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Economic Components of Urban Tree Value

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Introduction

While similarities exist between the ecological, social, and economic benefits of urban and rural forests, there are also significant differences. Rural production-oriented forests are often used for activities like timber production, recreation, and wildlife habitat; these tangible values are more easily quantified due to established markets and fees. Urban forests increase the quality of life for urban populations by conveying positive benefits, through services such as: reducing storm water runoff, decreasing energy consumption, providing a pleasant aesthetic environment, and increasing local economic participation.

The benefits provided by urban forests are often more difficult to quantify and measuring them requires different valuation strategies than those used for rural forests. Some valuation strategies include "contingent valuation," "willingness-to-pay," or "willingness-to-participate" in alternative scenarios. These methods are sometimes difficult to apply in real world situations, so more applied, less rigorous, and more understandable estimates of benefits are frequently desirable.

One way to calculate the benefits from an urban tree or forest is to use conventional on-line tree valuation software programs. Just like the many computer models that estimate financial returns from timber production, similar software exists for urban trees. Two examples are the

USDA Forest Service's Urban Forest Effects Model (UFORE) and the Casey Trees and Davey National Tree Benefit Calculator (NTBC). These models are designed to deal with the immense variety in urban tree location, species, and conditions.

The NTBC calculates the benefits from selected urban trees in the categories of property value, storm water reduction, air quality enhancement, carbon sequestration, natural gas savings, and electricity savings. Other software models calculate similar benefits for urban trees. Because the NTBC is a highly-regarded, well-developed model, and estimates some of the most commonly valued benefits associated with urban trees, we use it as the basis of the calculations discussed below.

These benefits generally follow the traditional expected economic patterns for a "growing" investment, but the patterns show interesting variation by tree species and geographic location. Foresters and arborists would intuitively know this; for example, an oak and a pine would have different benefit patterns due to respective species characteristics, and an oak in Atlanta, Georgia, might not have the same value as an identical oak in Seattle, Washington. The objective of this bulletin is to provide both urban and Extension foresters with a basic understanding of the nature of these individual tree and forest benefits in urban settings. The total tree or property value of urban trees is the sum of partial benefits. We show how these benefit patterns differ in a general way to illustrate the need for careful consideration of how benefit flow pattern will impact individual tree and urban forest financial analyses.

Individual Urban Tree Benefits

Urban trees can be considered a type of financial investment because they provide an intangible "revenue" stream. Financial investments are often assessed in the context of benefits and costs. The individual benefits of urban trees are actually partial benefits that then sum to the total benefits. It is these cumulative benefits that can be viewed as the intangible “revenue” stream from the tree, allowing for use of the standard valuation concept of discounted cash flow (DCF) analysis. Conventional valuation software programs calculate current revenue stream value using variables like tree species, diameter, and location.

In economic theory, the revenue function (revenue as a function of time) for many investments is represented as a flattened s-shaped curve showing an introductory sharp increase in revenue, a steady growth phase, and a latter maturation in which the revenue growth decreases. In our case, the revenue from an urban tree is a composite of its partial benefits, so we evaluated the partial benefit functions from urban trees to determine if they individually followed traditional revenue structures. Essentially, we were curious if these partial benefits followed similar growth patterns over time. What we found is that urban tree benefits relate directly to the tree’s physiological structure and are influenced by factors like growth, form, size, height, canopy, and overall tree health. The relationship between tree physiology and benefits is not consistent for partial benefits. While, in general, benefits for individual trees do follow the same general growth pattern, they also exhibit some interesting differences that are the basis of the following discussion.

Figure 1 illustrates the annual NTBC partial benefits by diameter breast height (DBH) for a white oak (*Quercus alba*) growing in Galveston, Texas. While all of the partial benefit functions increase over time, their slopes and accelerations differ. For example, the property value benefits have “straight-line” initial acceleration that soon tapers. This indicates that initially a tree’s growth causes a rapid increase in property value, but later tree growth has diminishing marginal returns. On the other hand, the function for storm water accelerates over the entire tree growth assessed until the maximum benefit is achieved. This suggests that as the tree grows, its ability to reduce storm water increases without limit.

Figure 1 also illustrates that the magnitude of the various partial values can differ significantly and, while all have a positive growth pattern, there are differences in benefit growth rates and when the maximum benefit is obtained. When using a benefit model it is important to note that the total benefit is the sum of many partial benefit values and they all contribute at different rates over time. Partial benefits are amply discussed in the literature, but mainly as components of total benefits. This shows the importance of recognizing absolute values of partial benefits, differing growth rates, differing maxima and stable or declining partial values post-maxima, and differing contributory values (towards total benefits) over time.

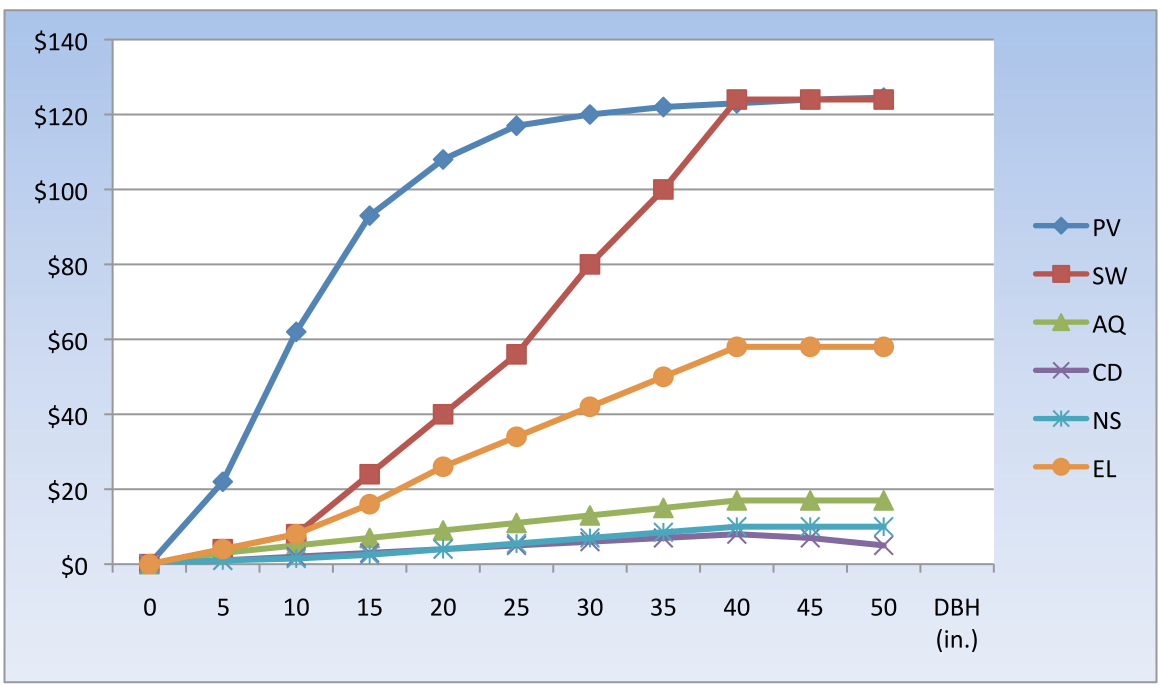

Figure 1. NTBC partial benefit growth patterns for property value increase (PV), storm water reduction (SW), air quality improvement (AQ), carbon sequestration (CS), natural gas savings (NG), and electricity savings (EL) for a white oak in Galveston, Texas.

There is an anomaly in the upper-tail of the graphs in Figure 1. A tree's growth slows over time as the tree spends more "time" in each DBH class. As a tree ages and annual benefits and tree growth slow, the amount of benefit allocated to each year also slows, and, thus, the tree growth in a particular larger DBH class may appear to be rather small. Although diminishing marginal returns in any revenue curve are expected, it is not feasible to have tree devaluation with a purely benefit-based assessment because factors that might decrease value (risk and cost) are not included. This represents an implicit challenge of graphing value versus a physiological measurement and needs to be recognized in both analysis and investment. Other than the upper-tail anomaly, all tree benefits increased in a consistent manner.

Analysis of the Temporal Patterns in the Benefit Flows

Studies comparing the urban tree benefit values in various municipalities reveal that the relationships between partial benefits and tree characteristics are not consistent between different municipalities and different species. Variation in tree location and species creates differing partial and total benefit structures. Although the trend of increasing total value at a decreasing rate relative to increasing size exists for many trees, the distribution of partial benefits from the value components does not follow a set pattern across species and location. Additionally, many of these benefits are autocorrelated; for example, a tree that is aesthetically pleasing likely also has a full crown that creates significant energy savings. Our analysis uses urban tree value data to draw out the inherent temporal patterns in urban tree benefits and DCF analysis shows the monetary implications of these patterns.

An effective way to look at variation between multiple components in data sets is principal component analysis (PCA). PCA helps to find patterns in complicated data where extraction of clear factors is difficult otherwise. Mathematically, the technique uses a covariance matrix to determine the “components” of greatest variation. For example, to illustrate the usefulness of PCA, the technique showed property value had the highest variance with other benefits (especially electricity, while benefits like carbon dioxide and natural gas showed little covariance). This bulletin is intended as a discussion of results and will omit specifics of the analytical technique and statistical outputs. Practical outputs and implications that are useful to the practicing urban forester will be discussed.

We have already shown that partial benefits for an individual tree will differ in magnitude and experience different rates of acceleration over time. The analysis shows further that these same differences occur geographically as well, at both the partial and total benefit levels. We show that even nursery stock reflect these value patterns. A visit to any nursery will show that some genera have much higher nursery stock values than other genera; these differences are correlated with the differences in partial and total benefits. Finally, we address how these differences in benefit patterns impact the net present value of urban trees.

Trees in different locations grow and convey benefits differently. Three primary factors cause the variation in values between the trees. First, tree growth differs by region; for example, trees grow faster in certain climates than in others. Second, consumers value different aspects of trees in different regions; for example, natural gas savings will valued more substantially in an area with more heating and cooling days than in an area that uses electricity as a primary temperature-control source. Third, regional markets differ; for example, costs of labor and services vary because of market conditions and these affect benefit values. Table 1 shows the values determined by the NTBC for a sixteen- inch magnolia tree in Phoenix, Arizona; Buffalo, New York; and Seattle, Washington.

Table 1. Values of benefits for magnolias in three large American cities.

Value	Phoenix	Buffalo	Seattle
Property Value	$25.90	$96.98	$37.98
Storm Water	4.80	16.75	32.58
Carbon Dioxide	1.28	1.50	1.28
Air Quality	4.85	13.20	3.51
Natural Gas	0.69	39.21	2.26
Electricity	13.69	13.39	3.30

Figure 2 shows total benefits for white oaks over time for four American cities. These benefits differ significantly; the nature of the total benefits equation (as a function of DBH) also differs. In Pittston, Pennsylvania, white oak reaches a maximum annual value of $429.81 at a DBH of forty-five inches. In Seattle, Washington, the maximum value for annual benefits from white oak is $344.77 at a DBH of thirty-four inches. White oaks in Galveston, Texas, have a maximum value of $335.90 at a DBH of forty inches and in Omaha, Nebraska, a maximum value of $386.51 is also achieved at forty-inches of DBH. The total benefit equation for the oaks in Seattle follows a curvilinear pattern; however, the total benefit equations for the oaks in all other analyzed regions follow a linear pattern (some with the anomalous upper tail).

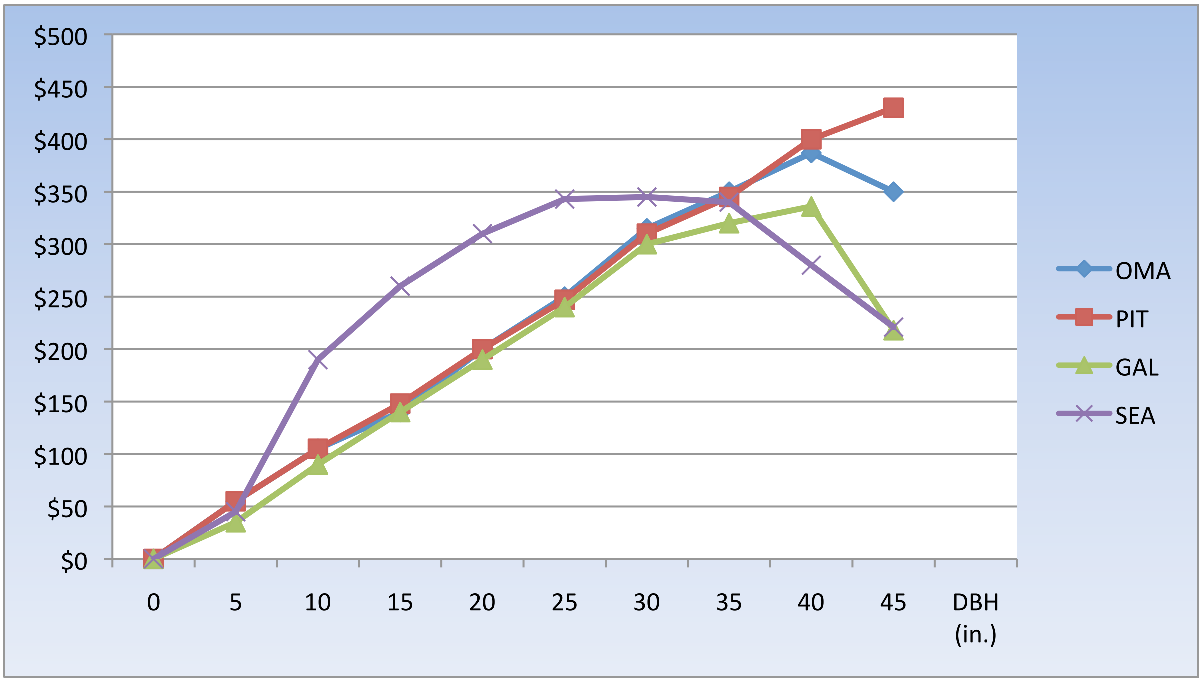

Figure 2. Total benefits by DBH for white oaks in four American cities.

Property value is the most influential component of the total benefit described by this model, and it affects the magnitude of other benefits. Figure 3 illustrates the differing shape of the "property value" benefit for three cities. A comparison of the situations for the white oak in Seattle and in Pittston (Figure 4) shows that the combination of the parabolic property value and exponential storm water partial benefits cause the Seattle white oak to have a greater total benefit equation slope in the lower DBH classes, but the combination of the steadily increasing property value and storm water benefits for the Pittston white oak create a greater value for it during the upper DBH classes.

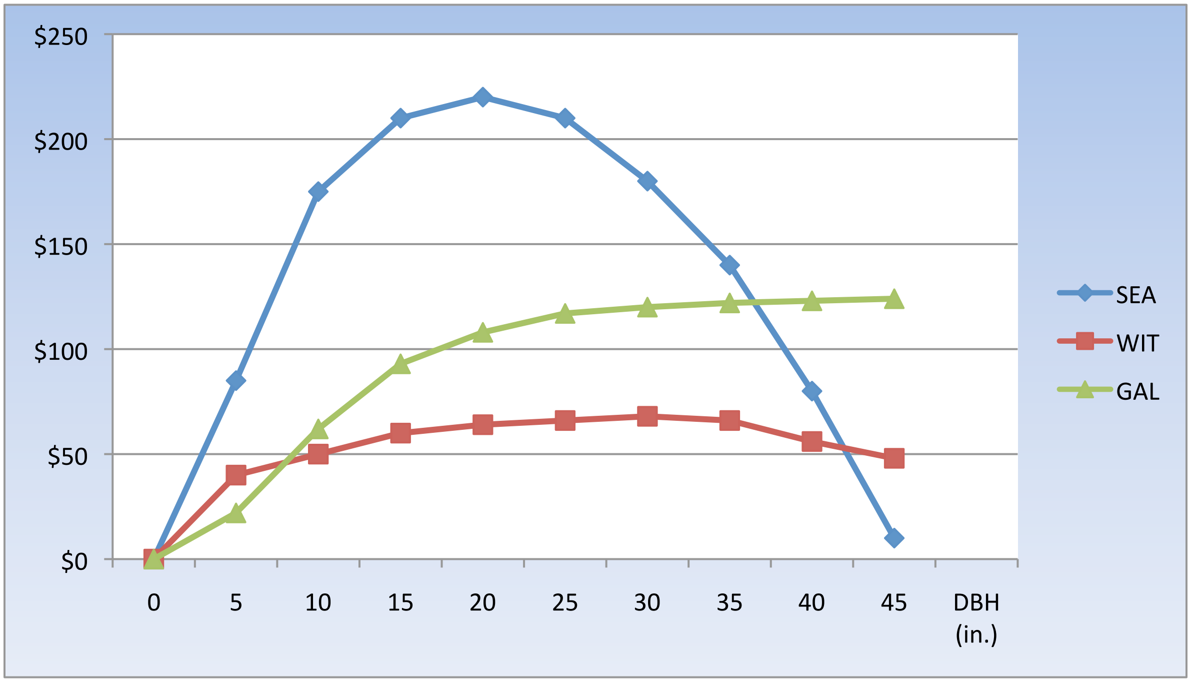

Figure 3. Property values (in thousands of dollars) for white oaks in Seattle, Galveston, and Wichita, Kansas.

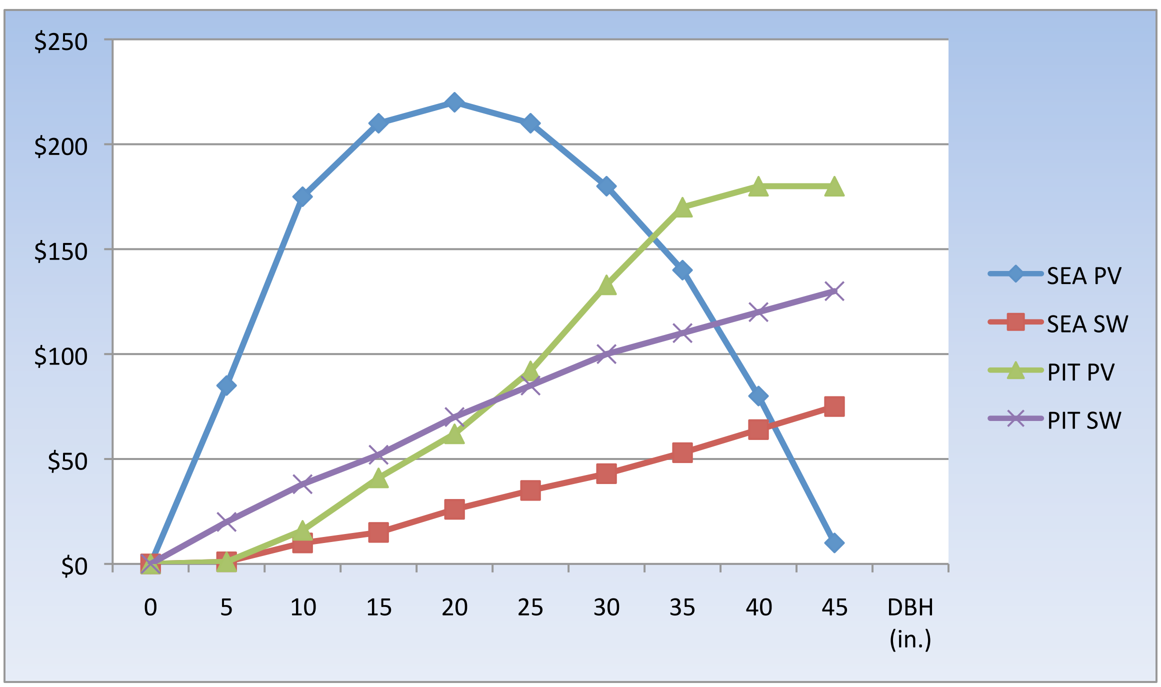

Figure 4. Comparison of property values and storm water benefits in Seattle and Pittston.

Analysis of the total and partial benefits for all trees in Atlanta, Georgia, reveals that trees of particular genera tend to follow the same benefit patterns. There are twenty-three benefit models in the Atlanta section of the NTBC and data are obtained for every tree in Atlanta at every size between one and forty-five inches to determine the existence of these "classes." As a general rule, it appears that trees with greater and slower potential growth fall into benefit "structures" that have greater values per inch of DBH and that there exists a consumer preference for trees that convey more future benefits. This suggests that urban trees are planted with future markets in mind; consumers choose trees that will grow larger, but also that will grow slower. Since the human lifespan does not extend the whole life of a tree, and most people do not live in the same residence throughout their lives, this suggests that (even if unconsciously), people are inclined to not only value trees that will bring themselves benefits, but also acknowledge dynamic benefits over time. This choice subverts one of the premier challenges in nonmarket valuation, how to value long-term benefits of forest services that will contribute to future generations; in this case, the choice to benefit future generations is preferable today.

We created histograms of common trees genera by benefit classes to determine the impact of genus on initial nursery stock value. These classes were created across national "ecogeoregions" to form a 15-class scale, rather than absolute price, to eliminate geographical differences in nursery stock prices. Where nursery stock was cheaper, the region might range in $5.00 increments and higher priced regions might range in $10.00 increments; the lowest benefit class being I and XV as the highest. Two typical genera, *Prunus* and *Quercus*, are shown in Figure 5. In all cases 5-inch nursery stock is compared. Each species within a genus represent a datum point.

Note that most of the *Prunus* species falls into the lower-valued classes and *Quercus* species tend to be higher-valued classes. While both tree genera were of equal size and would perform an identical ecosystem/landscape function at the time of purchase, consumer expectation for future results generated much different price structures. Generally, trees considered to be less valuable in timber production, or with a reputation of eventually being "small," had a lower value than trees considered being valuable for timber or "large". One general result was that many trees in the genus "*Prunus*" (cherries) have a lower initial value than trees in the genus "*Pinus*" (pines) that have a medium initial value, and trees in the genus "*Quercus*" (oaks) and "*Fraxinus*" (ashes) fall into classes with the highest initial value.

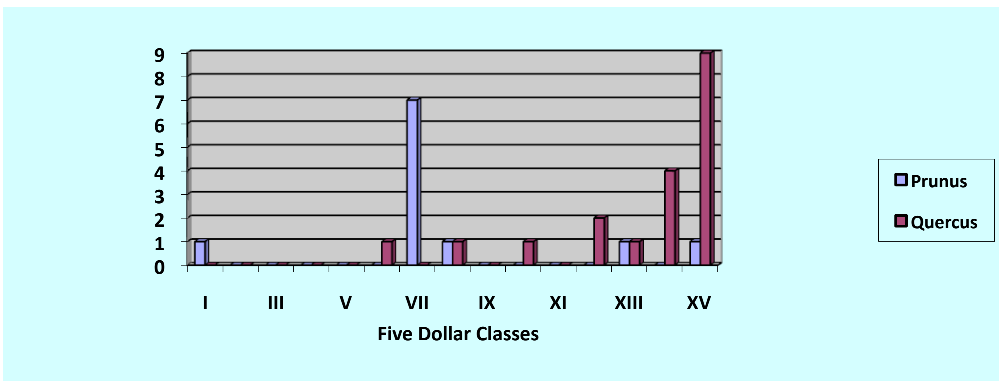

Figure 5. Frequency of genera Prunus and Quercus by benefit classes.

Impacts on Discounted Cash Flows

In a DCF analysis situation the benefits received near the present have a greater impact on the total value than those in the future due to the time value of money. Setting basic growth parameters on the data allows us to use the DCF analysis method to compare the net present values (NPVs) of white oaks in Seattle and Pittston after many years of growth. For example, assume that white oaks grow at a rate of one inch every four years for the first one-hundred years of its life (with a fifth year in the first period so that the first inch is actually for years zero through four), one inch every seven years for the next 100 years, and one inch every ten years until it reaches the age of 260. It is possible to use the standard DCF analysis calculations for annuities to determine the NPV of the two trees.

The setup of such calculation as a line-item assessment to be used in conventional forestry valuation software would appear as follows. This itemized list represents the cash flows from the Pittston white oak. In this example, shown in Table 2, the interest rate is five-percent.

Table 2. Net present value of a Pittston white oak at a five percent interest rate.

YEAR	ITEM	AMOUNT	NPV (@ 5%)
0-4	DBH 1	$28.85	$131.15
5-8	DBH 2	$46.53	$135.74
…	…	…	…
251-260	DBH 45	$429.81	$0.01
TOTAL			$1,466.15

A white oak growing for 260 years and achieving forty-five inches of DBH growth in Pittston is worth $1,466.15. The same setup (itemized list of cash flows) is used on a white oak in Seattle. If the growth pattern and interest rate are the same, then the white oak in Seattle will be worth $1,986.99 today. This result differs from that without DCF analysis (value in Pittston greater than value in Seattle) and shows that the time value of money must be taken into account when deciding on an investment. A standard comparison, without DCF, would suggest that the Pittston white oak is a better investment; however, with DCF it is apparent that the Seattle white oak is actually more profitable. Figure 7 shows the DCFs for the white oaks in Seattle and Pittston. The area under the curves represents the NPV. The benefits from the white oak in

Seattle are obviously greater, even though its value without looking at DCF appears to be less. Additionally, the area between the two curves is the additional benefit received from the Seattle white oak. Thus, at any point in time, how much more the Seattle white oak is worth than the Pittston white oak can be calculated. The basis of the calculation is incremental analysis or the difference between the two curves. This analysis could be extended to any trees using the same methodology.

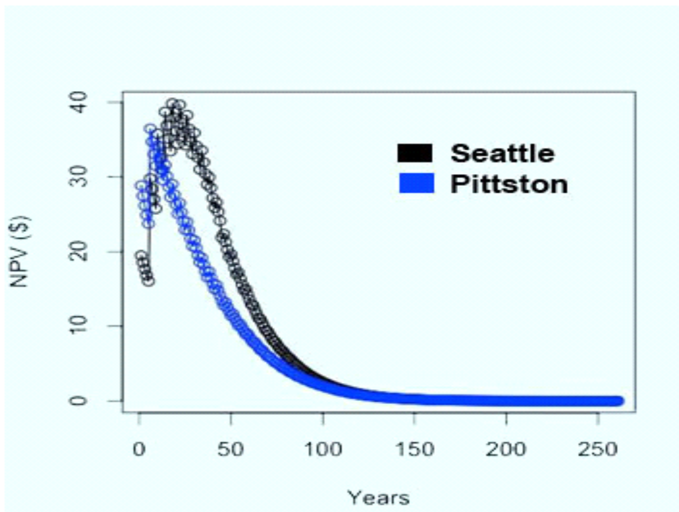

Figure 6. Discounted NPV for white oaks in Pittston and Seattle.

If the interest rate is ten percent, the NPV for both trees decreases because of the opportunity cost of the investments. This devaluation has a greater impact on the Seattle white oak (NPV at ten-percent is $601.40) than the Pittston white oak (NPV at ten-percent is $540.74) because of the shape of the benefit curves; the growth of the Pittston white oaks benefits in the latter years allows it to counteract the rapidly declining slope more effectively. At year 100 in a ten-percent interest rate situation, both the Seattle white oak and Pittston white oak have a NPV of approximately $0.01. The opposite situation occurs when the interest rate is decreased to one percent. The Seattle white oak has a significantly greater NPV ($20,663.04) than the Pittston white oak ($17,079.61). A lower interest rate takes advantage of the favorable investment in trees during the early years because the opportunity cost is lessened.

Another important note regarding the DCFs on white oaks is that at some point in time both the Seattle and Pittston white oaks reach a point of marginal irrelevance. In the five-percent interest situation, this occurs around year 120 (determined graphically, or mathematically, by where the NPV is less than a given minimum value to be "worthwhile"—for this analysis the minimum value decided on was one dollar). Knowing the point of marginal irrelevance allows us to reduce the volume of cash flows in a DCF analysis. For an investment period that extremely long, different strategies for discounting may be appropriate. Some financial analysts suggest reduced interest rates for extremely long term investments.

The species analysis showed that certain tree genera are more valuable than others as urban trees because of their expected future size and slow growth rate. In other words, consumer expectations play a significant role in the valuation of urban trees; in the face of some benefits that are immutably linked to size (such as storm water benefits), urban tree genera that are "preferred" accumulate additional benefit in the form of "property value." In Figure 7, the benefit curves for oak (*Quercus*) and holly (*Ilex*) are contrasted. Even though holly has an initially greater slope, relative to its scale, its benefits do not have the same magnitude as the benefits of oak in the long run. This initial increasing slope is due to the faster growth rate of the holly and its ability to create more physical benefits, such as carbon sequestration, which correspond to growth rate. This analysis does not change when discounting the benefits from the trees. At a five-percent discount rate, over time, the benefits of oak are still greater. Unlike the comparison between white oaks in Pittson and Seattle where the slope of the Seattle oak's growth enabled it to, after discounting, have a higher NPV than the white oak in Pittson, the

Atlanta Ilex's slow early growth rate never allows it to achieve equality with the *Quercus*, even after discounting. To maximize an urban tree investment, choosing trees with greater potential growth and longer life spans indicates high importance.

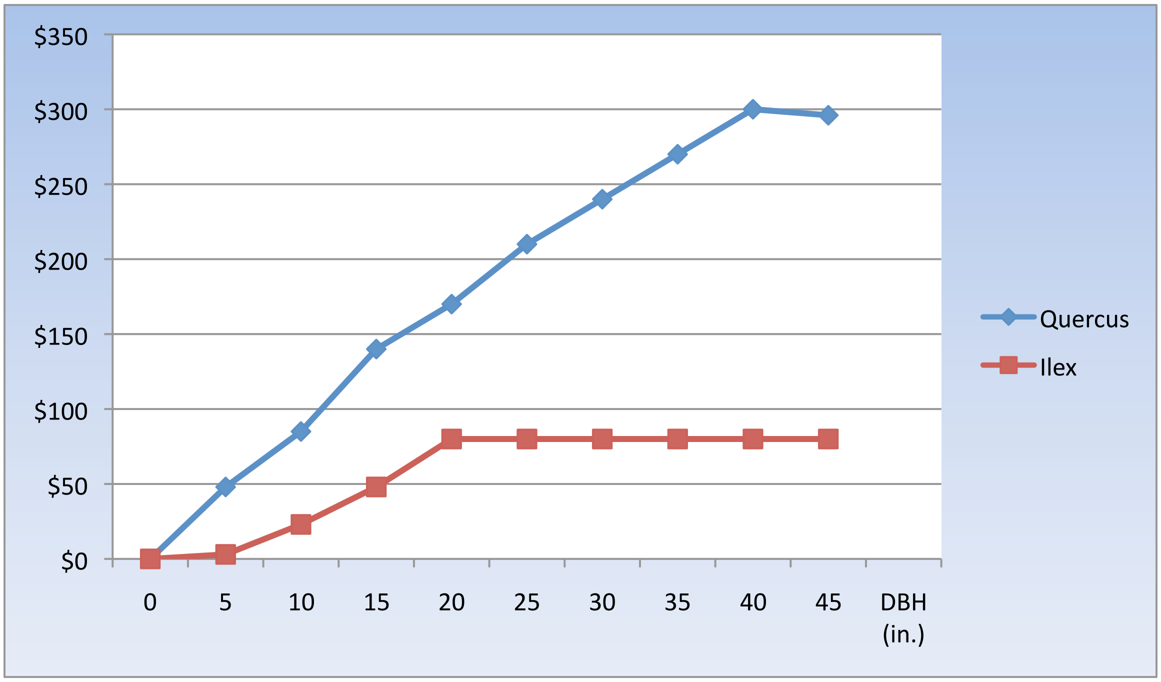

Figure 7. Benefit curves for genera Quercus (oak) and Ilex (holly) in Atlanta.

Table 3 shows an observation of partial benefits revealing more about this pattern; for "lower class" trees, the percent of benefits from property value (as a percentage of the total benefits) increase steadily as the tree increases in DBH. For larger trees, the partial benefits from property value (as a percentage of total benefits) decreases steadily as the tree increases in DBH. Attribution of this is due to the declining nature of the model caused by the slowed growth of the larger trees, and also to the consumer choice of a large future tree on the site. That is, when an oak tree is very small, it contributes largely to the property value of the site because of the expectation that it will become very large; when a holly tree is very small, it does not contribute as strongly to the property value because it is not expected to have a great future size. As it gets larger, however, it becomes more valuable relative to the site.

Table 3. Percent of value from partial sources in Ilex and Quercus.

Percent of Total Value Coming from Partial sources in *Ilex*

DBH	% PV	% SW	% CO2	% NG
5	21.18	28.18	5.56	10.77
15	27.72	34.55	4.34	4.16
27	30.65	40.60	0.60	10.81
45	30.62	40.60	0.60	10.81

Percent of Total Value Coming from Partial Sources in *Quercus*

DBH	% PV	% SW	% CO2	% NG
5	71.11	11.13	2.62	5.02
15	52.36	26.10	2.80	6.30
27	35.41	42.55	6.26	3.83
45	23.32	56.15	6.13	6.13

Conclusion

The various components of an urban tree's value or benefit reveal patterns that underline our social perceptions of trees. Understanding these components provides an adaptive framework that can be used in the development of future models and creates a social background in which consumer decisions and appraiser valuations can be assessed. This analysis showed that urban tree benefits can be "reduced" to certain principal components, largely tied to property value. This value comes from consumer preferences for fuller, larger trees, and that even when urban trees are of a small size, the expectation of their future growth augments their value.

DCF analysis shows that urban trees that have a high value in the future to actually be less valuable over their entire lifespan because of the time value of money, or discounting. We conclude that investing in urban trees with strong value in the present (which again is related to property value) can be a sound financial strategy given that no extraneous events occur. We also identified that trees of the same species in different geographic locations have differing values due to consumer preferences and needs. It is important to take the components of urban tree benefits into account when making financial decisions regarding urban trees.

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Abstract for use in Publication Listing

Urban tree benefits are complex. Little notice is given to the components of these benefits. Total urban tree benefits are a summation of partial benefits, including property value increase, storm water reduction, air quality improvement, carbon sequestration, natural gas savings, and electricity savings. We discuss the nature of these partial benefits, especially the geographical, temporal, diameter size, and rate of growth differences. These differences are even reflected in nursery stock valuation. Net present value analysis is used to illustrate the impact of these differences on financial return.