Available online at www.sciencedirect.com

ScienceDirect

Landscape and Urban Planning 84 (2008) 293–300

LANDSCAPE AND URBAN PLANNING

www.elsevier.com/locate/landurbplan

Demand for urban forests in United States cities[☆]

Pengyu Zhu[a,b,1], Yaoqi Zhang[a,*]

[a] School of Forestry & Wildlife Sciences, Auburn University, AL 36849-5418, USA

[b] School of Policy, Planning and Development, University of Southern California, CA 90007, USA

Received 24 June 2006; received in revised form 22 August 2007; accepted 10 September 2007
Available online 29 October 2007

Abstract

Extensive economic investigations have shown a variety of benefits derived from urban forests, but study on demand for urban forests remains limited. This study investigates the impact of selected potential factors on the demand for urban forests at the city level. An empirical economic model is used to examine and estimate the demand for urban forests in all cities with population over 100,000 in the United States. The empirical findings suggest that the demand for urban forests is elastic with respect to price and highly responsive to changes in income. Urban forest area increases as total population grows but at a lower rate than population growth.
© 2007 Elsevier B.V. All rights reserved.

Keywords: Population growth; Economic development; Urban land value; Urban forests; United States

1. Introduction

Trees have been recognized as an important component of urban landscapes. Like other forms of municipal infrastructure, urban trees provide a variety of values and services, including energy savings, improved air quality, aesthetics, health benefits, habitat for birds and other wildlife, and recreation enhancement. These factors are reflected in higher real estate prices, lower energy bills, and greater attraction to tourists and talented people and businesses (Bradley, 1995; Dwyer et al., 1992; Orland et al., 1992). Indeed, recent evidence shows that amenities function as new drivers for urban growth and communities dynamics (Clark et al., 2002).

While many studies on urban forestry have analyzed the benefits of urban trees (e.g., Gorman, 2004; McPherson et al., 1999; Dwyer and Miller, 1999; Thompson et al., 1999; Tyrvainen, 2001), very few studies have been conducted to investigate the demand for urban trees including the factors that influence this demand. Although it is obvious that urban forest canopy cover correlates with ecological and geographic factors as well as urban patterns, it is less known how socioeconomic conditions affect the urban forest demand. This issue is not only interesting from academic perspectives, but also has important policy implications.

Essentially, economics is the study of choice. An important aspect of economic choice is associated with the enjoyment of environmental amenities versus the enjoyment of traditional economic goods. Trees in cities can provide a variety of benefits, but they are not free. To have trees in cities, people not only need to bear the huge opportunity costs of the contributed land within urban areas, but also need to allocate a large amount of public funds to planting and maintenance. Therefore, any community has to face the tradeoff in allocation of its limited fiscal budget between planting trees and other purposes, and the tradeoff in allocation of its limited land between planting trees and other alternative uses. Individuals have to make the decisions of what lot size they should purchase for their homes and in which kind of urban settings they would like to live. So lot size and tree presence reflect, to some extent, the market forces determined by the welfare of the citizens and their preferences. Developers choose to build homes and develop landscape that they feel will attract buyers. Homeowners may modify their landscape to some degree based on their taste and affordability even after their purchase. Therefore, the presence of city trees also reflects individual choices. However, developers and individuals have to follow zoning, landscape and tree ordinances that are usually determined at city level.

[☆] This work was completed when Pengyu Zhu was an research assistant in the School of Forestry and Wildlife Sciences, Auburn University.

* Corresponding author. Tel.: +1 334 844 1041; fax: +1 334 844 1084.
E-mail addresses: zhupeng@auburn.edu (P. Zhu), yaoqi.zhang@auburn.edu (Y. Zhang).

[1] Tel.: +1 334 844 8043; fax: +1 334 844 1084.

0169-2046/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.landurbplan.2007.09.005

The purpose of this study is to investigate the impact of economic behavior on the demand for urban forests. We first discuss the major benefits of urban trees, then we formulate demand for urban trees. Cross-sectional data of all cities with population over 100,000 in the United States are used to estimate the demand for urban forests. Conclusions and discussions are presented at the end.

2. Urban forests as economic goods

Urban forests are economic goods that provide a variety of benefits. Trees in urban landscapes moderate temperature and microclimates, thereby reducing the need 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). Based on modeling of air pollution, storm water mitigation and energy impacts, the Urban Ecosystem Analysis of the Washington, DC Metropolitan Area concluded that tree cover reduced storm water storage costs by $4.7 billion and generated annual air quality benefits of $49.8 million (American Forests, 2002).

Urban trees also make neighborhoods aesthetically more appealing and add to the value of property (Schroeder, 1989). 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 8–20% higher than those of comparable properties elsewhere. Rental rates of commercial office properties were about 7% higher on sites having a quality landscape, which included trees (Crompton, 2001).

Studies on how trees affect shoppers' behavior in retail business districts have been addressed as well. These studies generally employed the contingent valuation method. Consumers claim they are willing to pay more for products in downtown shopping areas with trees, versus in comparable districts without trees (Wolf, 2005). Customer service, merchant helpfulness, and product quality are all judged to be better by shoppers in places with trees (Crompton, 2001).

Evidence also shows 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) 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. Other studies have shown that hospital patients recover more quickly and require fewer painkilling medications when they have a view of nature (Ulrich, 1984). Finally, office workers with a view of nature are more productive, report fewer illnesses, and have higher job satisfaction (Kaplan, 1993).

3. Economic model of the demand for urban forests

In a city, trees can broadly be divided into two categories by ownership. The first category includes the trees on public lands, e.g., trees in city parks and along city streets. All city citizens share and bear the costs of public trees together. Determining the presence of these public urban forests is a public choice on the public-owned land and streets. The second category of trees in the city refers to private trees, e.g., trees in individual yards and private lots. Individuals choose their subdivision/neighborhoods and the lot size based on their own preference and income. Someone may argue that urban forests are not subject to individual choice. For example, people who like trees will not move from Phoenix to Boston simply because Boston has more trees. However, these tree enthusiasts are able to move from a treeless part of Phoenix to a tree rich part. Hence, from a dynamic perspective, developers and city planners consider the expectations of their citizens in regard to trees, landscape and lot sizes. The owners also have some capacity to modify landscape after they purchase their houses. Therefore, the situation of urban trees and landscape could eventually satisfy each individual's preferences and affordability. In some situations, public trees and private trees might substitute for each other. Based on Escobedo et al. (2006), public urban forest structure is related to the socioeconomic strata of Santiago's different municipalities. The total public urban forest budgets were greater in the high socioeconomic strata. Regardless of this, when we look at the sum of private and public trees across a city, this summation reflects the average or aggregated demand for urban forests in that city, no matter how the share between public and private trees might differ from another city.

It could be very interesting to see how the share between these two affects the demand for urban forests, and how they substitute for each other. Unfortunately, no data currently exist on the different shares between public and private trees among cities. Hence, we aggregate the public and private trees at the city level, or alternatively at the level of per capita average amount. But we do think this is acceptable as an empirical study. Either public demand or private demand are mixed by individual choice as well as public choice. The share of public forests to some degree is individual choice since the budget, the land use are subject to the citizen approval. The share of private forests to some degree are subject to public choice since each individual (or developers) are subject to zoning, lot size regulation, landscape and tree ordinance that are determined by public choice. In terms of price of urban forests, it is not uncommon of trading between public land and private land. The costs of planning and maintaining trees should not vary very much between public domain and private sector.

Since urban forests provide a lot of public goods, free rider issue needs to be considered. However, as an aggregated study at city level, we think it is fine. Homeowners cannot do totally what they like on their private lots, some tree presence is often mandatory. Landscape and tree ordinances, zoning and other municipal codes play an important role in maintaining good environments and providing amenities for neighborhoods. In addition, what we find of interest is the fact that most households typically contribute much more than the regulations require. If homeowners free-ride on the positive benefits conferred by their neighbors, then no one in a given neighborhood has incentive to spend more time and money on the landscaping than required. The question is, does a homeowner really enjoy the good appearance of his own yard (especially the front yard) independent of how others view his yard or are his landscaping decisions influenced by his desire to have trees that pleases his neighbors? We know that free-rider problems exist in many contexts. However, not only do free rider problems not appear to plague residential neighborhoods, at least with respect to landscaping, in many cases we observe homeowners spending considerable time and money to produce landscaping that yields benefits for the neighborhood. That is, they are free providers rather than free riders. We suggest that the externalities generated by a homeowner's good landscaping (e.g., trees) constitute a form of social 'goodness' signaling. Individuals who engage in this type of behavior use the implicit and explicit investments that produce socially beneficial landscaping to convince other members of the community that they conform to the group's norms and, as such, are viable and valuable members of the community. The community embraces these individuals and rather more than individuals who do not engage in such signaling. Because the good landscaping signal is highly visible in neighborhoods, individuals have both an incentive to produce the signal and a disincentive to free ride.

Given the above justifications and considering the paucity of data about the share between private and public forests, our empirical model classifies the urban forests within a city into two components: (1) the average aggregated level of public and private forests (Q) or per urban forest per capita (Q/N) across cities that are determined by average welfare and natural environment, and (2) the variation across individuals from the average level (Q_i) within each city that is subject to individual taste and welfare.

The amount of Q is jointly the result of decisions made by local officials together with local citizens in allocating public funds and land, as well as in defining average requirements for trees on private land. However, each individual varies in his/her quantity demanded at his/her expense and by individual decision. The utility created by Q and Q_i could be different due to spacial reasons, as well as cost difference. After choosing aggregated quantity Q at city level and Q_i at individual variation of urban forests, individuals choose other composite good, y, to maximize the utility U in Eq. (1) subject to his or her income constraint in Eq. (2),

$$U_i = U(Q,\quad Q_i,\quad y_i) \tag{1}$$

$$I_i = \left(\frac{P_f}{N}\right) Q + P_f Q_i + P_y\, y_i \tag{2}$$

where I_i is individual income; P_f is the unit price of urban forest; P_y is the unit price of the composite good y. The cost of Q is shared equally by the total population N. The cost of Q_i is totally borne by private individuals. In this study, the focus is not on investigating how each individual's choice influences the demand for urban forests. Instead, we investigate the average or total level of demand, as our objective is to examine the variation across cities rather than across individuals. Hence, we delete the individual component and get following equations:

$$U = U(Q,\quad y) \tag{1$'$}$$

$$I = \left(\frac{P_f}{N}\right) Q + P_y y \tag{2$'$}$$

The typical household's demand for units of urban forest enjoyment, Q, can be derived from the utility maximization process, which is given in a general form as:

$$Q = Q\left[\left(\frac{P_f}{N}\right)\quad, P_y,\ I\right] \tag{3}$$

Assuming that the demand function in Eq. (3) can be written in constant elasticity form and that $P_y = \$1$, the demand function could be written as:

$$Q = k\left(\frac{P_f}{N}\right)^a I^b \tag{4}$$

Taking the natural logarithmic transformation gives the final estimation equation for econometric analysis,

$$\ln(Q) = b_0 + b_1\ \ln(P_f) + b_2\ \ln(I) + b_3\ \ln(N) \tag{5}$$

If we change the demand for total urban forests into demand per capita, Eq. (5) can be rewritten as

$$\ln\left(\frac{Q}{N}\right) = b'_0 + b'_1\ \ln(P_f) + b'_2\ \ln(I) + b'_3\ \ln(N) \tag{5$'$}$$

where Q/N is the urban forest per capita. This is a double log econometric specification, which implies that the elasticity is constant and equal to the coefficients regardless of the level when change is occurring. Such an assumption has some limitations, but it is simple since we do not need to calculate the elasticity at different level of dependent variables.

Based on the law of demand, quantity demanded for total urban forest should respond negatively to its price ($b_1 < 0$), and positively to per capita income ($b_2 > 0$). With higher per capita income, the city has more budget for urban tree programs. In addition, wealthy citizens are more able to afford larger lots for their homes and are able to spend more money on landscaping during the construction of their homes, leading to a higher number of trees planted or maintained.

As discussed later, many researchers have found empirically that parks and recreation services, the complements to urban forests, resemble a luxury good. If urban forest represents a luxury good, its income elasticity b_2 should be greater than 1.

The estimated coefficient on population gives us an indication for the effect of population growth on urban forest demand. If all other inputs are assumed to be constant, the impact of population growth on demand for urban forests is not clear at this time.

This is due to the fact that population increase would reduce the share of the cost per capita, but at the same time increase the congestion since urban forests are not purely public goods. For example, urban trees can promote city pride and improve air quality (public goods), while also provide protection of privateness and private woodlots for personal recreation (private goods). Both the marginal value and marginal costs of urban forests decreases when population grow: the optimum amount of urban forests that the average individual wishes to have (both the public as well as private for average individual) could be at the level where the marginal value for average individual is equal to the his or her cost share.

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 is highest in forested ecoregions, followed by grasslands and deserts, thus confirming ecoregion as an indispensable contributor to urban canopy variation at a national scale.

Following this line of reasoning, in a dynamic context, we see that the ecoregion condition may influence the changing amount of urban forest land during different stages of city growth. In forested ecoregions, cities are surrounded by forestland. As the city expands outward, more forestland will be delimited within city limits. Although part of the forestland will be converted into other uses such as residential or commercial use, the newly added area that has not been developed 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 those inside the urban area. Of course, once the area has been converted into urban use, tree canopy coverage is expected to increase, due to the impact of human demand. In conclusion, the ecoregion factor will have a significant contribution to our model. For simplicity as well as data limitation, we add a dummy of ecoregion, D_{eco}, and change Eqs. (5) and (5′) into:

$$\ln(Q) = b_0 + D_{\text{eco}} + b_1 \ln(P_{\text{f}}) + b_2 \ln(I) + b_3 \ln(N) \tag{6}$$

$$\ln\left(\frac{Q}{N}\right) = b'_0 + D'_{\text{eco}} + b'_1 \ln(P_{\text{f}}) + b'_2 \ln(I) + b'_3 \ln(N) \tag{6′}$$

4. Data

Our research will address all the big cities with population greater than 100,000 in the United States. After deleting some

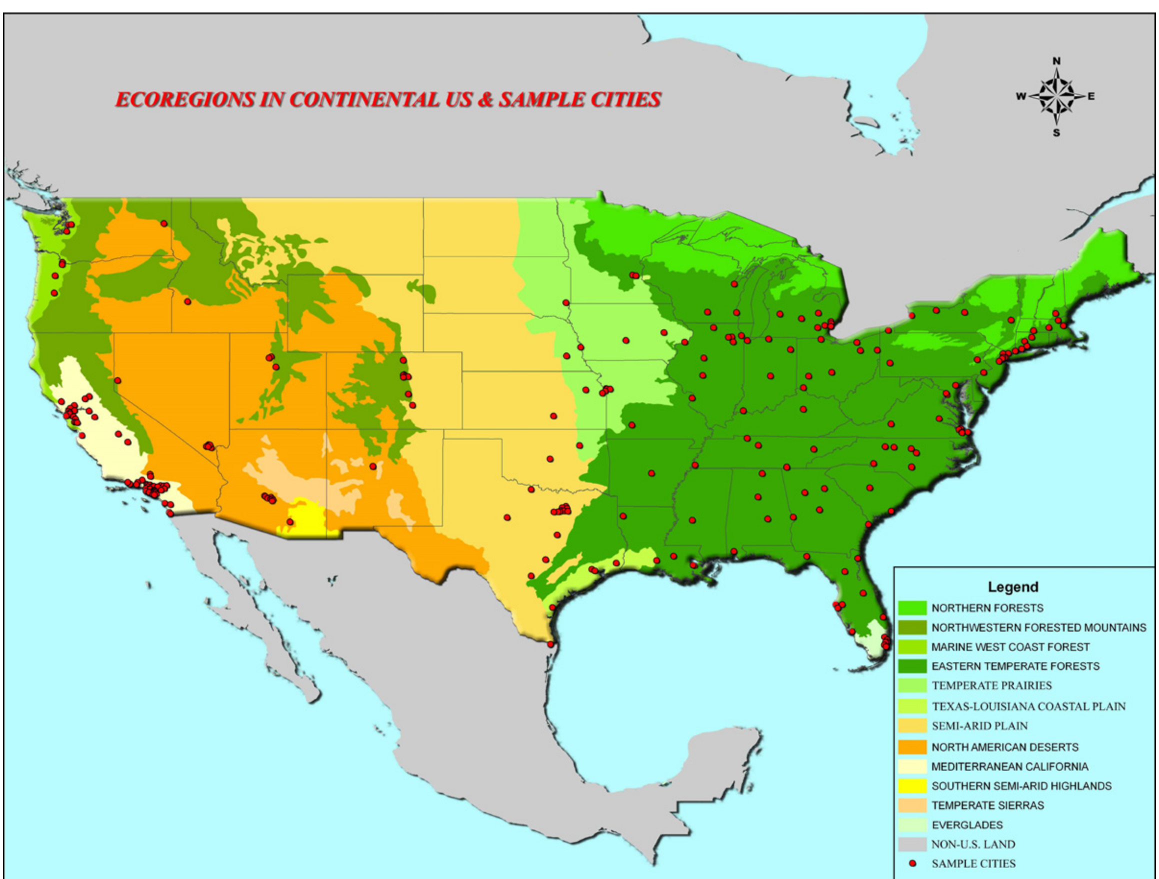

Fig. 1. Ecoregions of selected cities in Continental US.

cities with missing data or incorrect data. 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). We obtained data for 242 cities. The locations of these sample cities are exhibited in Fig. 1.

4.1. 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 of 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). As such, the Forest Service has summarized results at state, county, metropolitan statistical area (MSA), urban area, and Census Designated Places levels for the 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 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 the sample cities is 27.1 km^2. Based on the urban forest canopy cover data, land area data, and population data, we can calculate the dependent variable, per capita urban forest amount, for each sample city.

4.2. 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 was that this framework will foster an ecological understanding of the landscape, rather than an understanding based on a single resource, single discipline, or single agency perspective. Currently, 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 for 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 (http://www.epa.gov/wed/pages/ecoregions/na_eco.htm#Downloads).

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 well suited for tree growth. The tree canopy coverage data collected from Dwyer et al. (2000) also attests to the low canopy percentage in this region. All the sample cities in this region have their tree canopy coverage below 5%, with some even falling 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 Fig. 1.

As soon as the ecoregion division is ascertained, it is then left to ArcMap to match each sample city with the ecoregion map and extract the information of which ecoregion each city belongs to. This information is then used to build an ecoregion index with values shown in Table 2.

4.3. Economic and demographic data

Demographic and socio-economic data such as population, land area, and per capita income, can be obtained from the U.S. Census Bureau. We used the 2000 data. Since the price of urban forest is unavailable, we will use the opportunity cost of urban forest as its price. Urban forest, as one category of land use within city limits, competes with other land use types such as commercial and residential uses. After purchasing one lot of residential land, the owner can decide what percent of this lot will be developed 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.

Table 1
Results for the regression of residential land value

	Coefficient	*t*-Ratio
Constant	−10.8479	−9.89513
LN (population)	0.309519	3.95187
LN (land area)	−0.39496	−5.50185
LN (house value)	1.16041	12.6048
Adjusted R^2	0.867	

Table 2
Data description of variables

	Mean	S.D.	Min.	Max.	Sample number
Urban forest canopy cover percentage (%)[a]	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[b]	303565	620720	82026	8.01E+06	242
Land Area (km^2)[b]	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 ($)[b]	21009.8	6055.96	9762	68365	242
Residential land value (an average owner-occupied single-family lot in 44 big cities (thousands of current dollars)[c]	119.636	121.592	19	602	44
Single-family owner-occupied house value ($)[b]	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] Dwyer et al. (2000).
[b] U.S. Census Bureau (2000).
[c] Davis and Palumbo (2005).
[d] Omernik's ecoregion system.

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 and Palumbo (2005) conducted a research on land values of an average owner-occupied single-family lot in 46 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 (Within the 46 cities, Washington, DC and Providence, RI are not included in our sample cities. Therefore we only use the other 44 cities for this estimation.), 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 the 44 cities noted above, we regress the residential land price on house value, population and land area to determine the coefficients of every independent variable. Logarithm data are used in 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. 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.

Based on the coefficients of the 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 following equation: $\ln(LV_{resi}) = -10.848 + 0.31\ln(Pop) - 0.395\ln(LA) + 1.160\ln(HV)$. The estimated residential land value is described in Table 2.

In our model, it is not important for the residential land value to very accurately measure the opportunity costs of urban forests. This methodology is appropriate when the residential land value is able to indicate the trend or index of the opportunity costs of urban forests. Since land value is the most costly component of the urban forests, residential land value could be the best indicator of the urban forest price across cities.

5. Results

Table 2 presents the data description of all variables in our empirical analysis. The ecoregion index, as a control variable capturing the natural environmental effect, is inappropriate to be expressed in logarithmic form. After reviewing the data, we found that some cities' data about urban trees have obvious errors or outliners. Therefore, we keep 210 cities in our final regressions. The values of other variables are transformed by natural logarithm 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 3.

The regression results show that all of the estimated coefficients have their expected signs and are statistically significant at the 1% level. Ecoregion index in our model exhibits a very significant influence on the demand for urban forest. The positive sign before ecoregion index attests to the conclusions made by Nowak et al. (1996) and Dwyer et al. (2000). These prior studies claimed that urban tree canopy cover is also highest in forested

Table 3
Regression results of the demand for urban forests

	Eq. (6) (total urban forests)	Eq. (6') (urban forest areas per capita)
Independent variables	Coefficient (t-value)	Coefficient (t-value)
Constant	−18.580 (5.91)	−4.808 (1.53)
LN (income)	1.762 (5.34)	1.768 (5.36)
Estimated LN (urban forest price)	−1.260 (9.93)	−1.260 (9.94)
LN (population)	.799 (9.69)	−.202 (2.45)
Ecoregion index (dummy)	.348 (4.31)	.348 (4.31)
Adjusted R^2	0.591	0.490

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 1.76, 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 1.76% increase in the 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 −1.26, indicating urban forest is relatively sensitive to the 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 1.26%.

Our results show that the coefficient is positive between population growth and total urban forest, but negative between population growth and the per capita demand for urban forest. This means that total urban forest area increases at a lower rate than the total population growth. Such changes are likely caused by two forces: changes within the initial city limit and expansion of the city limits as the population grow.

6. Discussions and conclusions

One empirical finding we make from this study is that higher income populations or residents will have more demand for urban forests. Urban forests are economic goods. When income increases the demand will rise as well. Rich communities have larger budget on public forests, and have larger private house lots where private trees mostly are grown. Demand for urban forest is elastic with respect to price and highly responsive to changes in income. As the status of urban forest is a good indicator of urban environmental quality, higher income populations afford the expense of alternative land use, planting and maintaining of urban trees. This conclusion is also consistent with a recent study in the Southeastern United States (see Zhu and Zhang, 2006). Therefore, although economic development consumes more land for construction purposes, including residential and industrial development, the overall impact on environment is positive at least from the indicator of urban trees.

Our finding on the impact of price on the demand for urban forest is consistent with other empirical studies concerning the demand for public parks, recreation services, and environmental quality. Borcherding and Deacon (1972) found the own price elasticity for Park-Recreation to be −.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. Palmquist (1982) 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. The estimated price elasticity in this study is −1.26 that is comparable to the results of other 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 1.76 for urban forest is slightly higher than most of the other estimates for parks and recreation services. This is reasonable because urban forest has a larger private component 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.

In wrapping up this paper, it is appropriate to point out some weaknesses of this study. The first and most critical weakness is using one dummy (ecoregion) to cover geological and natural variation such as landscape, soil, climate, etc. Secondly, different specifications that might change the size of coefficients have not been investigated, partly because the data do not permit the development of more complicated models to conduct more complex estimates and testing. Thirdly, the variation of demand has only been investigated across cities, while the variation across individuals within each city (e.g., different subdivision) may also contribute to better understanding of demand for urban forests. Finally, the substitution effect by considering the landscape and environment around city and region has not been adequately addressed. All these issues are important to understand the demand for urban forests and could serve as focal points for future study. Therefore, on the one hand, we need to be cautious when we interpret elasticity of income, price and population; on the other hand, further investigation is needed to find how natural variables, individual income as well as the share between public and private urban forests affect the demand for urban forests. One potential approach that might overcome the above limitations is to explore the historical change in each city using time series analysis. This study and findings could be useful to continuous investigation for some policy implication for urban planning and decision makers.

Acknowledgements

We appreciate financial support provided by the Center for Forest Sustainability of Auburn University and the Challenge Cost-Share Grant Program of The National Urban & Community Forestry Advisory Council of USDA Forest Service. We appreciate Dr. David Laband, Dr. Brenda Allen and three anonymous reviewers' comments and suggestions. All opinions and errors are the responsibility of the authors.

References

American Forests, 2002. Urban Ecosystem Analysis for the Washington, DC Metropolitan Area: An Assessment of Existing Conditions and a Resource for Local Actions. Retrieved 10/05/2005, from: http://www.americanforests.org/downloads/rea/AF_WashingtonDC2.pdf.

Anderson, L.M., Cordell, H.K., 1985. Residential property values improve by landscaping with trees. South. J. Appl. Forest. 9, 162–166.

Anderson, L.M., Cordell, H.K., 1988. Influence of trees on residential property values in Athens, Georgia (U.S.A.): a survey based on actual sales prices. Landsc. Urban Plann. 15, 153–164.

Bender, B., Gronberg, T.J., Hwang, H.-S., 1980. Choice of functional form and the demand for air quality. Rev. Econ. Stat. 62 (4), 638–643.

Bergstrom, T.C., Goodman, R.P., 1973. Private demands for public goods. Am. Econ. Rev. 63, 280–296.

Borcherding, T.E., Deacon, R.T., 1972. The demands for the services of non-federal governments. Am. Econ. Rev. 62, 891–901.

Bradley, G., 1995. Urban Forest Landscapes: Integrating Multidisciplinary Perspectives. University of Washington Press, Seattle.

Brasington, D.M., Hite, D., 2005. Demand for environmental quality: a spatial hedonic analysis. Region. Sci. Urban Econ. 35 (1), 57–82.

Chenoweth, R.E., Gobster, P.H., 1990. The nature and ecology of aesthetic experiences in the landscape. Landsc. J. 9, 1–18.

Clark, T.N., Iloyd, R., Wong, K., Jain, P., 2002. Amenities drive urban growth. J. Urban Affairs 24 (5), 493–515.

Cook, D.I., 1978. Trees, solid barriers, and combinations: alternatives for noise control. In: Hopkins, G. (Ed.), Proceedings of the National Urban Forestry Conference. USDA Forest Service, SUNY College of Environmental Science and Forestry, New York, pp. 330–339.

Crompton, J.L., 2001. Parks and Economic Development. American Planning Association, Chicago, IL.

Davis, M.A., Palumbo, M., 2005. The Price of Land in 46 U.S. Cities. Federal Reserve Board, unpublished.

Davis, M.A., Heathcote, J., 2004. The Price and Quantity of Residential Land in the United States. Federal Reserve Board of Governors and Georgetown University.

Dwyer, J.F., McPherson, E.G., Schroeder, H.W., Rowntree, R.A., 1992. Assessing the benefits and costs of the urban forest. J. Arboricult. 18 (5), 227–234.

Dwyer, J.F., Nowak, D.J., Noble, M.H., Sisinni, S.M., 2000. Connecting People with Ecosystems in the 21st Century and Assessment of Our Nation's Urban Forests. Gen. Tech. Rep. PNW-GTR-490. U.S. Department of Agriculture, Forest Service, PNRS, Portland, OR.

Dwyer, M.C., Miller, R.W., 1999. Using GIS to assess urban tree canopy benefits and surrounding greenspace distributions. J. Arboricult. 30 (1), 102–106.

Escobedo, F.J., Nowak, D.J., Wagner, J.E., De la Maza, C.L., Rodrıguez, M., Crane, D.E., Hernandez, J., 2006. The socioeconomics and management of Santiago de Chile's public urban forests. Urban Forest. Urban Green. 4, 105–114.

Forest and Rangeland Renewable Resources Planning Act. Act of Aug. 17, 1974. 88 Stat. 476, as amended; 16 U.S.C. 1600–1614.

Gorman, J., 2004. Residents' opinions on the value of street trees depending on tree allocation. J. Arboricult. 30 (1), 36–43.

Heisler, G.M., 1986. Effects of individual trees on the solar radiation climate of small buildings. Urban Ecol. 9, 337–359.

Johnson, C.W., 1988. Planning for avian wildlife in urbanizing areas in America desert/mountain valley environments. Landsc. Urban Plann. 16, 245–252.

Kaplan, R., 1993. The role of nature in the context of the workplace. Landsc. Urban Plann. 26 (1–4), 193–201.

Kuo, F.E., 2003. The role of arboriculture in a healthy social ecology. J. Arboricult. 29 (3), 148–155.

Kweon, B.S., Sullivan, W.C., Wiley, A.R., 1998. Green common spaces and the social integration of inner-city older adults. Environ. Behav. 30 (6), 832–858.

McPherson, E.G., 1990. Modeling residential landscape water and energy use to evaluate water conservation policies. Landsc. J. 9, 122–134.

McPherson, E.G., Simpson, J.R., Peper, P.J., Xiao, Q., 1999. Benefit–cost analysis of modesto's municipal urban forest. J. Arboricult. 25 (5), 235–248.

Meier, A.K., 1991. Measured cooling savings from vegetative landscapes. In: Vine, E., Crawley, D., Centolella, P. (Eds.), Energy Efficiency and the Environment: Forging the Link. American Council for an Energy-Efficient Economy, Washington, DC, pp. 321–334.

Morales, D.J., 1980. The contribution of trees to residential property value. J. Arboricult. 1, 109–112.

Nowak, D.J., 1993. Atmospheric carbon-reduction by urban trees. J. Environ. Manage. 37 (3), 207–217.

Nowak, D.J., McPherson, E.G., 1993. Quantifying the impact of trees: the Chicago Urban Forest Climate Project. Unasylva 173 (44), 39–44.

Nowak, D.J., Rowntree, R.A., McPherson, E.G., et al., 1996. Measuring and analyzing urban tree cover. Landsc. Urban Plann. 36, 49–57.

Oke, T.R., 1989. The micrometeorology of the urban forest. Philos. Trans. R. Soc. Lond. 324 (Series B), 335–349.

Orland, B., Vining, J., Ebreo, A., 1992. The effect of street trees on perceived values of residential property. Environ. Behav. 24 (3), 298–325.

Palmquist, R.B., 1982. Estimating the Demand for Air Quality from Property Value Studies. Department of Economics, North Carolina State University, Mimeo.

Payne, B.R., Strom, S., 1975. The contribution of trees to the appraised value of unimproved residential land. Valuation 22 (2), 36–45.

Perkins, G.M., 1977. The demand for local public goods: elasticities of demand for own price, cross prices, and income. Natl. Tax J. 30, 411–422.

Rowntree, R.A., Nowak, D.J., 1991. Quantifying the role of urban forests in removing atmospheric carbon dioxide. J. Arboricult. 17 (10), 269–275.

Sanders, R.A., 1986. Urban vegetation impacts on the hydrology of Dayton, Ohio. Urban Ecol. 9, 361–376.

Santerre, R.E., 1985. Spatial differences in the demands for local public goods. Land Econ. 61, 119–128.

Schroeder, H.W., 1989. Environment, behavior and design research on urban forests. In: Zube, E.H., Moore, G.T. (Eds.), Advances in Environment, Behavior and Design. Plenum, New York, pp. 87–117.

Smith, W.H., 1981. Air Pollution and Forests. Springer, New York.

Thompson, R., Hanna, R., Noel, J., Piirto, D., 1999. Valuation of tree aesthetics on small urban-interface properties. J. Arboricult. 25 (5), 225–233.

Tyrvainen, L., 2001. Economic valuation of urban forest benefits in Finland. J. Environ. Manage. 62, 75–92.

Ulrich, R.S., 1984. View through a window may influence recovery from surgery. Science 224, 420–421.

USDA Forest Service, 1989. Draft 1990 RPA Program. Washington, DC, 186 pp.

Wolf, K.L., 2005. Business district streetscapes, trees and consumer response. J. Forest. 103 (8), 396–400.

Zabel, J.A., Kiel, K.A., 2000. Estimating the demand for air quality in four US cities. Land Econ. 76 (2), 174–194.

Zhu, P., Zhang, Y., 2006. Demand for urban forests and economic welfare: evidence from the Southeastern U.S. cities. J. Agric. Appl. Econ. 38 (2), 279–285.