 (0.0001)	-0.0024 (0.0001)
Local Impervious	0.0193 (0.0003)	0.0172 (0.0003)	0.0219 (0.0002)	0.0240 (0.0002)	0.0251 (0.0002)	0.0257 (0.0002)
Neighbor Canopy	-0.0003 (0.0003)	-0.0010 (0.0002)	0.0001 (0.0001)	-0.0001 (0.0002)	-0.0003 (0.0002)	-0.0005 (0.0002)
Neighbor Impervious	0.0119 (0.0003)	0.0170 (0.0003)	0.0137 (0.0003)	0.0136 (0.0003)	0.0147 (0.0003)	0.0153 (0.0003)
Neighbor Size	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)
Nearest Neighbor	-0.0038 (0.0000)	-0.0052 (0.0001)	-0.0069 (0.0001)	-0.0066 (0.0001)	-0.0061 (0.0001)	-0.0058 (0.0001)
Schools	-0.0186 (0.0006)	-0.0116 (0.0006)	-0.0082 (0.0006)	-0.0090 (0.0007)	-0.0091 (0.0007)	-0.0090 (0.0007)
Hospitals	-0.0116 (0.0002)	-0.0105 (0.0002)	-0.0092 (0.0002)	-0.0092 (0.0002)	-0.0092 (0.0002)	-0.0089 (0.0002)
Airports	-0.0071 (0.0004)	-0.0067 (0.0004)	-0.0065 (0.0004)	-0.0068 (0.0004)	-0.0072 (0.0004)	-0.0076 (0.0004)
Highways	-0.0120 (0.0007)	-0.0037 (0.0007)	0.0000 (0.0007)	0.0021 (0.0007)	0.0033 (0.0007)	0.0040 (0.0007)
Year 2001	10.8762 (0.0098)	10.8100 (0.0109)	10.9144 (0.0123)	10.8956 (0.0133)	10.8459 (0.0141)	10.8202 (0.0149)
Year 2005	11.0744 (0.0103)	10.9792 (0.0114)	11.0836 (0.0129)	11.0594 (0.0138)	11.0047 (0.0146)	10.9760 (0.0154)
Year 2008	11.0137 (0.0112)	10.8287 (0.0131)	10.9201 (0.0156)	10.8723 (0.0172)	10.7810 (0.0187)	10.7304 (0.0201)
R-Squared	0.6762	0.6803	0.6712	0.6620	0.6570	0.6540

Richmond

	Coefficients (Std.Error) by radial range (m ²)						
	100	250	500	750	1000	1250	1500
Canopy	-0.0001 (0.0002)	0.0018 (0.0002)	0.0016 (0.0002)	0.0014 (0.0002)	0.0014 (0.0002)	0.0013 (0.0002)	0.0013 (0.0002)
Impervious	0.0011 (0.0002)	0.0006 (0.0002)	0.0003 (0.0002)	0.0003 (0.0002)	0.0004 (0.0002)	0.0004 (0.0002)	0.0004 (0.0002)
Local Canopy	0.0012 (0.0006)	-0.0007 (0.0003)	0.0007 (0.0003)	0.0013 (0.0003)	0.0018 (0.0003)	0.0024 (0.0003)	0.0026 (0.0003)
Local Impervious	0.0034 (0.0006)	0.0173 (0.0004)	0.0187 (0.0004)	0.0185 (0.0003)	0.0187 (0.0003)	0.0191 (0.0003)	0.0193 (0.0003)
Neighbor Canopy	0.0074 (0.0007)	0.0127 (0.0003)	0.0099 (0.0003)	0.0101 (0.0003)	0.0111 (0.0003)	0.0113 (0.0003)	0.0116 (0.0003)
Neighbor Impervious	0.0062 (0.0006)	-0.0008 (0.0004)	-0.0102 (0.0004)	-0.0105 (0.0004)	-0.0095 (0.0004)	-0.0090 (0.0004)	-0.0103 (0.0004)
Neighbor Size	0.0005 (0.0000)	0.0002 (0.0000)	0.0003 (0.0000)	0.0003 (0.0000)	0.0002 (0.0000)	0.0002 (0.0000)	0.0002 (0.0000)
Nearest Neighbor	-0.0056 (0.0001)	0.0029 (0.0002)	0.0021 (0.0003)	0.0059 (0.0003)	0.0097 (0.0004)	0.0129 (0.0004)	0.0131 (0.0004)
Schools	0.0046 (0.0008)	0.0032 (0.0009)	0.0034 (0.0009)	0.0015 (0.0009)	-0.0022 (0.0009)	-0.0055 (0.0009)	-0.0069 (0.0009)
Hospitals	-0.0265 (0.0007)	-0.0319 (0.0008)	-0.0377 (0.0008)	-0.0404 (0.0008)	-0.0429 (0.0008)	-0.0450 (0.0008)	-0.0458 (0.0008)
Airports	-0.0040 (0.0007)	-0.0020 (0.0007)	0.0009 (0.0007)	0.0004 (0.0006)	0.0016 (0.0007)	0.0023 (0.0007)	0.0018 (0.0007)
Highways	0.0467 (0.0023)	0.0448 (0.0024)	0.0296 (0.0023)	0.0149 (0.0023)	0.0003 (0.0024)	-0.0111 (0.0024)	-0.0173 (0.0024)
Year 2001	9.6502 (0.0166)	9.1917 (0.0220)	9.2675 (0.0250)	9.0958 (0.0267)	8.9163 (0.0282)	8.7932 (0.0293)	8.8254 (0.0302)
Year 2005	9.8036 (0.0172)	9.3387 (0.0228)	9.4352 (0.0258)	9.2673 (0.0276)	9.0887 (0.0290)	8.9650 (0.0301)	9.0014 (0.0310)
Year 2008	10.0059 (0.0188)	9.5171 (0.0255)	9.7077 (0.0294)	9.5557 (0.0317)	9.3737 (0.0337)	9.2473 (0.0351)	9.3052 (0.0362)
R-Squared	0.3327	0.2808	0.3415	0.3576	0.3515	0.3402	0.3324

2. White Tests for 750 meter POLS

Non-Transformed Model				
	Clarke	Henry	Richmond	
D.F	116	117	117	
Chi-Square	1054	6423	4340	
P-Value	0	0	0	

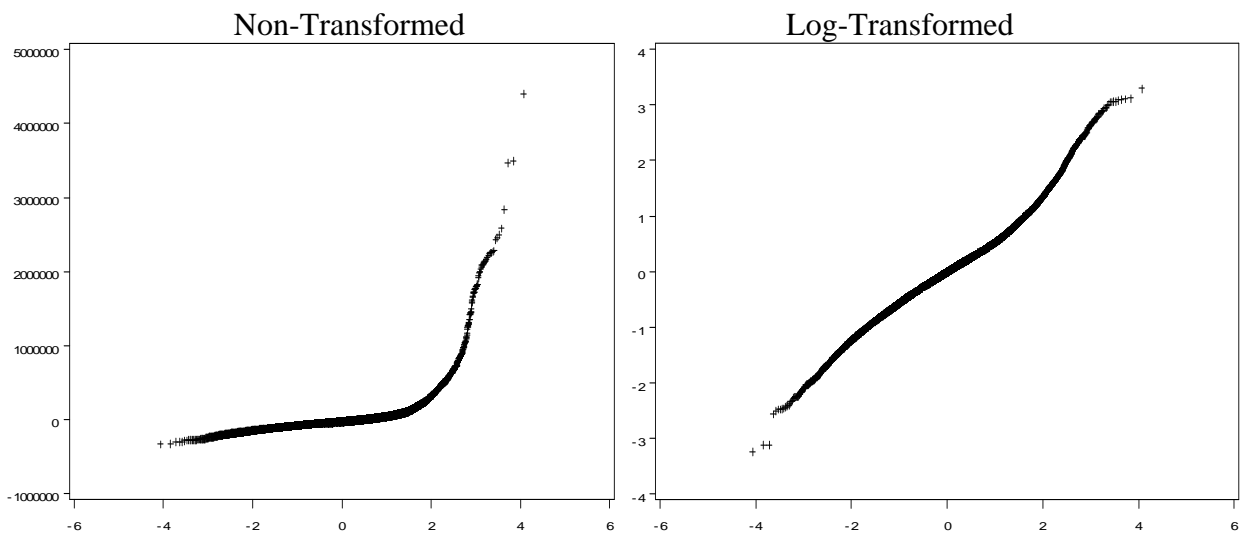
Log-Transformed Model				
	Clarke	Henry	Richmond	
D.F	116	116	117	
Chi-Square	1907	3843	5360	
P-Value	0	0	0	

White tests performed in SAS, using SPEC option of PROC REG procedure

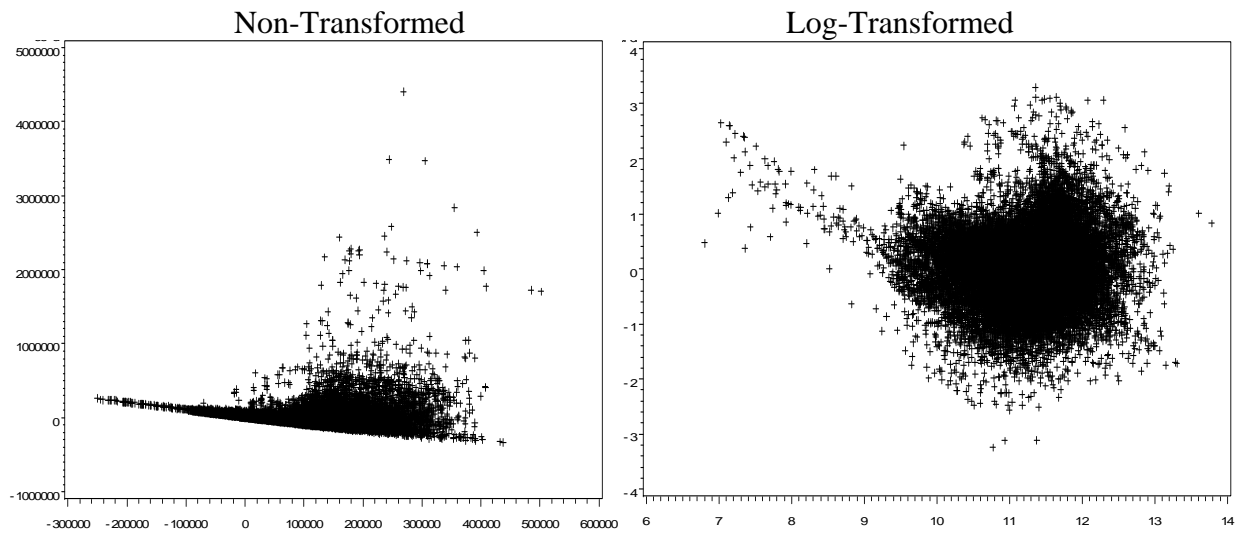
3. Residual Analysis plots for 750 meter POLS

Clarke

QQ-Plot for Normality

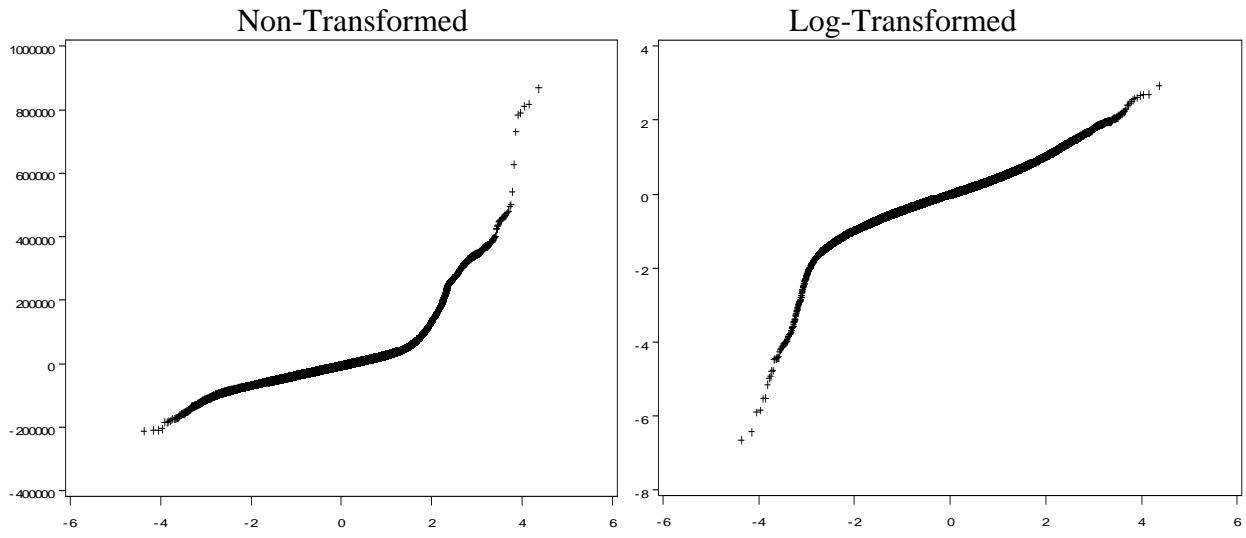


Residual vs. Fitted Plot for Heteroscedasticity

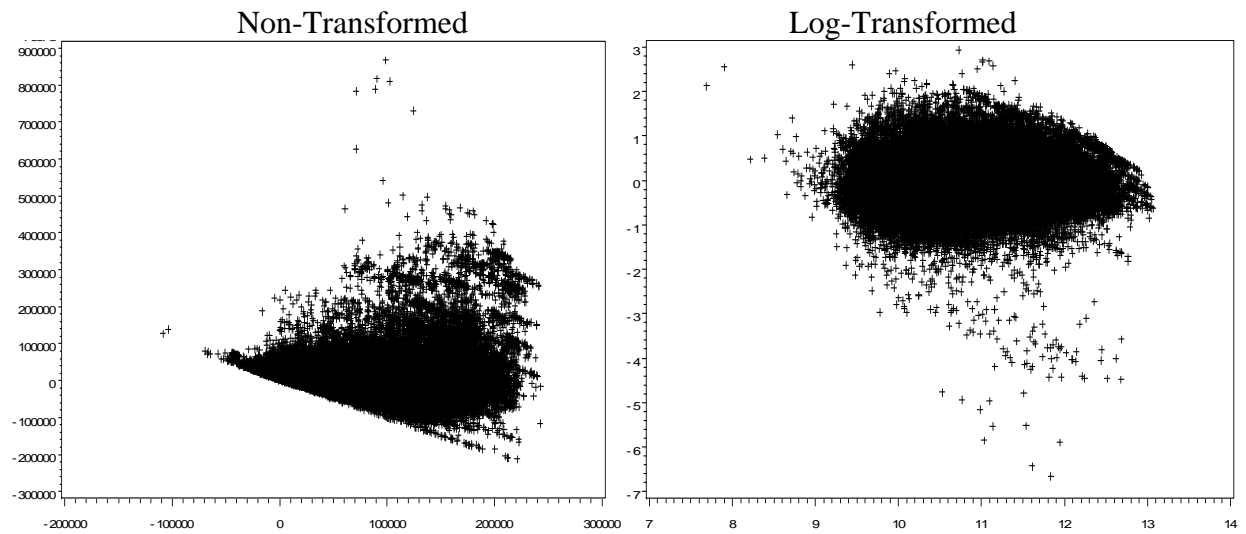


Henry

QQ-Plot for Normality

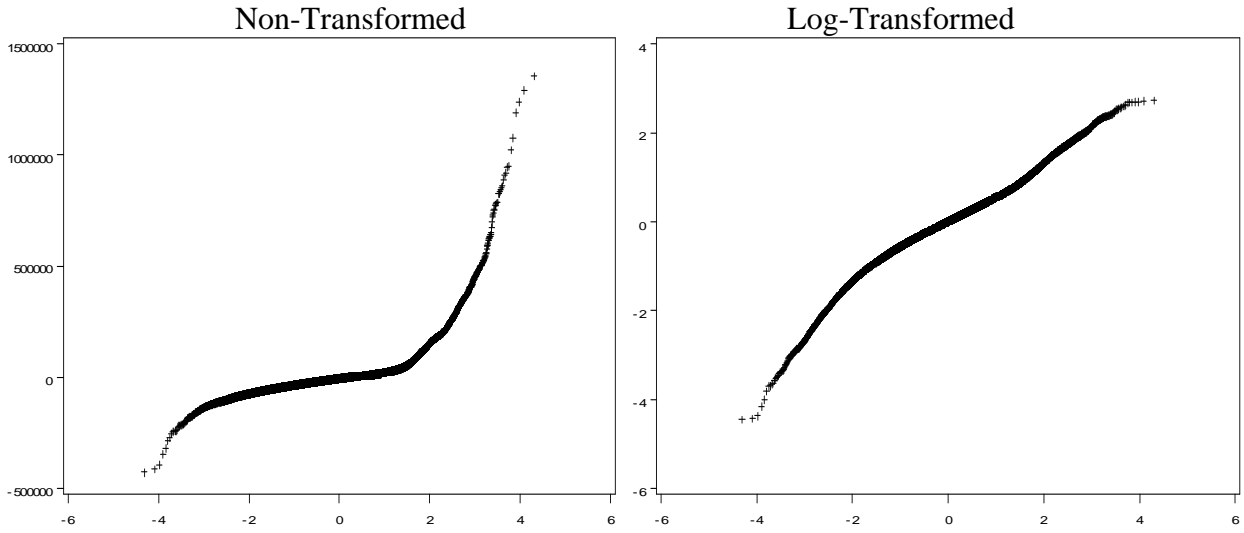


Residual vs. Fitted Plot for Heteroscedasticity



Richmond

QQ-Plot for Normality



Residual vs. Fitted Plot for Heteroscedasticity

