DEMAND FOR URBAN FORESTS: A NATIONAL AND REGIONAL STUDY

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DEMAND FOR URBAN FORESTS: A NATIONAL AND REGIONAL STUDY

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DEMAND FOR URBAN FORESTS: A NATIONAL AND REGIONAL STUDY

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THESIS ABSTRACT

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Various public policies have been designed to protect our green spaces and stimulate the demand for urban forests within communities. However, very few studies have been conducted to uncover the factors influencing the demand for urban forests and the sensitivity of demand to price and income. This thesis will shed some light by empirically estimating the demand for urban forests. It comprises two interrelated parts, in which two different models and two different data sets are used to test the relationship between various socioeconomic factors and demand for urban forests.

In Part I, a theoretical economic model is specified and per capita urban forest data as well as other socioeconomic data from all cities with population over 100,000 across the nation are collected and used for the estimation. The empirical findings suggest that the demand for urban forests is elastic with respect to price and highly responsive to changes in income. The results also show that population growth might induce a negative influence, while urban sprawl has a positive impact on the demand for urban forests.

In Part II, I examine the relationship between percentage of urban forests and household income and population density, focusing on cities with populations over 40,000 within the southeast region. Our empirical results show that urban forest percentage across the cities has characteristics of the Environmental Kuznets Curve. We find that household income around $39,000 is a turning point that changes the relationship between income and urban forest coverage from negative to positive; whereas the impact of population density on urban forests is just the opposite, from positive to negative when population density is around 180 persons per square kilometer.

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INTRODUCTION

Trees have been recognized as an important component of urban landscapes throughout the history of urbanization. As early as in 1902, Ebenezer Howard brought forward the “Garden City” concept in his book entitled *Garden Cities of Tomorrow*. This pervasive theme has run through all the various dimensions of urbanization in twentieth-century America. “Garden City”, conceived as an oasis of civilization not too far from a major urban center, connected to the center by some sort of congestion-free transportation system but separated from the center by a greenbelt, has placed a great emphasis on urban trees.

Now, one hundred years have passed. In this most important century of human development, various public policies have been designed to protect our green spaces and stimulate the demand for urban forests within communities. However, very few studies have been conducted to uncover the factors influencing the demand for urban forests and the sensitivity of demand to price and income. This thesis will shed some light by empirically estimating the demand for urban forest. It comprises two interrelated parts, in which two different models and two different data sets are used to test the relationship between various socioeconomic factors and demand for urban forests.

In Part I, a theoretical economic model is specified and per capita urban forest data as well as other socioeconomic data from all cities with population over 100,000 across the nation are collected and used for the estimation. The empirical findings suggest that the demand for urban forests is elastic with respect to price and highly responsive to changes in income. The results also show that population growth might induce a negative influence, while urban sprawl has a positive impact on the demand for urban forests.

In Part II, we examine the relationship between percentage of urban forests and household income and population density, focusing on cities with populations over 40,000 within the southeast region. Our empirical results show that urban forest percentage across the cities has characteristics of the Environmental Kuznets Curve. We find that household income around $39,000 is a turning point that changes the relationship between income and urban forest coverage from negative to positive; whereas the impact of population density on urban forests is just the opposite, from positive to negative when population density is around 180 persons per square kilometer.

The sample cities selected in the above two parts are different. In the first part, cities across the whole nation are studied. Due to the different temperature, precipitation and geographic factors, the possibility is greatly increased that natural environmental factors will have an impact on the accuracy of our estimation. Therefore, an ecoregion dummy controlling these natural environmental factors is used in our model. In the second part, we try to reduce the natural environmental impact to the minimum level. Cities within the southeast region are selected, due to their relatively homogenous climate and environment.

This thesis will contribute to our knowledge of how socioeconomic factors influence the demand for urban forests. This knowledge is essential to the formulation of effective urban forest policies in the future. It will also help to expand the scope of research within forestry. Previous work has largely focused on the value of urban forest and demand for other environmental goods. Now, it is time to elevate the discussion by beginning to focus on the demand for urban forests.

PART I – DEMAND FOR URBAN FORESTS IN UNITED STATES CITIES

1. Introduction

Trees have been recognized as an important component of urban landscapes throughout the history of urbanization. As early as in 1902, Ebenezer Howard brought forward the "Garden City" concept in his book entitled *Garden Cities of Tomorrow*. This pervasive theme has run through all the various dimensions of urbanization in twentieth-century America. "Garden City", conceived as an oasis of civilization not too far from a major urban center, connected to the center by some sort of congestion-free transportation system but separated from the center by a greenbelt, has placed a great emphasis on urban trees.

As urbanization continues, scientific understanding of how urban trees, forests and green spaces benefit people has expanded substantially to include environmental, social and economic domains. Sociologists and economists found that urban trees, in addition to providing environmental and aesthetic benefits, also brought a broad range of economic, social, and even psychological benefits. In recent years, urban forest valuation studies have addressed many facets of urban forest benefits. These economic valuations translate urban forest functions and benefits into terms that enhance public values.

Environmental Functions and Benefits

Trees in urban landscapes moderate temperature and microclimates, thereby reducing needs for air conditioning and saving energy (Heisler, 1986; McPherson, 1990; Meier, 1991; Oke, 1989). Urban trees help improve air quality and sequester carbon (Nowak, 1993; Nowak and McPherson, 1993; Rowntree and Nowak, 1991; Smith, 1981), help stabilize soils, reduce erosion, improve groundwater recharge, control rainfall runoff and flooding (Sanders, 1986), reduce urban noise levels (Cook, 1978), and provide habitat that increases biodiversity (Johnson, 1988). Based on modeling of air pollution, stormwater mitigation and energy impacts, the annual values of urban forest services are estimated. For instance, the Urban Ecosystem Analysis of the Washington D.C. Metropolitan Area concluded that tree cover had reduced storm water storage costs by US$4.7 billion and generated annual air quality savings of $49.8 million (American Forests, 2002).

Micro-scale studies which focus on street tree costs and benefits have also been conducted. Costs include tree planting, irrigation, pruning and other maintenance. Calculated benefits include energy savings, reduced atmospheric carbon dioxide, improved air quality, and reduced stormwater runoff. Economists have shown that these types of benefits may outweigh the costs of urban forestry programs by considerable margins (McPherson, 1992, 1994; McPherson and Biedenbender, 1991; McPherson et al., 1997; McPherson et al., 1998). For instance, a 2002 analysis for Seattle, WA, indicated that per tree average annual net benefits were $1 to $8 for a small tree, $19 to $25 for a medium-sized tree, and $48 to $53 for a large tree (CUFR 2002).

Economic Functions and Benefits

Urban forests can be planned to directly affect the economic development of a municipality or region. The most direct valuation is to estimate marketable goods, or the value of purchase substitutes. For example, urban forests can produce human and animal foods, building materials, fuels, and medicinal materials, thus contributing to the reduction of the costs of distribution systems needed if they are transported from rural areas.

Urban trees also make neighborhoods aesthetically more appealing and add to the value of property (Schroeder, 1989). Hedonic or amenity pricing is often used to measure a price increment that correlates with a desirable condition or situation. Previous hedonic price analyses showed clearly that trees increase the value of residential properties and that people are willing to pay more for housing with trees (Anderson and Cordell, 1985, 1988; Morales, 1980; Payne and Strom, 1975). More recently, Crompton (2001) concluded that a quality forest or green space has a positive economic ripple effect on nearby properties. Appraised property values of homes that are adjacent to parks and open spaces are typically about 8 to 20 percent higher than those of comparable properties elsewhere. Rental rates of commercial office properties were about 7 percent higher on sites having a quality landscape, which included trees (Crompton, 2001).

Studies on how trees affect shoppers' behavior in retail business districts employ the contingent valuation method. Consumers claim they are willing to pay about 9 to 12 percent more for products in downtown shopping areas with trees, versus in comparable districts without trees. Customer service, merchant helpfulness, and product quality are all judged to be better by shoppers in places with trees (Crompton, 2001).

Social Functions and Benefits

Evidences also have been shown that urban forests may reduce human stress levels (Ulrich, 1984), promote social integration of older adults with their neighbors (Kweon et al., 1998), and provide local residents with opportunities for emotional and spiritual fulfillment that help them cultivate a greater attachment to their residential areas (Chenoweth and Gobster, 1990). Furthermore, the presence of trees and "nearby nature" in human communities generates numerous psychosocial benefits. Kuo (2003) have found that having trees within high density neighborhoods lowers levels of fear, contributes to less violent and aggressive behavior, encourages better neighbor relationships and better coping skills. Hospital patients recover more quickly and require fewer painkilling medications when having a view of nature. Office workers with a view of nature are more productive, report fewer illnesses, and have higher job satisfaction. These are important, but often unnoticed, effects for urban people who have views of trees and nature in the course of their normal, everyday activities and experiences.

As these findings have emerged, urban forests exhibit many characteristics which contribute to the public good. Studies about its public value have been conducted broadly, as listed above. However, as a commodity, its supply and demand haven't been well studied from an economic view. What factors contribute to the variation in the demand for urban forest is a topic with critical implications to the enactment of effective urban forest policies. Although researchers have noticed that urban forest canopy cover correlates with ecological and geographic factors as well as with urban form, they have not shown how canopy cover varies with socioeconomic conditions that are known to vary across all regions. The absence of this critical point makes it impossible to fully understand the various supply-demand balances reached in different cities. In this paper, a theoretical economic model will be introduced. Then the urban forest canopy cover data for all big cities, as well as other socioeconomic data, will be used to test and illustrate factors contributing to variations in the demand for urban forests.

2. Economic Model of the Demand for Urban Forest

Many public choice theorists, including Borcherding and Deacon (1972), Bergstrom and Goodman (1973), and Perkins (1977), have assumed a simple majority rule voting system and have estimated public demands by observing the behavior of the median voter. A median voter is assumed to pay the median tax price and has the median income level in a jurisdiction. Another means for obtaining estimates of the demand for public goods proposes a two-stage procedure which uses the marginal prices from the first-stage hedonic regression to estimate the second-stage demand functions for characteristics. Studies conducted using this method include Nelson (1978), Harrison and Rubinfeld (1978), Palmquist (1982, 1983), Chattopadhyay (1999).

The demands for urban forests reflect the behaviors of public as well as individual choice and decision. Urban forests are supplied by both public as well as private entities, it is very difficult to observe the demand for urban forests from the market and at individual household level. We have to aggregate the demand at city level, and estimate the per capita demand at the average level. Aggregate demand for urban forests is the total amount of money that each city spends to have varying quantities of urban trees at different socio-economic and price levels. To investigate at the city level is a good alternative. So each city can be viewed as an approximate decision maker.

Our theoretical economic model, closely following Bates and Santerre (2001), begins by supposing that a typical person receives utility from units of urban forest enjoyment, q, and all other public and private goods as a composite good, y. Now suppose that local officials allocate the public budget and land, while individuals choose their communities and homes to maximize the utility, U, of the average person in Eq. 1 subject to his or her income constraint in Equation (2) ,

$$U = U (q, y) \quad (1)$$

$$I = \text{payment for enjoyed urban forest} + P_y\, y \quad (2)$$

Where, I is the typical person's income; P_f is per unit price of urban forest; P_y is per unit price of the composite good, y.

The amount of enjoyable units of urban forest for a typical person depends on the total amount of urban forest, Q, population in the city, N, and the degree of publicness associated with the urban forest, p. Mathematically, the enjoyable units of urban forest can be expressed as

$$q = Q / N^p$$

When p=0, urban forest is considered a pure public good and everyone in the city can enjoy Q units of urban forest. When p=1, urban forest is considered a private good and everyone in the city can on the average enjoy Q/N units of urban forest. Intermediate values of p represent some congestability or rivalry in consumption.

The price share for a unit of enjoyable urban forest can be expressed as

$$P_f * N^{p-1}$$

When p=0, urban forest is a public good and the price share of a typical citizen for a unit of enjoyable urban forest is P_f /N, because this person only needs to pay his/her share. When p=1, urban forest is a private good and the price share of a typical citizen for a unit of enjoyable urban forest is P_f , because he/she is the only person who enjoyed this urban forest and needs to pay all the price.

The payment of a typical citizen for his/her urban forest enjoyment is the price share for a unit of enjoyable urban forest times the amount of urban forest he/she can enjoy. It can be expressed as

$$(P_f *N^{p-1})* (Q / N^p) =P_f Q / N$$

It means that, in a specific city where P_f, Q and N are determinate, every citizen should on the average pay $P_f Q / N$ for their urban forest enjoyment, regardless of the publicness of the urban forest. This is reasonable. In a city, there are at least three kinds of urban forest: 1) private urban forest, e.g., trees in individual backyards; 2) public urban forest, e.g., trees in city parks; and 3) half-public urban forests. e.g., trees in community parks or residential communities. The urban forest enjoyed by every person always comprises these three categories. The enjoyment amount of every category can vary from person to person. For example, rich people may consume more private urban forest than poor people. However, the summation of every citizen's payment for their consumed urban forest should equal the aggregate urban forest price in the city. On average, every citizen pays $P_f Q / N$ for the urban forest.

Based on the above analysis, the income constraint in equation (2) can be expressed as

$$I = (P_f *N^{p-1}) q + P_y y \qquad (3)$$

$P_f *N^{p-1}$ is the shared price for one unit of urban forest enjoyment and q is the units of urban forest enjoyment captured by this typical person. The typical person's demand for units of urban forest enjoyment can be derived from the utility maximization process and given in a general form as

$$q = q [P_f *N^{p-1}, P_y , I] \qquad (4)$$

Assuming that the demand function in equation 4 can be written in constant elasticity form and that P_y =$1, the demand function can be specified as

$$q = k\,(P_f * N^{p-1})^a\, I^b \qquad (5)$$

In equation (5), a and b denote the price elasticity and income elasticity of demand for urban forests. Because q is not measurable, equation (5) is multiplied by N^p on both sides to determine Q, the total amount of urban forest, and then divided by N to express urban forest in per capita terms, yielding

$$Q = k(P_f * N^{p-1})^a I^b N^p$$

$$Q/N = k(P_f * N^{p-1})^a I^b N^{p-1}$$

$$Q/N = kP_f^a I^b N^{(p-1)(a+1)} \qquad (6)$$

The dependent variable becomes the per capita urban forest, which is available to us. Taking the natural logarithmic transformation gives the final estimation equation for econometric analysis,

$$\ln(Q/N) = b_0 + b_1\ln(P_f) + b_2\ln(I) + b_3\ln(N) \qquad (7)$$

where $b_0=\ln(k)$, $b_1=a$, $b_2=b$, $b_3=(p-1)(a+1)$.

Demand for urban forests should negatively respond to its price ($b_1<0$), while a positive relation between per capita income and the demand for urban forest can be expected ($b_2>0$). In fact, the positive effect of income on the demand for urban forest might be specified from two aspects. Firstly, with higher per capita income, the city has more budget for urban tree programs. Secondly, wealthy individuals are affordable to have bigger lot for their house and are able to spend more money in their budgets for landscaping in the construction of their houses, more importantly thereby causing more trees to be planted or maintained.

Besides, an interesting question concerns whether urban forest represents a luxury good with the income elasticity greater than 1. As discussed later, many researchers have found empirically that parks and recreation services, complements to urban forests, resemble a luxury good. The estimated coefficient on population gives us an indicator for the effect of population growth on urban forest demand. Population growth tends to indicate higher rates of landscape fragmentation as more competing demands are placed on limited resources. Because concentrated populations place many pressures on vegetation growth, a negative relationship between population growth and per capita demand for urban forest is hypothesized ($b_3<0$).

Another necessary control variable that must be considered in our model is the natural environmental factor. It is well known that natural vegetation in undisturbed environments is primarily a function of temperature and precipitation or geographic factors such as ecoregion or altitude that correlate with them. A large area that includes generally similar ecosystems and that has similar types, qualities, and quantities of environmental resources is known as an ecoregion. Nowak et al. (1996) and Dwyer et al. (2000) show that urban tree canopy cover also is highest in forested ecoregions, followed by grasslands and deserts, thus confirming ecoregion as a indispensable contributor to urban canopy variation at a national scale. These findings are not surprising, but they are important, for they make it clear that human modification of vegetation in urban places through activities like irrigation have not fully superseded the general effects of ecoregion characteristics.

Moreover, in a dynamic context, it becomes more understandable that the ecoregion condition might influence the amount of urban forest under urbanization or urban sprawl. In forested ecoregions, the cities are surrounded by forestland. Once the city grows, more forestland will be delimited within city limits. Although part of the forestland will be converted into other uses such as residential or even commercial use, the newly added area will greatly contribute to the increase of urban forest. However, in grassland or desert ecoregions, the situation will be different. Most regions outside the city limit will have a lower forest coverage than urban area, leading to a mathematical decrease of its average urban forest coverage under urban growth. Of course, once the area has been converted into urban use, tree canopy coverage is expected to increase in the future, due to the impact of human behavior. In conclusion, the ecoregion factor will have a significant contribution to our model. After adding a dummy of ecoregion, D_{eco}, equation (7) changes into:

$$\ln(Q/N) = b_0+D_{eco}+b_1\ln(P_f)+b_2\ln(I)+b_3\ln(N) \qquad (8)$$

3. Data

Our research will address all the big cities with population over 100,000 in the United States. After deleting some cities with missing data or incorrect data[1], we finally get 242 cities. The locations of these sample cities are exhibited in Figure 1-1.

Urban Forest Canopy Cover

The United States Department of Agriculture (USDA) Forest Service collected and published canopy cover data (Dwyer et al., 2000) in accordance with the Forest and Rangeland Renewable Resources Planning Act (1974), which requires the Forest Service to assess "the current and expected future conditions of all renewable resources in the Nation"(USDA Forest Service, 1989). The Forest Service has summarized results at state, county, metropolitan statistical area (MSA), urban area, and census-designated place (CDP) levels for the entire contiguous United States. These estimates of canopy cover are based on the USDA's national resources inventory (NRI) and advanced very high-resolution radiometer (AVHRR) data. Urban forest canopy cover, on a 0-100 percentage scale, was calculated for every 1 km^2 in the United States using statistical models for particular physiographic regions and 1991 AVHRR data.

These statistical models predict forest density per square kilometer based on the proportion of individual AVHRR pixels or cells within it with particular land cover. Selected jurisdictional boundaries (e.g., state, county, urban area) were added to the data set after the complete coverage for the United States was generated. The accuracy of the

[1] The urban tree coverage in some cities is less than 0.05%. In these cases, the coverage percentage is regarded as 0 in the National Urban Forest Report (Dwyer et al., 2000).

estimates of canopy cover was determined through comparisons with canopy inventories of selected urban areas around the United States, based on aerial photography (Nowak et al., 1996). However, the urban forest canopy cover data are statistical estimates and are most suitable for large areas (Dwyer et al., 2000). Despite this limitation, the data are well suited for our analysis since the minimum land area of our sample cities is 27.1 km^2. Based on the urban forest canopy cover data, land area data, and population data, we can calculate our dependent variable, per capita urban forest amount, for each sample city.

Ecoregion Classification Data

In the mid-1990s, the National Interagency Technical Team (NITT) was formed to develop a common framework of ecological regions for the nation. The intention is that the framework will foster an ecological understanding of the landscape, rather than an understanding based on a single resource, single discipline, or single agency perspective. Till now, there are two broadly recognized ecoregion division systems: Omernik's ecoregion system and Bailey's ecoregion system. After comparing their different classification criteria, we find Omernik's ecoregions are more suitable to our analysis.

The Omernik ecoregion system is hierarchical and considers the spatial patterns of both the living and non-living components of the region, such as geology, physiography, vegetation, climate, soils, land use, wildlife, water quality, and hydrology. There are four levels in the Omernik ecosystem hierarchy. Level I ecoregions were mapped and described by the North American Commission for Environmental Cooperation (CEC) in 1997. A combined data set in Arc/INFO Export format, with Level

I, Level II, and Level III ecoregions for all of North America, is available from the EPA Ecoregions of North America download page[2].

In this study, a mixed use of Level I and Level II ecoregions was proposed. In southern Florida, the Level I ecoregion system classifies this region as “Tropical Wet Forests”. But in Level II, this region is defined as “Everglades”, which is not apt for tree growth. The tree canopy coverage data collected from Dwyer et al. (2000) also attests the low canopy percentage in this region. All the sample cities in this region have their tree canopy coverage below 5%, with some of them even below 1%. Moreover, in the central US, Level I generally classifies this region as “Great Plains”. But as stated in the Level II ecoregion system, “Great Plains” includes temperate prairies, west-central semi-arid prairies, south central semi-arid prairies, Texas-Louisiana coastal plain, Tamaulipas-Texas semi-arid plain. Urban forest coverage varies greatly among these regions, with normally over 10% in temperate prairies or Texas-Louisiana coastal plain and less than 5% in others. In these cases, the Level I classification of ecoregion is neither sufficient nor accurate for our study. Based on Omernik’s Level I and Level II ecoregion divisions, a revised ecoregion classification for our specific study is presented in Figure 1-1.

Figure 1-1 Ecoregions of selected cities in Continental US

As soon as we ascertain the ecoregion division, we can use the ArcMap to match each sample city with the ecoregion map and extract the information of which ecoregion

[2] http://www.epa.gov/wed/pages/ecoregions/na_eco.htm#Downloads

each city belongs to. This information is then used to build an ecoregion index with values shown in Table 1-2.

Economic and Demographic Data

Demographic and socio-economic data, such as population, land area, per capita income, etc., come from the U.S. Census Bureau. Since the price of urban forest is unavailable, we use the opportunity cost of urban forest as its price. Urban forest, as one kind of land use within city limits, competes with other land use types such as commercial land and residential land. After purchasing one lot of residential land, the owner can decide what percent of this lot will be used to build house and what percent will be used to plant trees or lawns. In this case, the price or opportunity cost of urban forest is best exhibited by the residential land price.

Unfortunately, the residential land price for these sample cities is also unavailable. At the national level, researchers have concluded that the logarithms of the nominal price index for residential land, disposable income, and interest rates are cointegrated (Davis and Heathcote, 2004). However, this research addresses the aggregate residential land price across the whole nation. At the city level, very few studies have been conducted. Davis (2005) conducted a research on land value of an average owner-occupied single-family lot in 44 large cities by Metropolitan Statistical Area. This is the only available data of the residential land price in specific cities. We will use this available residential land price in 44 cities, and single-family owner-occupied house value which is available in the US Census, to estimate the residential land price for each sample city in our study.

Previous studies have shown that residential land price is mainly correlated to house value, population, and city land area. Based on the existent residential land price of

44 big cities, we regress the residential land price on house value, population and land area to get the coefficients of every independent variable. Data are logged prior to estimation of the model to correct for nonnormality of the distributions.

The results of this regression including the values of each coefficients and t-ratio are listed in Table 1-1. The R^2 of 0.87 indicates the strong explanation power of our model and the high reliability of our forthcoming estimation for residential land price in other cities which is based on this model.

Table 1-1: Results for the Regression of Residential Land Value

Based on the coefficients of every independent variables: population (Pop), land area (LA), and single house value(HV), we estimate the residential land price (LV_{resi}) for each sample city in our study using the following equation:

$$Log\ (LV_{resi})= -10.848+0.31*Log\ (Pop)\ -0.395*Log(LA)\ +1.160*\ Log\ (HV).$$

The estimated residential land value is described in Table 1-2.

Table 1-2: Data Description of Variables

4. Results

Table 1-2 presents the data description of all the variables in our empirical analysis. The ecoregion index, as a control variable capturing the availability of natural environmental effect, is inappropriate to be expressed in log form. The values of other variables are logged prior to estimation, according to the analysis of our theoretical model. Standard ordinary least square estimates are obtained for the demand equation and presented in Table 1-3.

Table 1-3: Regression Results for the Demand for Urban Forests

The regression results show that all of the estimated coefficients have their expected signs and are statistically significant at the 1% level. As expected, the coefficient on population provides a negative relationship between population growth and the per capita demand for urban forest. Ecoregion index in our model exhibits a very significant influence on the demand for urban forest. It supports that natural environmental factors still haven't been completely replaced by the increasingly intense impact of human behavior. The positive sign before ecoregion index attests to the conclusion that Nowak et al. (1996) and Dwyer et al. (2000) suggested: urban tree canopy cover is also highest in forested ecoregions, followed by other ecoregions such as grasslands and deserts,

As hypothesized, the demand for urban forest varies positively with income. The income elasticity of the demand for urban forest is 2.4, indicating urban forest is highly responsive to changes in income and may exhibit some characteristics of a luxury good.

This income elasticity estimate means that a 1% increase in per capita income would cause a 2.4% increase in the demand for urban forest. For a typical city with 100,000 people and an average of 100 m^2 urban forest canopy coverage per person, that 1% increase in per capita income will cause an increase of 2.4 m^2 in per capita urban forest demand and an aggregate of 0.24 km^2 additional demand for urban forest.

Similarly, the demand for urban forest varies inversely with its price, as we expected. According to the regression results, the price elasticity of the demand for urban forest is approximately -1.37, indicating that demand for urban forests is relatively sensitive to changes in its price. This price elasticity estimate means that with a 1% increase in the price of urban forest, the demand for urban forest will decrease 1.37%. For the same typical city, a 1% decrease in the price of urban forest will cause an increase of 1.37 m^2 in per capita urban forest demand and a total amount of 0.137 km^2 additional demand for urban forest.

Another important objective of this paper is to find the effect of urban sprawl on the demand for urban forest. Although urban sprawl may convert some forestland into urban use and thus decrease the amount of aggregate forest area, it also extends the city limits and more forest becomes defined as urban forest. For example, developers today often try to incorporate rural tree stands into new urban developments. However, opposite conclusions also exist. In studying the fate of natural rural vegetation during urbanization from 1937-1975 in southeastern Wisconsin, Sharpe et al. (1986) concluded that rural landscapes undergo complex transformation during urbanization with most rural forests being destroyed rather than being incorporated into urban areas. Whether the effect of urban sprawl on the demand for urban forest is positive or negative remains unknown and the research on this issue will have critical implications to the enactment of future urban forest policy.

Urban sprawl, as a very popular topic, has been studied for a long time. Many researches have been conducted covering every aspect of this topic since the 1970s. A more recent comprehensive research report on urban sprawl index has been published by Smart Growth America in 2002. The title of the report is *Measuring Sprawl and its Impact* (Ewing et al. 2002). This comprehensive and academically rigorous study truly breaks new ground by going a step beyond the index to demonstrate how sprawling development patterns affect the way people live. It uses 22 variables to rate metro areas on four different aspects of their development. The “scores” for each factor indicate how badly those regions have sprawled in terms of housing and population spread; segregating homes from the activities of daily life; lacking the focus of strong economic and social centers; and building poorly connected street networks. The final report ranks 83 metropolitan areas according to their overall sprawl index scores. Based on this sprawl index score, we will test the effect of urban sprawl on urban forest.

From the regression results in the second column of Table 1-3, we find the coefficients for income, price, population and ecoregion index still keep close to the results without considering the urban sprawl index (the first column of results in Table 1-3). The adjusted R^2 increases very little, indicating that this additional variable doesn’t contribute strongly to the explanatory power of our model. However, the t-ratio shows this new variable is statistically significant. Since a higher index score means less sprawling, the negative sign before the sprawl index score indicates a positive relationship between urban sprawl and demand for urban forest. The more sprawl a city has, the more demand for urban forest it has.

While the results of using this sprawl index were satisfying, this method also greatly reduced the number of our sample, since the final report of *Measuring Sprawl and its Impact* only ranks 83 metropolitan areas. After reviewing the regression process, we find our observations in the regression model decreased from 242 to 133. Moreover, some of our sample cities must have the same sprawl index score, if they are located in the same Metropolitan Statistic Area.

Although these limitations of the sprawl index used in our model exist, the 133 samples can still give us a solid conclusion. Frankly, it is possible that the coefficient of sprawl index might change if we use different sprawl indicators such as population density change as well as a different number of samples. However, what we are concerned with in our analysis is whether urban sprawl has a positive or negative influence on the demand for urban forest. How seriously urban sprawl will affect the demand for urban forest is too difficult to identify and is well beyond the focus of this paper.

5. Conclusions and discussion

One of the most important empirical conclusions we make from this study is that higher income will cause more demand for urban forests. Our empirical findings in this study suggest that the demand for urban forest is elastic with respect to price and highly responsive to changes in income. The status of urban forest is a good indicator of urban environmental quality. Higher income will lead to higher environmental quality at the expense of alternative land use and the planting and maintaining of urban trees. Therefore, although economic development may convert more land, including open and green space, for construction purpose, societal wealth is significant in affording a higher quality environment. This is another evidence in support of the Environmental Kuznet's Curve, which claims that in the beginning of economic development pollution increases along with industrialization; after a threshold, when basic physical needs are met, interest in a clean environment rises, reversing the trend.

Our conclusion is consistent with other empirical evidence concerning the demand for public parks, recreation services, and environmental quality. Borcherding and Deacon (1972) found the own price elasticity for Park-Recreation is -.50 and -.41. Bergstrom and Goodman (1973) reported an average price elasticity estimate of -.19 for parks and recreation services. Perkins (1977) found a price-elastic demand for park and recreation with an average elasticity estimate of -2.12, while Santerre (1985) uncovered price elasticity estimates of -.35 on average. Other research concerning environmental quality also concluded similar own price elasticity. Nelson (1978) found that air quality price elasticity ranges from -1.2 to -1.4, while Bender et al. (1980) reported a range from -0.262 to -0.503. Zabel and Kiel (2000) found a price elasticity of -0.479 for ozone and -

0.128 for particulates. More recently, Brasington and Hite (2005) concluded their price elasticity of demand for environmental quality to be -0.12. Our price elasticity estimate of -1.37 for urban forest is comparable to the results of these studies.

As far as income elasticity is concerned, Borcherding and Deacon (1972) reported estimates ranging from 1.29 to 2.74 for parks and recreation services whereas Bergstrom and Goodman (1973) estimated an income elasticity of 1.32. Other findings about income elasticity estimates for parks and recreation services were relatively lower, with an average of 0.65 for Perkins (1977), and 0.71 for Santerre (1985). Our income elasticity estimate of 2.4 for urban forest compares a little bit higher to most of the estimates for parks and recreation services. This is reasonable because that urban forest is more private compared to other public goods such as parks and recreation services. Privately owned urban forest, such as trees in the backyard, can be seen everywhere and will greatly contribute to the whole urban forest system. However, this is not the case for parks or other recreation services. Private parks are probably only possessed by wealthy people and average income families can barely afford them. In this case, personal income contributes more to the demand for urban forest, due to its more private characteristics, thereby inducing higher income elasticity relative to parks and other recreation services.

Another interesting and reasonable finding is that urban sprawl may impose a growing demand for urban forest. The more sprawl a city is experiencing, the more demand for urban forest it has. This result proves that urban sprawl is not as bad as many researchers have stated, at least from the perspective of urban forest. One driving force of urban sprawl is that people look for bigger green space and house lots. People who prefer to live in suburban areas are often wealthier and place more emphasis on environmental quality. But we need to keep in mind that the urban sprawl index used in this paper reflects many other social factors in addition to urban expansion, since we were not able to find another index that measures urban expansion more precisely. It could be an important aspect that we should examine in future studies.

We must point out some weaknesses of this study. Even though we used the ecoregion dummy, this only provides a rough estimate due to a great variety of natural conditions such as landscape, soil, climate, etc. Moreover, different model specifications or different sample cities will possibly change the size of coefficients. So we need to be cautious when we interpret income as well as price elasticity. However, the results will not vary essentially and will still have applicable significance.

PART II – DEMAND FOR URBAN FORESTS AND ECONOMIC WELFARE: EVIDENCE FROM THE SOUTHEASTERN US CITIES

1. Introduction

Economics is the study of how individuals, as well as societies, allocate scarce resources to satisfy their various needs. Economic decisions are reflected not only in individual choices, but also in public decisions such as public budgets, policies and regulation. An important aspect of economic choices is associated with enjoyment of environmental amenities versus traditional economic goods. The Environmental Kuznets Curve (EKC) was coined after the relationship between environmental quality, such as air quality, and income was found following the analogous relationship between income inequality and national income first observed by Simon Kuznets (1955). EKC has been tested in many studies (e.g., Stern et al., 1996; De Groot et al., 2004; Lindmark, 2004; Rupasingha et al., 2004).

Studies of forests in this empirical framework have focused on the relationship between forest coverage and income at the national level and regional level. The results were mixed. Shafik and Bandyopadhyay (1992) found that net change in forest cover did not significantly relate to income in 149 countries between 1961 and 1986. Panayotou (1993) used strictly cross-sectional international data and found a turning point in deforestation at $1275 (in 1985 prices) of household income. Cropper and Griffiths (1994) created pooled time series cross-section data for three separate regions of the world and found that per capita national income was a significant factor in both Africa and Latin America, but not in Asia.

So far we have not found any similar studies on urban forests. In fact, one of the best indicators of the urban environment and amenities is the status of trees present in a city. Trees have been recognized as an important component of urban landscapes throughout the history of urbanization. Sociologists and economists found that urban trees, in addition to providing environmental and aesthetic benefits, also brought a broad range of economic, social, and even psychological benefits. Trees in urban landscapes moderate temperature and microclimates, thereby reducing the needs for air conditioning and thus saving energy (Heisler, 1986; McPherson, 1990; Meier, 1991; Oke, 1989).

Urban trees help improve air quality and sequester carbon (Nowak, 1993; Nowak and McPherson, 1993; Rowntree and Nowak, 1991; Smith, 1981), help stabilize soils, reduce erosion, improve groundwater recharge, control rainfall runoff and flooding (Sanders, 1986), reduce urban noise levels (Cook, 1978), and provide habitat that increases biodiversity (Johnson, 1988). Urban trees also make neighborhoods aesthetically more appealing and add to the value of property (Schroeder, 1989). Evidence has also been shown that urban forests may reduce human stress levels (Ulrich, 1984), promote social integration of older adults with their neighbors (Kweon et al., 1998), and provide local residents with opportunities for emotional and spiritual fulfillment that help them cultivate a greater attachment to their residential areas (Chenoweth and Gobster, 1990).

Trees in cities are good but are not free. They require space that is usually very costly in a city as well as planting and maintenance. Any community has to face the difficulties in allocation of its limited budget for planting trees and other purposes, in allocation of the urban land for planting trees and other alternative uses. Individuals have to make the decision of what size of lot to purchase for their homes and in which kinds of urban settings. So lot size and tree presence reflect, to some extent, the market forces determined by the welfare of the city citizens and their preferences. This study tests the relationship between the economic welfare and the tree presence in urban areas.

At the city level, which factors contribute to the variation in status of urban forests is interesting and may have some policy implications. Although researchers have noticed that urban forest canopy cover correlates with ecological and geographic factors as well as with urban form, they have not shown how canopy cover varies with socioeconomic conditions across all regions. Is there an EKC for urban forests? In the following sections, we first introduce econometric models and data, and then the results are presented and conclusions are made.

2. Econometric Model

Urban forests are either public goods, private goods or a combination of both. They are determined by demand and supply. Unfortunately, it is impossible to get the prices and costs. Neither shadow prices nor instrumental prices or indicators, such as the residential land values, are available for each city. Only two variables, population density and income, that should be strongly related to the presence of urban forests, are obtainable for all cities. Since other variables (such as residential land value) might be fundamentally determined by these two variables, we simply use the reduced form of urban forests (FOR) as a function of population density and income:

$FOR= F\ (POD, INC) + e$

(1) $lnFOR=a_0+a_1lnINC+a_2lnPOD+a_{11}(lnINC)^2+a_{22}(lnPOD)^2+a_{12}(lnINC*lnPOD)+e_i$

Where FOR represents the percentage of urban forest canopy coverage; INC is the median household income in 2000; POD represents the population density in the city; $a_1,a_2,a_{11},a_{22},a_{12}$ are the coefficients of the variables respectively; e_i is the error term. It should be noted that a_{11} and a_{22} measure the second-order effect of income and population density on the urban forest canopy cover percentage, respectively; and a_{12} measures the cross effect.

There are no studies on urban forests, but some studies on other issues may be relevant. For example, most studies have concluded that public parks or recreation services, a substitute for urban forests, is a normal good with a positive income elasticity, either less than 1 or greater than 1 (Borcherding and Deacon 1972, Bergstrom and Goodman 1973, Perkins 1977, Santerre 1985). Basically, all these conclusions agree that higher income will result in more demand for environmental amenity. The difference among them is only whether environmental amenity represents a luxury good with the income elasticity greater than 1.

EKC suggests that urban forest would decrease firstly with economic development since people choose to sacrifice environment in order to get other uses, but later it would increase with economic development because wealthy people can afford more environmental amenities. In fact, this subsequent positive effect of income on the demand for environmental amenity might be specified from two aspects. Firstly, with higher income, the city gets richer and has more money in the budget for urban environmental programs. Secondly, rich people will also have more money in their budgets for landscaping in the construction of their houses, thereby causing more trees to be planted or maintained.

Our economic model can test whether there is a threshold that can change the impacts of income on urban forests. To get the turning point, we simply derive the function by income:

$$\frac{\partial \ln FOR}{\partial \ln INC} = a_1 + 2a_{11} \ln INC + a_{12} \ln POD = 0$$

$$INC^* = e^{\frac{-a_1 - a_{12} \ln POD}{2a_{11}}} \qquad (2)$$

We suppose that a similar relationship may exist between urban forests and population density. The biggest difference between urban areas and rural areas is that there exist various urban management programs in cities. With people firstly clustered in cities, urban services and programs, including urban forest programs, start to provide citizens abundant urban civilizations. At the beginning of urbanization, the clustering of people doesn’t actually reduce the urban forest volume. Inversely, various urban forest programs will have an overwhelming influence on the volume and health of our urban forests.

To get the turning point, we derive the function by population density:

$$\frac{\partial \ln FOR}{\partial \ln POD} = a_2 + 2a_{22} \ln POD + a_{12} \ln INC = 0$$

(3) $$POD^* = e^{\frac{-a_2 - a_{12} \ln INC}{2a_{22}}}$$

3. Data

Considering that the natural environment will have a great impact on the urban tree situation, we try to find a region with relatively more homogenous climate and environment. So we decide to select nine southeastern US states (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee and Virginia). Cities with populations below 40,000 are considered rural communities and their surrounding areas become strong substitutes to urban forests, therefore these cities are excluded from our analysis. We selected a total of 149 cities for this study. Demographic and economic data, such as population, land area and median household income, are obtained from the U.S. Census Bureau.

The United States Department of Agriculture (USDA) Forest Service collected and published forest canopy cover data (Dwyer et al., 2000) in accordance with the Forest and Rangeland Renewable Resources Planning Act (1974), which requires the Forest Service to assess "the current and expected future conditions of all renewable resources in the Nation"(USDA Forest Service, 1989). The Forest Service has summarized results at state, county, metropolitan statistical area (MSA), urban area, and census-designated place (CDP) levels for the entire contiguous United States. These estimates of canopy cover are based on the USDA's national resources inventory (NRI) and advanced very high-resolution radiometer (AVHRR) data. Urban forest canopy cover, on a 0-100 percentage scale, was calculated for every 1 km^2 in the United States using statistical models for particular physiographic regions.

These statistical models predict forest canopy per square kilometer based on the proportion of individual AVHRR pixels or cells within particular land cover. After the complete coverage for the United States was generated, selected jurisdictional boundaries (e.g., state, county, urban area) were added to the data set to extract the urban forest canopy cover percentage within these boundaries. Table 2-1 presents the data description of all the variables in our empirical analysis.

Table 2-1: Data Description of Variables

4. Results

Standard ordinary least square estimates are used for the regressions. The results are presented in Table 2-2. Moreover, we compare two models in our estimation to infer the significance of the cross effect of income and population density on the demand for urban forest, one with the interaction part (Model A), another one without the interaction part (Model B).

Table 2-2: Regression Results

We find that including the cross effect term in the empirical model decreases the adjusted R^2 value (from 0.408 to 0.405), indicating that the cross effect term doesn't contribute to the explanation power of the model. Moreover, the t ratio of the cross effect term is as low as 0.58, suggesting that its value is not statistically significant at all. Therefore, we will use Model B to interpret our results.

The regression results in Model B show that all of the estimated coefficients are statistically significant at the 1% level. As expected, the positive coefficient on the second-order effect of income suggests a first negative and then positive impact of income on the demand for urban forests. Inversely, the negative coefficient on the second-order effect of population density suggests a first positive and then negative influence of population density on the demand for urban forest. Based on Model B, the equations used to calculate the threshold income value and population density influence in equations 2 and 3 will be transformed as below:

(4) $$INC^* = e^{\frac{-a_1}{2a_{11}}}$$

(5) $$POD^* = e^{\frac{-a_2}{2a_{22}}}$$

Substituting the coefficients estimated for Model B into the above equations, we get that the income threshold value is $38,739 per household and the population density threshold value is 179 persons per square kilometer.

The existence of income threshold value provides more powerful evidence in support of the EKC. When the household income is less than $38,739, the percentage of urban forest cover decreases as income increases, indicating a negative income elasticity. As the income approaches the critical point, the income elasticity also approaches 0. After the income surpasses the threshold value, the income elasticity becomes positive and the demand for urban forest increases with the increasing income.

Similarly, there also exists a population density threshold value --179 persons per square kilometers. When population density is less than 179 persons per square kilometer, the percentage of urban forest increases as population density increases. This is because the urbanized areas use land more efficiently than rural areas and save more land for urban forest development. After the population density surpasses the critical value, the demand for urban forest decreases with the increasing population density, due to the increasing stress on providing sufficient accommodation.

The income elasticities of the demand for urban forests for all the sample cities are calculated using the following equation:

(6) $$\varepsilon_{Income} = \frac{\partial \ln FOR}{\partial \ln INC} = a_1 + 2a_{11} \ln INC$$

Results are presented in Figure 2-1. The income elasticities vary from -2.86 to +4.92. The critical value of the income influence locates on the point where income elasticity equals 0. As the income gets farther away from this critical value on both sides, the absolute value of income elasticity also increases. The highest (+4.92) and lowest (-2.86) income elasticities are reached where the highest ($93,561) and lowest ($23,483) income stand. The income elasticity for the mean household income ($39,787) in our sample cities is 0.11, indicating urban forest coverage is inelastic to income. However, we must point out that this mean income elasticity doesn't have much applicable significance, compared to the income threshold value found in our analysis.

Figure 2-1: Income Elasticity in Sample Cities

5. Conclusions

This paper analyzes the relationships between urban forest presence and income and population density. Our results indicate a similar trend of EKC in urban forests. With continuous economic development and urbanization, its impacts on urban forests are mixed. In general, population growth will cause urban forests to be replaced by other land uses. As a result, although urban forest programs still endeavor to protect urban forests, many urban forests and green spaces are inevitably converted for construction purposes to accommodate the increasing population. In this period, the demand for urban forests will continuously decrease due to the increasing population density which places a higher and higher pressure on the urban land use.

Economic welfare will finally play a positive role in urban forest after reaching a certain level. Better economic welfare will make people more affordable to have more urban forests and other green spaces. Higher income will lead to higher environmental quality at the expense of alternative land use and the planting and maintaining of urban trees. Therefore, although economic development may convert more land, including open and green spaces, for construction purposes, societal wealth is significant in affording a higher quality environment.

We must point out some weaknesses of this study. Even though we limit our sample cities to the southeastern US, the climate and natural conditions, such as landscape and soil, still vary significantly from city to city. However from the relative good R square, we can say that income and population density are good indicators of the variation in urban forests.

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Table 1-1: Results for the Regression of Residential Land Value

	Coeff.	t-ratio
ONE	-10.8479	-9.89513
Log of Population	0.309519	3.95187
Log of Land Area	-0.39496	-5.50185
Log of House Value	1.16041	12.6048
Adjusted R^2 =0.867		

Table 1-2: Data Description of Variables

	Mean	S.D.	Min.	Max.	Sample Number
Urban Forest Canopy Cover Percentage (%)[b]	17.6475	14.9355	0.1	69	242
Urban Forest Area per capita (m^2/person)	193.211	305.548	0.21	2126.44	242
Population 2000[a]	303565	620720	82026	8.01E+06	242
Land Area (km^2)[a]	214.506	263.089	19.5	1965	242
Population Density 2000 (persons/km^2)	1716.33	1244.51	225.73	10007.8	242
per capita Income ($)[a]	21009.8	6055.96	9762	68365	242
Residential Land Value (an average owner-occupied single-family lot in 44 big cities (thousands of current dollars)[c]	119.636	121.592	19	602	44
Single-family owner-occupied house value($)[a]	138766	76388.3	40900	495200	242
Estimated Residential Land price (thousands of current dollars)	125.17	103.52	24.81	615.44	242
Ecoregion index[d]	1=forest, temperate prairie, coastal plain 0=desert, semi-arid plain, everglade, and others				

a. U.S. Census Bureau (2000).

b. Dwyer et al. (2000).

c. Davis and Palumbo (2005)

d. Omernik’s ecoregion system

Table 1-3: Regression Results for the Demand for Urban Forests

Independent Variables	Coefficient (t value)	
	Model 1 (without sprawl index) (Sample =242)	Model 2 (with sprawl index) (Sample =133)
Constant	-11.345	-9.522
	(5.09)	(3.36)
Log of Income	2.405	2.386
	(10.48)	(8.43)
Estimated Log of Urban	-1.368	-1.258
Forest Price	(15.85)	(11.63)
Log of Population	-0.294	-0.295
	(4.42)	(4.00)
Ecoregion Index	2.187	2.062
	(18.90)	(14.69)
Log of Sprawl Index Score		-0.4488
		(2.33)
Adjusted R^2	**0.795**	**0.809**

Notes:

1) The dependent variable is the log of urban forest area per capita.
2) Urban forest price is substituted by its opportunity cost -- residential land price.
3) Ecoregion index is inappropriate to be expressed in log from.
4) The higher sprawl index score indicates less sprawl of the city (see Ewing et al. 2002).
5) The sprawl index score was logged prior to estimation of the model to correct for nonnormality of the distribution

Table 2-1: Data Description of Variables

	Mean	S.D.	Min.	Max.	Sample Number
Urban Forest Canopy Cover Percentage (%)[b]	27.4	19.7	0.2	74.4	149
Urban Forest Area per capita (m^2/person)	422.56	776.002	0.85	8559.47	149
Population 2000[a]	112118	112989	40214	735617	149
Land Area (km^2)[a]	146.24	235.655	12.9	1965	149
Population Density in 2000 (persons/km^2)	1208.56	796.47	61.45	4831.48	149
Median Household Income ($)[a]	39786.5	12924.4	17206	93561	149

a. U.S. Census Bureau (2000).

b. Dwyer et al. (2000).

Table 2-2: Regression Results

Independent Variables	Coefficient (t value)	
	Model A (with cross effect) (Sample =149)	Model B (without cross effect) (Sample =149)
Constant	322.093	328.696
	(3.53)	(3.64)
Log of Income	-66.1883	-64.5134
	(3.85)	(3.82)
Log of Population Density	8.86332	4.3839
	(1.12)	(2.69)
Square of Log of Income	3.26349	3.05329
	(3.74)	(3.85)
Square of Log of Population Density	-0.444164	-0.422496
	(3.53)	(3.53)
Log (Income) *Log (Population Density)	-0.398351	
	(0.58)	
Adjusted R^2	**0.405**	**0.408**

Notes:

1) The dependent variable is the log of urban forest canopy cover percentage.

2) Cross effect is represented by the last term in Model A: $a_{12}(\ln INC*\ln PD)$.

Figure 1-1: Ecoregions of selected cities in Continental US

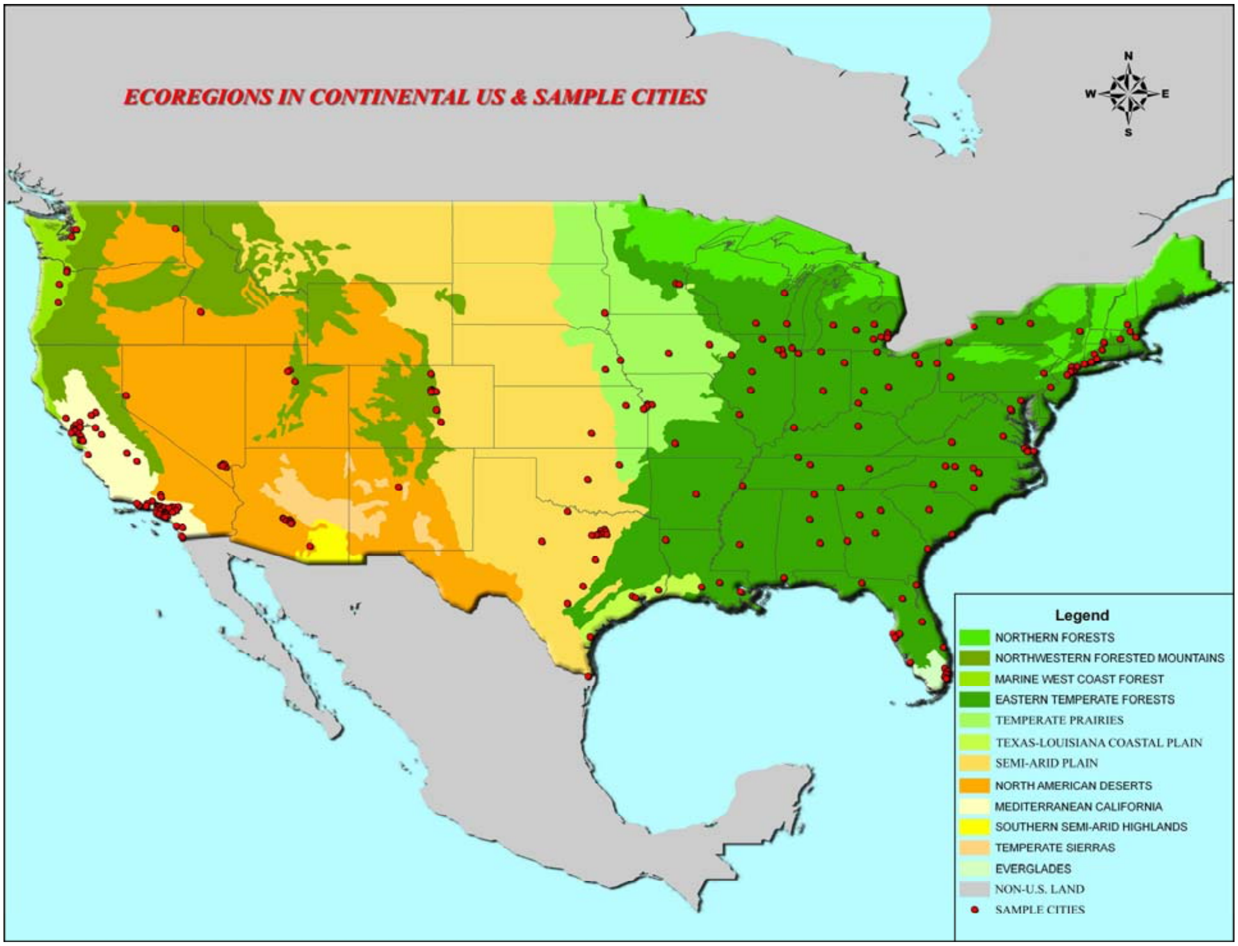

Figure 2-1: Income Elasticity in Sample Cities