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A DISCOUNTED CASH FLOW METHOD OF VALUATION FOR SINGLE TREES AND URBAN FORESTS

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A DISCOUNTED CASH FLOW METHOD OF VALUATION FOR SINGLE TREES AND URBAN FORESTS

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ABSTRACT

Urban foresters need a consistent method for valuing single trees with specific non-timber values. There are several accepted methods to accomplish this; comparison of results across the methods ensures consistency. Discounted cash flow analysis (DCF) is one of these methods, but many appraisers or others valuing urban tree are reluctant to use it because it requires complex calculations and assumptions. However, DCF has the advantage of accounting for the time value of money and certain intangible benefits presented by urban trees. Current models are adapted to specific locations and species; a general method for urban tree valuation has not been outlined. The purpose of this research is to determine the scope and nature of urban tree benefits, propose models for these benefits as a series of cash flows, unite these models into a common method that allows for the computation of urban tree benefits as a net present value, and create a guide for using various appropriate systems, particularly FORVAL, to make investment decisions based on this model. This will provide urban foresters (as well as anyone involved with the financial aspects of urban trees) with an accurate and applicable tool for making investment decisions.

DEDICATION

This thesis is dedicated to Drew Hillyer, who passed away March 12, 2010. Drew fought a seven-year battle with leukemia and its complications with unconditional joy. He is an inspiration to myself and my family and will be truly missed.

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CHAPTER 1

INTRODUCTION

Trees produce benefits that differ according to locations and beneficiaries. Forests offer natural benefits to species of plants and animals located within, and they also offer significant benefits to humans. The nature and classification of urban tree benefits has been thoroughly explored and it is well documented in the literature. To a forester, trees are an investment, a crop that can be managed to yield returns in the form of timber, biomass, carbon credits, or other positive pecuniary cash flows (Davis and Johnson, 1987). To an outdoor enthusiast, trees create an atmosphere of recreation and foster healthy pastimes such as hiking, hunting, and fishing (Burger, 2009). And for a city resident, trees planted in urban environments encourage productivity and create a pleasant, restorative experience (Nordh et al., 2009; Dwyer et al., 1992). In fact, significant efforts have been made to describe and categorize the various benefits created by trees planted in urban areas (Dwyer et al., 1991, 1992; McPherson, 1992). Many researchers have come to recognize a specific set of benefits that urban forests create, repeatedly referring to various modes of climatic amelioration, aesthetic vitalization, energy conservation, noise and wind reduction, and social contribution as primary types of urban tree benefits (Sanders, 1989; Ulrich, 1984; Dwyer et al., 1991).

The total benefits conveyed by an "urban forest" are usually calculated as an aggregation of the benefits of individual urban trees viewed in the cultural and spatial context of a particular city (McPherson, 1999; Nowak, 2002; Rowntree, 1984). It is therefore appropriate to view urban forestry as both silvicultural and arboricultural management and to recognize that both arborists and urban foresters need a consistent and financially sound method for valuing individual trees or groups of trees that are located in urban areas. Many valuation models address this for timber production but fail when trees are not being valued for their timber products. While the models that exist in commercial timber situations usually assign a monetary value to the total number of single trees on a per acre basis based on accumulated positive and negative cash flows (such as those from thinning, treatments, and harvest), similar models are not used in urban forestry because of the difficulty in quantifying cash flows for urban trees.

A forest designated for timber production provides some abstract benefits, but its value is often described primarily in terms of the concrete products it creates (timber) that can be bought and sold at a market price, giving the trees a market “value” (Davis and Johnson, 1987). Since urban trees provide benefits above and beyond just those related to the trees’ physical “values,” and many of these benefits are hard to evaluate since they are intangible, alternative valuation strategies must be used (Dwyer et al., 1991; McPherson, 1992). The values for intangible benefits are determined through methods that quantify consumer’s willingness-to-pay for intangible amenities. Methods used successfully to quantify the benefits created by urban trees include hedonic pricing (Jim and Chen, 2008; Payton et al. 2008), shadow-valuation (Diaz-Baltiero and Romero, 2007), and variations on contingent valuation (Jim and Chen, 2008; McPherson, 1999). All of these methods use opportunity costs to look at intangible benefits in terms of distinct, definite cash flows. Understanding these cash flows, and how to use them to make an investment decision, can be difficult for an arborist or urban forester without a strong financial background and familiarity with complicated software and statistical methods.

The literature shows that the discounted cash flow (DCF) analysis method of valuation has been largely avoided in the arboriculture and urban forestry professions, and urban trees are often appraised using methods of valuation that inherently disregard the time value of money and the time-sensitive nature of some intangible benefits. It is recognized that DCF is an accepted method of valuation for trees and it can be used aptly in an arboriculture or urban forestry context. It can and should be used as a tool to support other common urban tree appraisal methods. This document facilitates the use of DCF for valuing urban trees by explaining, organizing, applying, and analyzing a general method of urban tree DCF.

The first step of the model explicated here is to organize and classify urban tree benefits into general categories that reflect what has been commonly described in the literature (Dwyer et al., 2002; McPherson and Simpson, 2002; Ulrich, 1984; Nowak et al., 2005). By classifying and quantifying urban tree benefits, specific, individual benefit models are created that reflect the intricate pattern of cash flows that characterize urban forests. These models provide a framework that can be used for specific valuation scenarios, making visualization of the cash flows over the life of the tree simpler and more accessible. The method used to evaluate the discounted cash flows from example urban trees can be applied to any urban tree because it has been purposefully chosen to use publicly available resources in order to obtain the basic values and uses a methodology of application that is simple and broadly applicable.

The data system chosen for this analysis uses the National Tree Benefit Calculator, which is available online. Through the Davey Tree Expert Company's National Tree Benefit Calculator (NTBC), anyone can access a database of urban tree benefit information (Davey, 2009). For discounted cash flow analysis calculations, the use of FORVAL, financial analysis software designed specifically for foresters is exemplified here (Bullard, Straka and Landrum, 1998). FORVAL is a standard, reputable, financial model; it is user-friendly and is also available freely online. This technique can, however, be extended to other financial models and used with the same structure and efficiency. The applicability of the model to multiple systems is recognized in the context of understanding that any forester or other professional with access to a computer and knowledge of basic accounting principles should be able to use both the NTBC and FORVAL.

The use of computer models to simulate the growth and financial returns from trees has gained popularity since its onset in the 1960's with basic models for crops that calculated growth and yield based on photosynthetic rates and market pricing. Computer models for forest valuation are considered to have six viable parts: background, economic objectives, analytic objectives, spatial and temporal scale, biophysical data generation, and platform interface and input-output system (Graves et al., 2005). This method for urban tree valuation fits into this basic structure, although urban forests are simpler on some parts and more complicated on others. The main difference between this model and existing models for timber forests is the situation-specific manual entry of current data. Timber models can be extended over large areas because of tree consistency and owner objectives; urban forest models are more specific and can reflect individual particularities and discontinuities that timber models cannot (Church et al., 1999).

The background, analytic objectives, and spatial and temporal scale of this method are all “user-defined;” that is, a user’s location, personal or professional objective, and scale (single tree to green resource, short time span up to “perpetual” investment) vary from user to user and do not affect the systematic of the model, only the inputs. This simplifies the basic model structure; instead of constraining the model to a specific location, objective, or scale, it simply reduces the input to only calculate for a certain location, objective, or set of trees. However, the economic objectives, biophysical data generation, and platform interface and inputs-outputs are more complicated. Because an urban forest is highly variable, these objectives, data, and inputs must be manually defined by situation. The outputs of the model also require an understanding of financial terminology, which will be explained in this document and further defined in Appendix A. While this appears more complicated than a traditional model, urban forests are more variable than timber forests and therefore require customized application structures in order to engender accurate valuations.

In this document, the current practices used for urban forest valuation are reviewed and their abilities and flaws assessed. The importance of costs and the basics of cost modeling are discussed and an elaboration on DCF analysis of common DCF situations is presented. Next, partial (benefit and cost specific) and full (including both benefits and costs for real examples) financial models that can be used in any urban forest situation are provided. Then, the results of these models are examined with a mathematical discussion of this model in the context of its data and financial implications. Included are also tutorials on both the use of the NTBC and FORVAL, with "step-by-step" pictures and text to show how the benefit models can be entered into FORVAL and a financial decision can be made. Finally, suggested areas where further research regarding urban forests and benefit-based valuation could be used to improve the current level of study are presented.

CHAPTER TWO

THE NEED FOR A NEW METHOD OF URBAN TREE VALUATION

By standard models, valuation of urban trees is limited to either structural benefits (those caused by the tree's physical form creating a beneficial externality for its owner) or easily quantified external benefits (positive externalities from an urban tree to a community at large). Beyond the benefits that can be easily qualified and quantified, trees also convey "immeasurable" benefits including historic, recreational, or aesthetic value (Dwyer et al., 1991). The following two examples display two situations in which these benefits are of great magnitude, but where current valuation models would fail to view them as significant reason to invest.

"The Tree That Owns Itself," Athens, GA

"The Tree That Owns Itself" grows between North Finley Street and Spring Street in Athens, Georgia. This is a bustling residential area and "The Tree That Owns Itself," a white oak (*Quercus alba*) obstructs a minor intersection (Appendix B, Figure B-1). Despite being a nuisance for traffic and a liability for residences proximal, "The Tree That Owns Itself" is an adorned landmark in Athens, Georgia. Following the deed in the will of its planter, William Jackson, "The Tree That Owns Itself" was given rights to its own structure as well as eight feet of land surrounding it on any side. Since the tree is growing, this eight-foot leeway is constantly expanding. Although the tree was once felled by strong winds, it has since been replanted from its own acorn on the same spot and continues to grow under its own ownership (ACC, 2009).

"The Tree That Owns Itself" shows how an urban tree can have positive intangible benefits despite the fact that it causes negative externalities (spatial interference and human discomfort). Some benefits of urban trees come from their importance as historical elements in the landscape (Maurer et al., 2000). Assessment of its value with a technique that did not account for intangible benefits would be inadequate. In fact, if the negative externalities were great enough, it might be concluded that "The Tree That Owns Itself" was a liability instead of a valuable landmark because the calculations did not represent the tree's true worth (Tietenburg and Lewis, 2008).

The value of "The Tree That Owns Itself" is sufficiently greater than a value that could be computed solely based on the tree's physical presence outside of its historical context. Specifically, the value of any tree can be described by the basic formula:

(Eqn. 1) $$TV = (B_P + B_I) - C$$

Where:

"TV" represents the total value of the tree
"B_P" represents the value of the physical (tangible) benefits
"B_I" represents the value of the intangible benefits
"C" represents the cost of the tree.

This formula shows the general structure for accounting for tree worth, but does not account for the time value of money. A discounted cash flow analysis model uses a factor to account for the interest rate charging or accumulating money over time. This factor is used to “discount” or “compound” cash flows to the present time, year zero (Straka and Bullard, 1998). The mechanics of discounted cash flow analysis are discussed further in Chapter Three, but for the sake of clarity here, a hypothetical discounted cash flow analysis valuation of “The Tree That Owns Itself” is presented.

This example shows how a discounted cash flow analysis for “The Tree That Owns Itself” might appear given a five-percent interest rate. This example takes the form of an “itemized list,” and examples of this nature will appear throughout this document. Standard accounting parenthetical notation for negative cash flows has been chosen to avoid confusion. Net present value is abbreviated “NPV” and here reflects a value at year zero (“V_0”) of the planting year for this tree.

Table 2.1 Hypothetical cash flows for “The Tree That Owns Itself” at a Five-Percent Interest Rate

ITEM	YEAR	AMOUNT	NPV @ 5 % interest
Plant	0	($200,00)	($200.00)
Benefit A	10-50	$5.00	$55.74
Replant	50	($100.00)	($8.73)
Benefit A	65-110	$5.00	$3.93
History Val.	70-110	$40.00	$23.87

The sum of the NPV column in the above list represents the value of the tree at its planting year. To know the equivalent value at any time in the future, the NPV can be compounded forward for “n” years (where “n” represents the number of years ahead of time zero). Compounding is simply the opposite process of discounting; it enables forward motion on the timeline (Straka and Bullard, 1998).

This analysis produces not only a more financially accurate valuation for the tree’s net worth, but in the case of “The Tree That Owns Itself”, it also accounts for changes in the tree’s history. Of course, it is recognized that some of these values conveyed over time are hard to determine and an inappropriate valuation could diminish accuracy; however, an undiscounted valuation is fallacious in its own way. Without including the discount rate, a valuation tells the value of the tree at one point in time; a discounted cash flow valuation (albeit dependent on the accuracy of the valuations by which it is composed) accounts for the tree’s benefits when it was first planted, the change in those benefits when it was felled and replanted, and its current benefits at a size greater than the original planting size. In the case of “The Tree That Owns Itself,” the final value on the itemized list, “history value,” is an outstanding intangible benefit and quantifying the monetary significance of “The Tree That Owns Itself’s” historical value is imperative for using discounted cash flow analysis to assess it.

Hotelling is frequently credited with the first recognition of the need to quantify non-market benefits (such as historic value) based on a letter written to the National Park Service in 1947 (Stenger et al., 2009). His method of travel-cost valuation is not applicable to urban forest valuation because urbanites generally do not need to travel very far to experience an urban forest. The strategy of contingent valuation or "willingness-to-pay" is much more applicable for urban forestry. This method involves determining how much the market is willing to spend in order to continue the status quo; it is used in the second example (Tietenburg and Lewis, 2008).

The $21,000.00 Oaks

The rapid growth of the Orwood Park neighborhood in Atlanta, Georgia caused a pair of architects designing a home on a lot endowed with several large oaks to take precautionary action against their future removal. This action was taken for the sake of the "experience" that the oaks provide (Peters, 2009). Atlanta's Urban Tree Ordinance stringently protects big trees; legislation from a 2003 addendum rules that trees above a certain minimum diameter at breast height (six inches for deciduous and twelve inches for conifers) may not be removed without the incurrence of a fine (City of Atlanta, 2009). This "recompense law" specifies that unless a tree is "damaged, diseased, or dangerous," removal of a tree above the minimum size requires a replanting of tree of the same size and of "in-kind" species (from an approved tree list) or a payment of a "recompense fee," which is a flat rate of one-hundred dollars, plus thirty dollars per additional inch of diameter (City of Atlanta, 2009).

On large lots, where many trees may be removed, expense of this sort might surmount to a sizeable deterrent to development, but in the case of smaller lots with fewer (but still significant) big trees, this formula clearly underestimates tree value. To prohibit removal, the architects drafted a “Tree Protection Easement” for the two oaks, placing them into a conservation easement similar to a historic preservation easement or forest conservation easement (Peters, 2009; Levert et al., 2009). The architects had the trees appraised by the Atlanta City Arborist and their value was determined to be approximately $21,000.00. The total value of the property was appraised at $204,000.00. The creation of the easement reduced the property value by $40,000.00 (Peters, 2009). This $19,000.00 loss for creating the easement ($40,000.00 lost property value - $21,000.00 standing tree value) represents the value of the trees above and beyond their physical value at the time of easement creation. This real value is one example of how intangible benefits can be quantified (before DCF) and demonstrates the existence of intangible values for urban forests.

CHAPTER THREE

LITERATURE REVIEW

A review of the relevant literature shows that many urban foresters, arborists, realtors, appraisers, lawyers, and researchers have attempted to come up with an accurate way to value the individual trees that compose urban forests. Urban forests differ from a timber forests in two ways: first, they are located within densely populated areas, and second, urban forests have an open definition for minimum size (Sanders 1984; Tait et al. 2009). Whereas what is hypothetically thought of as a “forest” is considered as a large collection of trees, the term “urban forest” may refer to a small group of trees or to the green resource of an entire city. The expansion from a single urban tree to any size urban forest is not mathematically difficult; the challenge in urban tree valuation is defining and quantifying the value of an urban tree itself.

The fundamental published research recognizing the benefits of urban trees begins around 1980 with the birth of specific benefit-based valuations, especially those noting a tree’s ability to enhance quality of life (Ulrich, 1984), mollify urban climates and intercept storm water (Bernatzky, 1982), provide energy savings and barricade from wind (Harrje et al., 1982; Heisler, 1984) and generally increase residential property value (Anderson and Cordell, 1985). Valuation of these benefits can either be calculated implicitly or explicitly. An implicit calculation uses market prices to determine the value of an urban tree, and the benefits described are considered as components of that value. An explicit calculation determines the value of the benefits themselves, and unites them into the value of the tree. Neither calculation method is “right” or “wrong,” and multiple methods of tree valuation add perspective to an appraisal (Contato-Carol, 2008).

Three primary approaches are currently used for the valuation of urban trees. These are the comparable sales approach, the loss-replacement approach, and the CLTA (Council of Tree and Landscape Appraisers) Formula Method. In some cases, urban forests may be valued with a combination of all of these methods (McPherson et al., 2005). Because the methods of urban tree valuation are constantly evolving, urban tree appraisals are often done with several different methods, and understanding the advantages and disadvantages of each method in comparison with one another is important. Although each of these commonly used methods has its benefits and produces a value for urban trees, none of the current methods directly account for the time value of money. In this section, a summary of the current valuation methods and a description of the common benefits and costs incurred by urban trees is detailed, and the applicability of the NTBC as a data source based on these benefits is discussed. This sets the stage for the DCF valuation model developed in this document and leads to a discussion of “The Problem”—the need for methods that account for the time value of money—which will be discussed in Chapter Four.

The Comparable Sales Approach.

Anderson and Cordell (1985) determined that each large, front-yard tree on an urban property corresponds with a 0.88 percent increase in sales price. This figure was determined by a comparison between two properties (one with trees and one without; the 0.88 percent comes from a total price alteration of 4.5% divided by the average number of large trees on the front lot) and it exemplifies application of the comparable sales approach. Essentially, the comparable sales approach in urban forestry is a hedonic method of valuation that evaluates trees as an aspect of a property. Two similar properties may be compared and the amenity value of the trees is implicitly defined as the difference between the prices of the two properties (Præstholm et al., 2002).

The first step of the comparable sales method is a comparison of property values and compared measurements of the urban trees present. In other words, the comparable sales method requires that the user know the values of the properties being compared and the difference in the amount and characteristics of trees present on the property. Even without further analysis, this first step of valuation can provide valuable information about how the presence of trees alters property value. Jim and Chen (2008) successfully used this approach to determine the equivalent (in United States dollars) of a seventy-five thousand dollar premium (approximately fifteen-percent of total value) on apartments in Hong Kong proximal to parks and green areas.

The comparable sales method has also been employed in conjunction with geographical information systems to compare canopy cover (implying denser vegetation) and housing prices in Marion County, Indiana. This study found that tree cover had a significant, positive impact on home prices (Payton et al., 2008). Importantly, this showed that the comparable sales method could be used accurately as a component of a remote sensing analysis, verifying the possibility of a remotely sensed appraisal. An underlying assumption of this analysis is that urban trees generally provide an increase in property value, and therefore a property with urban trees would have a greater value than one without. However, there could be a situation where an urban tree was particularly hazardous, in which case it would be a liability to the property as opposed to a benefit. In this case, the comparable sales method would need to be altered to reflect a calculation of tree liability, or an alternative method of valuation would need to be used.

The second step in the comparable sales method is the determination of the amenity value of the individual trees, tree group, or "forest" based on the difference between the compared values. This step, then, attributes the difference between the property values to specific components on the landscape, one of which is the difference in (the measured qualities of) trees present. Outside of a set experiment, however, it is rare that any two properties will be exactly the same; therefore, some of the difference in value could be attributed to something other than tree presence. Differences in property values can be attributed to everything from proximity to nuclear power plants (Gamble and Downing, 1982) to capacities of local waste facilities (Zeiss and Atwater, 1989) to property taxes and the local economy (Oates, 1969). However, the comparable sales method can deal with this situation through statistical analysis of data gathered about the site. One advantage of the comparable sales method is its relative suitability to regression models. Specific characteristics of the properties being valued can act as variables between compared properties to determine which component in a landscape provides the most value to that landscape. For example, a photographic study conducted in Sweden showed urbanites various images of similar parks with varying amounts of green elements. These photographs were quantitatively balanced to include particular amounts of light, buildings, and other controlled variables. The value of "trees" as a component of the regression analysis of landscaping components monetized by the comparable sales method determined that "trees" accounted for a mean 32.49 percent of a greenspace's value (Nordh et al., 2009). The potential for regression analysis allows for, if necessary, extrapolation of this data to alternative situations. In this sense, comparable "sales" method can also be used for non-monetary valuation. In the aforementioned study, the researchers expanded their study to find that the value of the variable "trees" on a property is strongly correlated to a person's feelings of "restoration" while viewing that same property (Nordh et. al., 2009). The participants were asked to rate which parks they found to be the most "restorative" and which elements in the images contributed to this restoration. Large green elements, including trees, had the greatest impact on participants' feelings of restoration, and were therefore considered the most "valuable" (Nordh et al., 2009).

Another significant benefit of the comparable sales method is that it can be relatively easy to use and still produces reliable results. Realtors, for example, often use the comparable sales method; house price indices are based on the principles of comparable sales and are both widely and easily used (Bourassa et al., 2006). The efficacy of the comparable sales method has been demonstrated in comparison with professional tax appraisals. Stepwise regression was performed on the total monetary values of residential properties in Austin, Texas, and a basis determined by recording the costs of various elements on the properties' lots and physical improvements (Martin, 1989). Between thirteen and nineteen percent of property value was attributed to trees (R-squared 0.82). The values determined by this study were then compared to professional tax appraisals of landscape elements in the same cities and less than two-percent discrepancy was found. The next step in this type of analysis would be regression of data determined by the comparable sales method to illuminate endogenity in market values and help to determine methods, such as types of spatial expansion that account for local biases, to separate the trees actual worth from market preferences and expand the conclusions determined by the study (Cho et al., 2008; Smith et al., 2002).

The comparable sales method is a relatively straightforward and accurate way of predicting the value of an urban forest at a given moment in time. However, the fundamental concept of “comparable sales” insists that two similar properties be compared. Therefore, the scale of the comparable sales method is limited to properties that can be adequately viewed in the context of one another. This calls for certain assumptions, such as the exclusion of non-specific “market benefits” such as carbon sequestration and independence of property characteristics with regard to their substitution values (Anthon et al., 2005). Additionally, like the other methods in this discussion, the comparable sales method does not account for the time value of money. A large tree growing on one property for one-hundred years compared with a medium sized tree growing on a similar property for fifty years will have a financial relationship that is exponentially, not linearly, related.

The Loss-Replacement Approach

The loss-replacement approach is another valuation technique used by urban foresters. It requires a more astute procedure than the comparable sales method but provides more accurate results. Loss-replacement is a type of compensatory valuation; in short, a tree's value is defined as what it would cost to replace the tree. The simplest example of this form of valuation is a literal replacement scenario. For example, if a fifteen-year old silver maple (*Acer saccharinum*) is removed, the tree's value could be adequately described by the loss-replacement approach as the cost to replace the tree based on purchase price from a nursery. In this sense, the loss-replacement method is a cost-based technique and is therefore subject to market fluctuations; however, receiving up-to-date market information for urban trees is not particularly difficult. Databases of transplantable tree values can be obtained from the International Society of Arboriculture (Nowak et al., 2002). Additionally, nursery prices for transplantable trees can be found by executing a search for "local nursery prices" in an online search engine.

An advantage of this method over the comparable sales method is that it can be used to assess larger urban forests. Nowak and colleagues (2002) used the loss-replacement approach to value all urban forests in the United States (2.4 trillion dollars worth) by extrapolating data collected from the largest cities to the nation as a whole. The loss-replacement approach can also be used as a hypothetical situation to elicit a consumer valuation response. Urban residents in Colorado were asked how much they would have to be paid to accept a loss of tree density in familiar parks (200 trees reduced to 175 trees reduced to 150 trees). This “willingness-to-accept” loss represented the cost the consumers placed on the trees in the context of their removal. A loss of twenty-five trees per acre was valued at $855.50 cost to accept, and a loss of fifty trees per acre was valued at a $1734.40 cost to accept (Brookshire and Coursey, 1987). A continuation on this study verified the “willingness-to-accept” cost as not significantly different from the same question asked in terms of a “travel-cost scenario” showing that different methods of cost-based questioning produce similar results (Walsh et al., 1989).

The loss-replacement approach can also be useful for determining the consumer value for urban tree treatments. Participants in a Texas survey were shown images of damaged trees in a recreational area and asked their willingness to pay to visit this area; they were then shown the same trees in a healthy state and asked the same question. Resulting values of greater than $5000.00 indicated that the value for the loss of parts of trees (in this case to Southern Pine Beetle) was extensive (Leuschner and Young, 1978). Treatment cost evaluation by a willingness-to-accept perspective through the loss-replacement approach is particularly relevant for urban forests threatened by exotic pests or management incapability (Nowak et al., 2005). This is another example of the “travel-cost” approach. Although it can be used in this sense for urban tree valuation, it is often not relevant as a loss-replacement technique for urban trees in a residential context; it implies that the beneficiary has to pay a value in order to cross the distance to benefit from a tree, which is not the situation that exists with residential urban trees, since they are located in the area of residence for urbanites.

The primary disadvantage of the loss-replacement method is that it often cannot be applied to trees valued by urban foresters—large, old, "irreplaceable" trees—trees of this size and stature are not grown in nurseries and could not be economically transported to a site if they were. To face this difficulty, the Council of Tree and Landscape Appraisers (CTLA) created a loss-replacement equation that determines how a summation of smaller trees can be used to "equal" the value of a single, large tree. The following formula is used:

(Eqn. 2)

$$V_B = C_R + (P_B * T_A * T_R * V_S)$$

Where:

"V_B" is the "basic value" of the tree
"C_R" is the cost of replacement of the largest transplantable tree
"P_B" is the basic price (the local average cost per unit of trunk area in dollars per square centimeter
"T_A" is the trunk area of the appraised tree
"T_R" is the trunk area of the replacement tree
"V_S" is the species value

Adjustments to the CTLA formula for loss-replacement have been proposed that take into account the way that trees "depreciate" over time (Hollis (a), 2009). These adjustments would allow the basic value to change over time. Species value tables for this method are available from the CTLA (Nowak et al., 2002). While this method is practical mathematically, five ten-inch trees do not equal a fifty-inch tree. There is an inherent difference between the benefits of one large tree and several smaller trees that "add up" to the same value.

<u>The Council of Tree and Landscape Appraisers (CTLA) Formula Approach</u>

The third method of urban tree valuation, and a popular one for appraisals and arboricultural use, is the CTLA formula valuation approach. This method is used to assess the value of a tree based on a basic trunk formula plus proportionate deductions for species, location, and condition. Burns (1986) determined that the basic value of a tree was twenty-two dollars per square-inch of cross section measured at diameter at breast height (DBH). He wrote out the CTLA formula method as follows:

(Eqn. 3)
$$TV = V_B * S * C * L$$

Where:

"TV" represents total value

"V_B" represents basic value of the tree as determined by the CTLA

"S" represents species class as an adjustment factor between zero and one, usually in increments of 0.10

"C" represents condition class as an adjustment factor between zero and one, usually in increments of 0.10

"L" represents location class as an adjustment factor between zero and one, usually in increments of 0.10

An example of this model in use shows how two trees of the same size, condition and species can be compared across locations. One fourteen-inch live oak (*Quercus virginiana*) in a residential area has a basic value of $3,388.00 with one-hundred percent species class (1.00), eighty-percent condition class (0.80), and eighty-percent location class (0.80), amassing a total value according to the formula of $2,168.32. Another fourteen-inch live oak in a wooded area has the same basic value ($3,388.00), species class (1.00), and condition class (0.80), but has a ten-percent location class (multiplier 0.10), so its total value is $271.04 (Burns, 1986). Because of the urban tree's presence in a residential environment where it could be "enjoyed," the urban tree had a greater value according to the CTLA formula than the forest tree.

In other nations, similar formula-based approaches to valuation are also used (Price, 2003). For example, in the United Kingdom, Helliwell's system is often used for legal appraisals. Helliwell's system consists of seven components and its formula for calculating tree value ("TV") is:

(Eqn. 4)

$$TV = [SizeofTree]*[UsefulLifeExpectancy]*[ImportanceofPositioninLandscape]* [PresenceofOtherTrees]*[RelationtoSetting]*[Form]*[SpecialFactors]* [\$22.60]$$

The multiplier at the end of Helliwell's system ($22.60) is similar to the "basic value" component of the CTLA formula method; it turns the indefinite product of the terms into cash (Price, 2003). The value of $22.60 has been determined from the original value in pounds, £14.00, at 2010 exchange rates. The terms in Helliwell's system are also similar to the terms in the CTLA method, indicating that the characteristics used to observe tree value are used globally.

The formula method produces consistent results catered to the specifications of each tree. The repeatability allows the formula method to determine values that can be accurately compared against one another, even when trees are located in different locations. However, this formula does have limitations in its applicability; it was designed for a standard set of location inputs, which means that it may not create an adequate measurement of urban tree value in other situations, such as extremely high-density housing. Jim (2005) acknowledged the inability of the CTLA formula method to account of for some of the additional benefits generated by "heritage trees" or trees existing in a particularly dense urban area with an exceptionally low tree-person ratio (Hong Kong). His suggestion for a revamped formula method (the formula expert method, FEM) includes various calculations of tree "score" and a three-year moving average calculation for property value increase. FEM values ranged from seventeen to 1218 times the magnitude of CTLA formula values with an average value of sixty-six times the CTLA value. Without saying anything about the formulas themselves, this difference indicates the possible variability that can occur in formulaic valuations of urban trees.

Although the FEM method uses price averaging, neither it nor the original CTLA method accounts for the time value of money. Because the discount rate works exponentially, and a tree growing on a site is a time-consuming investment, money invested in a tree, over time, can be dramatically altered depending on the interest rate. For example, suppose an urban forester needed to decide whether or not to cut down a now seventy-year old oak tree. This removal would happen five years in the future in preparation for the construction of a highway on the site ten years in the future. The value of the tree now, at the time of cutting, and at the time of the project will all be different, not just because of an increase in the tree's size or a decrease in its condition, but also because the discount rate available will affect the value of all cash flows associated with that tree. Although this will be discussed further in Chapter Four, the basic interest formula, $V_n=V_0 (1 + i)^n$, shows how "V_n" (the future value) is augmented from V_0 (the present value) by a factor of (1 + i), where "i" is the interest/discount rate for "n" periods of investment.

As "i" or "n" increase, the difference between the values of V_0 and V_n also increases. In other words, the larger the discount rate or the longer the investment period, the more change will occur between present and future value. In contrast to this, the formula method is limited to assessing the physical value of the tree at a given time; it does not account for this potentially enormous change in value between time of assessment and time of action, nor does it account for any additional benefits or costs that the tree incurs over the course of its life (which also must be viewed through the lens of discounted cash flow analysis). Finally, formula method valuation only values the trees through the eyes of the appraiser. Certain trees, especially larger urban trees or those with particular historical significance may have a fair market value that exceeds their appraised value (Hollis (b), 2009). Valuation strategies such as those that have been continuously mentioned throughout this paper (hedonic pricing, travel cost, willingness-to-pay, willingness-to-accept, contingent valuation) can be used to determine the cash flow associated, but these cash flows still need to be discounted or compounded in order to assess an urban tree in a financially accurate way.

Urban Tree Benefits

The value of an urban tree is described in terms of "benefits" minus "costs." This section contains an enumeration and discussion of current research regarding tree benefits. These benefits can be both physical (benefits based on the structure of the tree), and intangible (benefits based on the tree's inherent qualities). The formula below is repeated from chapter two in order to emphasis this point here; total value ("TV") is a sum of physical and intangible benefits ("B_p" and "B_I") minus costs ("C"). Equation one is also repeated below for clarity on this relationship:

(Eqn. 1) $$TV = (B_P + B_I) - C$$

Based on the literature reviewed, twelve categories for benefits from urban trees were determined:

1. Energy Savings
2. Wind Break Savings
3. Soil Enhancement
4. Privacy Benefits
5. Sound Barrier Benefits
6. Carbon Sequestration
7. Air Quality
8. Storm Water Reduction
9. Recreation and Health
10. Aesthetic Benefits
11. Local Economic Development
12. District Sales Increase

These benefits fall into the same two sets: "physical" benefits, which can be measured based on the opportunity cost of a commodity not purchased, and "intangible" benefits, which have to be determined based on an indirect method of valuation. Additionally, the benefits can also be separated by beneficiary; some benefits apply to only an individual property-holder, whereas others apply to a non-definite group of beneficiaries. In terms of the classical economic description, all benefits conveyed by urban trees can be considered "indirect," since the benefits do not result from the commodification of the tree as a product.

In chapter five, examples of DCF analysis for each of these benefits are presented individually. For now, each is considered to be a component benefit (of the whole total benefit a tree can convey) and their presence in the literature is discussed.

1. Energy Savings

Trees create shade, which reduces the cost of cooling in summer and prevents heat transpiration in the winter, reducing the cost of heating. The shade creation is primarily the result of shadow coverage by leaf surface area. This cooling effect is known as a “cool-island” effect and has been described as mitigation for the common “heat-island” effect often seen in cities that causes increased electricity bills and decreased quality of life (Hamada and Ohta, 2010). Remotely sensed data (high-resolution imagery) has been used to provide information about the relationship between urban tree crown size and structure, the thermal dynamics of urban areas, and the effects of the urban energy budget (Weng, 2006). It has been shown that trees with dense crowns, particularly coppice trees, create microclimates around them that are significantly cooler than urban land without tree growth. This is partly attributed to the shade created by the crown, but also attributed to the wetness of soil proximal to urban trees of this form and the planting of grass species with rapid transpiration on urban lawns (Hardin and Jensen, 2007). Direct shading from trees significantly reduces solar radiation, indicating that broadleaf deciduous trees create more shade than conifers (Heisler, 1986). However, dense conifers or a unit of several conifers might provide similar energy benefits to a single broadleaf tree.

It has been determined that vegetation on a landscape lowers the nearby surface temperatures by about thirty degrees Fahrenheit on average; in Phoenix, reductions in electric bills averaged near eighty percent, whereas in Philadelphia the reduction in electric bills averaged closer to thirty percent (McPherson and Rowntree, 1993). This study suggested the full difference was due both to the difference in temperature range in the northeast and southwest, but variation in the amount of heating and cooling days allocated to natural gas could also provide for some of the savings.

2. Windbreak Savings

Trees can act as windbreaks, protecting a structure against damage from hazardous gusts or precipitation. Windbreaks may also reduce fuel use by acting as a natural form of insulation (Heisler, 1978). Wind speed reduction in particularly gusty areas or with relation to housing structures that lack significant insulation, such as mobile homes, may reduce heating bills by up to forty percent (McPherson and Rowntree, 1993). Spherical thermographs were compared with a computational fluid dynamics model to assess the significance of both the wind speed reduction and the thermal insulation provided by residential trees, and it was found that the windbreak effects of an urban tree can be simulated precisely by models (He and Hoyano, 2009). Additionally, in certain urban environments, it has been shown that the windbreak effect from urban trees slows the dispersion and intensity of foul odors (Lin et al., 2007). The ability of a tree to provide windbreak benefits is dependent on its size, leaf porosity, structure type, and distance from the structure being protected. Windbreak savings by a tree are then highly variable, but amount to a substantial benefit in some situations.

3. Soil Enhancement

Trees provide nutrients, such as nitrogen, by converting chemicals in their roots, dropping nutrient rich foliage in the fall, and aerating the soils through root penetration. The exact way that a tree enhances soil is dependent on the tree species, competition, and local climate (Ayers et al., 2005). However, the notion that trees increase soil nitrogen by undertaking and fostering N_2 fixation is a generally accepted principle, and the relationship between tree roots and fungal mycorrhizae is a well-documented relationship that benefits soil characteristics (Buresh and Tian, 2004). Additionally, the presence of tree roots in the soil promotes the sequestration of carbon, and encourages underground nutrient transport (Nair et. al., 2009). Urban landscapes are not optimal for tree growth; construction and human use compacts the soil in a way that can harm soil health. It has been estimated that between forty and eighty inches of good soil are required for the planting of urban trees; much of the organic matter composing this soil is made up of fallen debris from standing urban trees (Sæbø and Ferrini, 2006). Thus, the presence of an urban tree enhances the soil for other uses, but also enhances the soil for its own growth and well-being, so that soil enhancement is a positive cycle caused by a continued urban tree presence.

4. Privacy Benefits

Trees create a barrier between a home and a public area. A single large tree or a row of well-planted smaller trees may prevent drive-by traffic from peering into one's home or office (Matsuoka and Kaplan, 2008). The increased comfort from privacy benefits the property owner. It has been shown that people will choose "private" habitations over ones close to others, and this desire for privacy is linked with the tree-filled exurban environment (Johnson, 2008). Additionally, valuables may be concealed, decreasing the need for a home alarm system. The benefits of privacy are contingent upon the needs of landowner based on location.

No current, peer-reviewed literature contains a benefit calculation of privacy from trees, although undoubtedly one can be determined. Nor does a model exist for calculating this benefit mathematically; however, case-by-case values for cash flows can be determined through contingent valuation. In this situation, that would be asking a property owner how much additional money he or she would pay for added privacy on a per-year basis. Further data could also be collected and incorporated if necessary.

5. Sound Barrier Benefits

Trees create a barrier against sounds. Extended exposure to loud noise promotes anxiety and increases possibility for illness; a reduction in sound is beneficial for increasing psychological quality of life and physical health. Reduction in noise, particularly from freeways, ameliorates sleep problems and decreases stress levels (Arenas, 2008). Sound waves are dispersed by the presence of leaves and branches, and “persistent foliage from the ground up” provides the best sonic barrier (USDAFS, 1990). Valuations for noise reductions suggest that trees are able to provide roughly six to eight decibels sound reduction apiece (Leonard and Parr, 1970).

It has been shown that in order of decreasing ability to contribute to sound barrier benefit, belt width (for more than one tree in a “belt” of acoustic barricade), tree height, and constancy of trees within the barrier are the most substantial contributors to tree sound barrier benefit creation. Models have been created that can simulate the effects of trees on sound, and these models can be used to design landscaping elements that have the most sound barrier benefit ability (Fang-Fang and Ling, 2005). Because the sound barrier benefit may not be desired or necessary for all urban tree beneficiaries, discrimination should be used when deciding to include this benefit in an analysis.

6. Carbon Sequestration

Carbon sequestration occurs when a tree “locks up” carbon in its woody structures, preventing extraneous particles from escaping into the atmosphere and causing damage to the ozone. Estimates from Hangzhou, China, indicate that urban trees offset 18.57% of the city’s industrial emissions (Min et al., 2009). Although carbon sequestration from trees is not as effective as sequestration from industrial methods such as injection, trees utilize the sequestered carbon to produce oxygen, which geothermic processes do not produce. Additionally, benefits of carbon sequestration are coexistent with the benefits of energy savings; a tree reduces the need for emissions creating processes such as heating, therefore keeping carbon out of the air.

Research has been done to determine an individual tree's ability to sequester carbon. Trees' abilities to sequester carbon are based on both their growth rates and current sizes. It has been shown that trees grown in an open area have less ability to sequester carbon than those in a woody area; allometric equations and conversion factors exist for many genuses and locations (Nowak et. al., 2002). As the tree grows, it contains more woody biomass that can hold sequestered carbon, meaning that its benefits will increase throughout its life. Measurements taken once every seven years in Syracuse, New York by spectral imaging indicated that the total amount of carbon stored in Syracuse's trees was increasing over time (Myeong et al., 2006). Additionally, after the tree is removed, it will still convey benefits, as its wood retains the stored carbon from its lifetime, and post-removal release is slow (although it can be calculated) (Nowak et al., 2002).

Carbon sequestration benefits from urban trees are less applicable to a single tree or property than they are to an entire tree resource, but they should not be neglected. Carbon sequestration benefits occur regularly and are beneficial not only monetarily but also for human and animal health.

7. Air Quality

Trees reduce the amount of pollutants (specifically, volatile organic hydrocarbons such as ozone, sulfur dioxide, and nitrogen dioxide) in two ways. First, they provide the benefits detailed in the energy savings section that reduce the amount of pollutants put into the atmosphere by decreasing per capita energy expenditure (Yang et al., 2005). Second, they also retain volatile air pollutants through a process of deposition (Nowak et. al., 2002). Reduction in these pollutants increases air quality and human health. Diseases such as asthma, cancer, and heart disease have been shown to be reduced in pollutant-free environments; in Beijing a ten-percent increase in daily air pollution corresponds to a 3.52% increase in daily deaths from lung disease (Yang et al., 2005). Benefits from increased air quality are incurred on an annual basis. They are relative to the tree's DBH, the pollution problem present in an area to begin with, and the health of the benefit recipients.

An extensive study of dry deposition velocities in the context of the United States Environmental Protection Agencies meteorological data found that air pollution removal was most effective by urban trees in areas where the canopy structure was dense and unmixed. This study selected Jacksonville, Florida as the best example of urban trees enhancing air quality. In fact, the total annual estimated air quality benefit for all urban trees in the United States was 3.8 billion dollars (Nowak et al., 2006). An urban tree's air quality benefit is particularly important in certain areas where air quality is reduced; the spurious planting of urban trees in an area may enhance the area's living capacity by making it a healthier place for residence.

8. Storm Water Reduction

Trees store water in their crowns and boles, enhancing the water quality and reducing the water quantity of runoff. Especially in an urban area, this runoff may carry within harmful chemicals that are costly to clean up and may not meet local pollutant standards, causing administrative issues (McPherson, 1999). It has been shown that the presence of a vegetative layer, including trees, allows only the passage of nine percent of running water, while a surface layer lacking trees allows up to seventy percent of water runoff (Silva et al., 2006). The presence of tree roots support the soils, preventing harsh floods, mudslides, erosion and the structural damage that ensues. McPherson and Simpson (2002) regressed data regarding trees' effects on storm water in Modesto, California and came up with a strong benefit model. Dividing the storm water control budget by the basal area of all the trees in Modesto, this study determined the annual value per cubic meter of live wood for storm water control at $.05 per cubic meter. Research into Modesto's flood control strategy indicated that retention basins were used to prevent flood control and using contingent valuation they priced each basin at $121,439.00 per acre with an annual cost of $800.00 per acre.

Preliminary costs (installation, materials, operation) also occurred on a twenty-year cycle regarding these basins, with each basin costing $137,400.00 per twenty years.

Risk functions were used to determine frequency of flooding in the area versus the cost; a 50% probability that an average rainfall would fill the basins and mitigate damage ultimately indicated that the twenty-year cost of the basins (based on the above factors) was $2.07 per cubic meter every twenty years. McPherson et al. assessed that trees provide the same benefits as flood basins, and the benefits from each would be identical; that is, the benefits of an urban tree is $2.07 per cubic meter every twenty years in terms of flood mitigation.

McPherson and Simpson's method for determining the value of an urban tree with respect to storm water benefits excels because its reliance on alterative costs allows it to be applied in any situation where the above data can be collected. This method for storm water benefit data will also have this broad applicability.

9. Recreation and Health

Trees have been shown in several studies to be a source of and a contributor towards physical recreation (providing the natural structure for city parks and shaded sidewalks and creating the opportunities for tree climbing, swinging, and outdoor games) as well as physical and emotional "healers." Ulrich's (1984) classic article addresses the reduction in surgery recovery time that results from simply viewing urban trees outside a hospital window. The CDC has reported that trees increase motivation for people to engage in physical activity (Wolf, 2004). In the elderly, wooden paths with seating and large overhangs create relaxing surroundings (Verlande et al., 2007). Children with attention deficit disorder have been found to become more attentive in environments with visible trees; hospital patients require fewer painkillers when they are exposed to natural views; office workers report higher job satisfaction if they can see trees (Wolf, 2004).

In terms of recreation, an urban forest provides the opportunity for many pastimes, such as walking, bird-watching, and playing outdoor games. A study found that "jogging" is the most popular urban forest activity; sixty two percent of participants in this study engaged in it, and nature observation was another popular recreational use of the urban forest (Tyrväinen et al., 2003). In Guangzhou, China, urbanites visit urban forests, such as parks, two to three times per week. These particular urbanites were surveyed about the value of urban trees for recreation, and it was determined that the only factor that significantly impacted their valuation of trees' recreational values was personal income (Jim and Chen, 2009). This indicates that recreation as related to urban trees is a universal value and is not exclusive to certain populations.

Both recreational and health benefits are difficult to quantify, but surely contribute to tree value in certain cases. Opportunity cost models for this valuation could include factors such as visits to the doctor not taken, pain medications not needed, increased productivity in a work setting, and contingent valuations put on the quality of life. European scientists have assimilated into a group called COST that evaluates the recreational benefits of urban trees and forests, indicating the practicality of modeling the benefits that urban trees provide in the field of recreation (Verlande et al., 2007). It has been suggested that the recreation benefit of trees is reflected in the increase in property value for lots that have urban trees; however, it is important to understand the arenas through which this benefit is conveyed (Anderson and Cordell, 1985).

10. Aesthetic Benefits

Trees increase the "beauty" of an area, providing shelter for animals and enjoyable areas for people to visit. It has been shown that people prefer urban forests that are managed to have the appearance of being unmanaged; this suggests that the "wilderness" aesthetic is highly valued. One method used to determine the value of urban tree aesthetics has been ranking urban trees on a scale ranging from "spectacular" to "unsightly," and then using hedonic pricing to put a definite number on these values (Price, 2003). This method of organizing the values does give a monetary value for urban trees, but could be more specific in relating to particular markets, tree sizes, or tree species. Another approach at valuing this increase in beauty due to urban trees, and, the one that is used here, is the increase in property values that result from the presence of an urban tree or forest on a lot. Every visible tree on a lot increases the property value by 0.88% (McPherson, 2002). Proving this idea through its opposite, it has also been shown that for every kilometer a property is away from a greenspace, its value decreases by 5.9 percent (Tyrväinen and Miettenen, 2000). It has been shown that in areas with higher property values, the aesthetic return from trees was also higher, indicating that the direct relationship between property value and tree value hold, but are augmented in areas with a greater real estate market (Thompson et al., 1999). Thus it is important to take into account the real estate values of a particular area when valuing the aesthetic benefits of urban trees for a comparative analysis.

11. Local Economic Development

Trees provide opportunities for people to get involved in local communities. Gatherings to plant trees, local tree protection societies, and historic preservation are positive benefits of trees. Residents of the United Kingdom actively participate in coppicing their urban forests in groups in order to increase safety and engender community spirit (Neilsen and Møller, 2008). These benefits lead to cumulative benefits for the community, such as future commitment to a better landscape (Dwyer, 1991). Additionally, studies have shown that trees deter criminals and tree-lined areas have less violence than open ones (Wolf, 2004). Children also benefit from trees, as trees foster outdoor activity and social interaction in a healthy setting (Tyraväinen, Silvennoinen, and Kolehmainen, 2003). These benefits from trees should be computed in relation to the tree resource of an area as a whole (Jim and Chen, 2006). The benefits can be derived from contingent valuation, which can be determined by an urban forester through surveys or by a researcher through regressions from sets of preexisting databases. Local economic development benefits from urban trees are more applicable when looking at an urban tree resource or urban forest resource; certainly every tree contributes its part to the economic development of the community, but it is the mass involvement of the community with mass trees that makes the local economic development benefit powerful and effective.

12. District Sales Increase

The presence of trees in commercial settings increases the amount of sales in the area. Trees induce a positive response with respect to current stimulus. This is believed to be a reaction to reduced stress, and it facilitates both the consumer and the producer. Sales people are inclined to behave more naturally, and therefore sell more effectively, whereas buyers are inclined to spend more in a less stressed environment (Joye et al., 2010).

A study in Athens, GA, by Anderson and Cordell (1985) showed that tree-lined shopping districts received nine to twelve percent more sales than treeless districts. The benefit from trees in relation to sales increase, then, is proportionate to the amount of trees in the area and the amount of sales generated by the area in question. For example, a California study found that over a twelve-month period, the additional sales attributed to urban forestry (directly or indirectly) over the state amounted to almost 3.8 billlion dollars (Templeton and Goldman, 1996). Additionally, the trees will not generate substantial revenue increases until they are of sufficient size to be what might be considered aesthetically appealing. The benefits from trees to the district sales increases should also be considered in the context of a large area, as one tree will not have as much of an impact on an area's sales increase as a group will. The district sales increase benefit, like several of the benefits that have been discussed, can be viewed through the lens of property value increase for valuation; an area that generates more sales will have better property value than an area where sales are deficient.

Urban Tree Costs

Costs for an urban forest vary depending on many factors: species, location, magnitude, labor, and owner preference, to name a few (Dwyer et al., 1992). This text primarily focuses on the benefits of urban trees because they are more difficult to quantify. However, the costs of urban trees play a vital role in determining the tree's total value. Urban tree costs are fairly straightforward and can be put into four general categories:

1. Planting costs
2. Maintenance costs
3. Disease costs
4. Removal costs

1. Planting Costs

Planting costs include the market value of the plant at the nursery, the cost to transport the plant, the costs of any preliminary measures for its planting (removal of sidewalk, irrigation system, tree brace, deer wire), and the labor cost of getting the tree into the ground. All planting costs occur at the same time for urban trees, which is "year zero" when the tree is placed into the ground. A planting cost is an upfront cost, and often researching planting costs is fairly simple; in the current literature, evaluations of "cost-effectiveness" often compare planting costs with various benefits to determine whether or not a tree investment is viable (McPherson, Scott, and Simpson, 1998). This method is valuable, especially when viewed in a time-sensitive (discounted) context.

2. Maintenance Costs

Maintenance costs include the costs to keep the tree in a healthy state throughout its life. Two types of maintenance costs exist: recurring and one-time. Recurring costs occur on a serial basis. For example, a regular prune every five years is a recurring cost. One-time costs occur only once as single sums. Removal of a hazardous branch struck by lightening at year fifty is a single sum cost. Both of these types of costs can occur during the life of a single urban tree, and, as will be discussed further in chapter five, require specific discounting procedures for investment analysis.

As for the value of these costs in the context of the year in which they occur, the valuation of maintenance costs is often done subjectively prior to work; however, an objective approach following it is more reliable. Many arborists may estimate the work to be done visually, often adding in a premium for personal profit. Man-hours, equipment and labor costs, and transportation costs following a “job” determine the actual cost of tree work (Abbott and Miller, 1987). A preliminary estimation may not be equivalent to an after-operation analysis; therefore, it is important to review the source of valuation. The value of a cost following the application of the work will reflect the actual cost attributed to the tree, whereas a preliminary estimation that includes a profit premium also reflects the cost of the service provided, which may exceed the cost attributed to the tree itself.

Owner preference is the predominant criterion in determining maintenance costs. Some owners may desire very little work done to maintain a tree, while others may require frequent treatments. Additionally, many urban sectors (cities, municipalities, parks, neighborhoods) have ordinances requiring a certain amount of tree work. Discussion of required work with the owner can be used to generate serial costs. Many actions promoted by regular costs, such as regular pruning, may prevent single sum costs, such as branch removal. It is recommended that serial costs be used for preliminary financial evaluations, and the combination of single sum and regular costs be used for follow-up financial evaluations.

3. Disease Costs

Disease costs are similar to maintenance costs in their calculations; disease costs take two forms: preventative and responsive. Preventative disease costs should be included in a preliminary discounted cash flow analysis for tree value; responsive disease cost calculations should be used when disease is detected and an investment decision (treat, remove, leave standing) need be made. Preventative disease costs are serial; responsive disease costs can be either serial costs or single sum.

If disease control is practiced, the cost of disease control will include labor and transportation costs, as well as the cost of the chemical, application, and the amount of application needed. Chemicals may be priced per ounce or gallon and require a dilution solution and special applicator (hypo-hatchet, injector), the costs of which must be included in a cost valuation as well.

Disease control is in itself an investment decision. When deciding to undertake preventative measures against diseases, tree benefit valuation need occur; it is senseless to invest more money in preventing a disease than a tree is actually worth. Sherwood and Betters (1981) succinctly categorize this analysis of benefit as an opportunity cost valuation; in regard to Dutch elm disease (*Ophiostoma ceratocystis*), they note that disease control measures should occur where the cost of tree removal exceeds the cost of disease control. In the situation of Dutch elm disease, this is particularly relevant, since vascular wilting may create a structurally unstable tree very rapidly; other diseases, however, may not necessitate tree removal. In the case of a sooty mold (*Capnodium spp.*), the aesthetic benefit of the tree may diminish, and the loss of benefit should be compared with disease control costs in order to determine a mode of action.

Disease costs are highly variable depending on species, location, tree condition, and relevant epidemics; it is important to understand that they will play an enormous role in some urban tree valuations, but may not even be applicable in others.

4. Removal Costs

Urban trees are removed from sites if they are structurally unstable or another tree is favored for the site. Costs of removal are similar to costs of planting; the cost of labor, equipment, and transportation are included. However, tree removal may also generate a revenue, depending on the species and condition of the tree removed. A black walnut (*Juglans nigra*) will have a greater market value at the time of removal than a crape-myrtle (*Lagerstroemia indicata*) may not. The market value of a tree at the time of removal would be based on its value as a timber asset; thus, the walnut tree could provide potential wood products, whereas the crape-myrtle tree would not. This, of course, would also have to do with the condition of the tree at the time of removal; a damaged, decayed, or otherwise malformed tree would not have as much removal value. Additionally, a single tree removed has less value than several. The importance of assessing the possible benefit concurrent to the removal cost is to determine the most useful removal strategy. If the tree can be removed for timber, using an arborist that associates with a timber processing company is essential; if not, an arborist that will simply remove the tree from the lot at least cost (without incurring the additional cost of transport to a mill) is a preferable choice.

Why NTBC?

The primary methods of valuation used to determine urban tree cash flows have been discussed, as well as the relevant benefits and costs these methods can obtain. All of these data have been obtained through scientific study and published in peer-reviewed journals. This means that the amount of effort put into the data collection, analysis, and subsequent valuation was both enormous and highly specific. While arborists could spend their time going through the process of determining these values themselves for every job, using this much time and effort is not effective in light of accessibility to multi-user urban-tree inventory databases, particularly the NTBC.

The NTBC is a valuable tool for determining the benefits from urban trees. This tool is based on the inventory package i-Tree, formerly known as STRATUM, which assesses benefits and management needs for urban trees based on collected or existing inventory data (Davey, 2009). In particular, the NTBC is based on the i-Tree Streets application, which divides the United States into sixteen different climactic zones, allowing for spatially specific calculations of structure (species composition), function (environmental and aesthetic benefits), value (annual monetary benefits and costs), and management needs (pruning, removal, canopy evaluations). Users can either input their own inventory data or work with pre-existing inventory data accumulated from other users. This pre-existing inventory data does not include “cost data,” as management needs differ by situation (however, recall that determination of urban tree costs is generally less arduous than determination of benefits), but users of the tree benefit calculator who do not input their own inventories can still use the benefit function. As the Davey Tree Expert Company aptly states, “the more information (input) you enter, the more information Streets will return in the form of reports” (Davey, 2009).

The appeal of the NTBC to urban tree valuation is multifold, and a few of the model’s best characteristics will be discussed here. First, the NTBC is accessible and easy to use. The accessibility of the calculator (online) means that, in the presence of wireless internet, urban tree valuations can be conducted almost anywhere and by anyone. The easiness of the calculator also contributes to this by reducing the time (and sometimes total cost) of labor and effort. Second, it provides six categories of benefits that encompass the benefits discussed in the previous section. The benefits calculated by the NTBC are property value, storm water reduction, carbon dioxide sequestration, air quality enhancement, natural gas savings, and electricity savings. Many of the intangible benefits mentioned fall into the context of "property value" enhancement and can be elucidated from the value given by means of proportionate analysis based on individualized research, if necessary. The NTBC calculates these benefits with reference to diameter at breast height (DBH), location, species, and adjacent structures, meaning that the benefit calculations are very specific. This leads to the third benefit of the NTBC: it comes from a reputable source and is frequently updated. As more users input their inventory information into the benefit calculator, these inputs are assimilated into the equations that determine the benefit calculation. This eliminates a large bit of effort on the part of the user; since the professionals at the Davey Tree Expert Company assimilate the equations, an arborist does not have to venture into the realm of being an economist. Finally, the NTBC's most outstanding feature is that benefits are given in relation to DBH. DBH is a common measurement and can be translated into years based on growth rates. When it comes to doing DCF analysis, it is absolutely necessary to know the years in which cash flows occur; determination of cash flows with respect to DBH is a method not used in the literature (often, difficult measurements such as leaf surface area are used instead), but a viable one, since DBH is a customary measurement for arborists. Because of the accumulation of real data in the NTBC, the DBH to cash flow relationship is both accurate and applicable.

The NTBC, then, is a rapid, simple to use source of data that can be used to create a financial profile for an urban tree.

CHAPTER FOUR

THE PROBLEM

The literature shows few practical examples of traditional discounted cash flow analysis (DCF) used for the valuation of urban trees. DCF is a preferred method of analysis for forest valuation with a timber production objective, but it has not previously been considered in the context of urban trees. Permutations of certain DCF criteria, such as the benefit-cost ratio, have been to look at the viability of certain urban tree investments on an annual basis, but valuation for urban trees based on net present value and other financial criteria have not been used successfully or practically (McPherson 1999; McPherson et al., 2005). In fact, even the absence of the discounted cash flow method is itself not strongly noted in the current literature. Therefore, to surmise a few reasons for this deficiency: one, calculation of urban forest benefits is difficult; complex valuation strategies create a "barrier to entry." This is similar to the economic concept of "barrier to entry"; the additional intellectual "cost" of learning the methods of DCF may seem concerted in the face of simpler methods such as comparable sales. Second, the DCF techniques are not entirely intuitive and require an understanding of financial concepts that may be foreign to some urban foresters and generally associated with a tangible return on investment mentality. Finally, the time span for urban forestry investments is long and fluctuations in interest rates and market prices make its application to environmental valuations appear tenuous (Gollier, 2008).

The difficulty in identifying and valuing intangible benefits has been studied thoroughly by forestry professionals and profuse amounts of literature exist on the subject. This has been discussed thoroughly in the preceding chapter; it appears that consistently the same categories of benefits are identified and the quantification deals with how the valuation is affect by the variables of location and species. Models for how urban trees sequester carbon dioxide, decrease air pollution, reduce natural gas and electricity savings, contribute to human health, and provide an aesthetically pleasing experience have all been discussed at large (Nowak et al., 2002; McPherson et al., 1992; McPherson et al., 2005, Ulrich et al., 1984; Panaguopolos, 2009). These models have shown that intangible benefits for urban trees can be quantified reliably and effectively. Better yet, ready access to online journal servers such as Science Web and EBSCO-host facilitate the dissemination of these models to anyone who needs apply them. In the method proposed, even this much research is unnecessary for a standard urban tree valuation; the NTBC provides an accurate estimation of these benefits sans the effort of understanding complex math.

Difficulty in using or understanding discounted cash flow techniques can also be easily overcome. This document contains a brief description of DCF fundamentals. Outside of this document, the learning curve can also be overcome thanks to user-friendly innovation on the technological front. Many professionals in various fields use DCF, and applications to assist in their computation abound. In this document, the use of Microsoft Excel for basic algebra and tabulation and FORVAL for financial criteria is highlighted. Because DCF does not discriminate between cash flows that are physically transacted and those that are accumulated as intangible benefits or costs, it is applicable to both timber situations and standing trees.

The length of the time period involved in an urban forestry investment does present some difficulty to DCF; however, various strategies to view long-term economic investments outside of the context of discounting have proven no more applicable than simply choosing to use DCF with a low interest rate reflecting a long term investment (Gollier, 2008). Kannianen (2009) analyzed increasing project value in terms of geometric Brownian motion confirming that cash flow factors were superior to more complicated methods of future value determination. For certain urban tree investments with large markets, moderate durations, and high demands, it has been shown that submarket clustering can ascertain more accurate benefit values (Poudyal, 2008). This would produce more specific cash flows for future expansion. In a sense, the National Tree Benefit Calculator does this by grouping trees by region and proximal edifice, and, as as shown Chapter six, by genus. Additionally, as the time period over which an investment is analyzed increases, the economic returns from the cash flows as net present values are minimized, therefore making extremely lengthy investments less concerting than they may initially appear. In the examples provided, an interest rate calculated from US Census data between 1900 and 2010 is selected for use. The average rate over this period of time is 4.56 percent, which, for the sake of simplicity in this example, has been rounded to five-percent. This rate represents the average rate incurred over a one-hundred and ten year span, a length of time which is relatively similar to the time span used for these urban tree investment models (US Census Bureau, 2010).

In the context of traditional forestry, DCF is frequently used to analyze investments on everything from timber harvests to bobwhite quail (Huang, 2009). It seems logical that a system of financial analysis successfully used for tree investments in this context would also be used for tree investments in an urban forestry context, but this is not the case. This deficiency in urban forestry practices today is uniquely recognized and DCF exists as another viable way to look at urban forestry investments that should be considered as a supplement to current methods.

The discounted cash flow analysis method in urban tree valuation is fundamentally very simple. Using a financial time line, cash flows that occur during the life of a tree are organized. This time line appears as a horizontal line. These cash flows take two forms: costs (negative cash flows) and benefits (positive cash flows). Cash flows appear as vertical arrows originating at a specific point on the time line, with positive cash flows pointing "up" and negative cash flows pointing "down." Examples of time lines are shown in Appendix C for the models from Chapter Five. While the costs of trees are relatively straightforward to define, the benefits of trees, particularly urban trees, must be defined through one of the aforementioned valuation strategies. A discussion of strategies in respect to specific benefits with which they have been successfully used is given in Chapter Four. They enable us to view intangible benefits as monetary transactions, and these transactions can be assessed with discounted cash flow analysis.

The central principle of discounted cash flow analysis in forestry is the determination of the net present value (NPV) of the cumulative benefits and costs that represents the value of the tree. DCF allows this value to be moved to any point in time through discounting and compounding so that a user can value the tree at any year. It is the best method of urban tree valuation because it accounts for the inherent value of the tree, the benefits it accrues over time, the costs of its retention and replacement, and the time value of money. The basic formula for DCF analysis is simple. It calculates the future values of a single sum. All subsequent formulas are, if the time is taken to calculate them, some permutation of this formula:

(Eqn. 5)

$$V_n = V_0(1+i)^n$$

Where:

"V_n" represents the value of at time "n"
"V_0" represents the value at time zero
"i" represents the interest rate (expressed as a percent)
"n" represents the duration of the investment

So, the value of a cash flow that occurs today (V_0) at a time "n" years in the future (V_n) is $(1 + i)^n$ times its current value. This is the formula used for compounding—moving cash flows forwards on a time line. Likewise, this equation can be solved for "V_0" to show the present value (PV) of a future cash flow:

(Eqn. 6)

$$V_0 = \frac{V_n}{(1+i)^n}.$$

Where:

"V_n" represents the value of at time "n"

“V_0” represents the value at time zero
“i” represents the interest rate (expressed as a percent)
“n” represents the duration of the investment

The value of a cash flow (V_n) that occurs “n” years in the future is worth “V_0” today. This is the formula for discounting—moving cash flows backwards on a time line.

To determine the net present value of an investment, DCF is used to bring every cash flow in that investment to the time “year zero” (when V_0 occurs). This process can be very time-consuming if one has many cash flows. For example, some urban tree investments may have the same cash flow occurring every year for one-hundred years. This does not mean that it is possible to add up these cash flows and discount them because each cash flow needs to be discounted with respect to the year in which it occurs, but it does mean that an inclusive formula can be used to run one calculation instead of many. Uniform cash flows that occur annually can be calculated using a formula that is an extension of the basic DCF formula. It determines the present value of a terminating annuity:

(Eqn. 7)

$$V_0 = a\frac{(1+i)^n - 1}{i(1+i)^n}.$$

Where:

“V_0” represents the value at time zero
“i” represents the interest rate (expressed as a percent)
“n” represents the duration of the investment
“a” represents the value of the annuity

In this formula, “a” represents the cash flow that occurs annually and “n” represents the number of years throughout which that annual cash flow occurs. “V_0” with respect to an annuity represents the year prior to the first year of the annuity. For example, if an annuity of $1.00 per year occurred for years five through nine on a time line, the “V_0” calculated with the annuity formula would actually be “V_4” and would represent the value of the annuity at year four. The value for “n” in this scenario would be five because the cash flow occurs five times, even though “nine minus five” equals four. It cannot be overemphasized the importance of drawing a time line or counting years when determining the length of an investment. To get the true “V_0” at year zero, the value at year four would need to be discounted back an additional four years using the fundamental DCF formula.

Cash flows of equal magnitude may also occur on a periodic basis. These cash flows are called periodic series. Another DCF formula can be used to compute these values. This is the present value of a terminating periodic series calculation:

(Eqn. 8)

$$V_0 = a\frac{(1+i)^{nt} - 1}{(1+i)^t - 1(1+i)^{nt}}$$

Where:

“V_n” represents the value of at time “n”
“V_0” represents the value at time zero
“i” represents the interest rate (expressed as a percent)
“n” is the number of periods
“t” is the length of each period

“a” represents the value of the annuity

Like the annuity formula, this formula also determines the value of the periodic series one year before its initiation, so further discounting to the true “V_0” may also be necessary. The periodic series formula differs from the annuity formula because “n” represents the number of years between each cash flow. The NPV’s for the periodic series formula and the annuity formula can compounded forwards in time using equation 5, if necessary.

A final DCF formula that can be applied to urban forestry investments is the perpetuity formula. Perpetuities are cash flows that occur regularly “forever.” An annual perpetuity is very simple to calculate as:

(Eq. 9)
$$V_0 = \frac{a}{i}.$$

Where:

“V_0” represents the value at time zero
“i” represents the interest rate (as a percent)
“a” represents the value of the annuity

In this case, “a” is the annual cash flow. Perpetuities that occur periodically forever are calculated with the formula:

(Eq. 10)
$$V_0 = \frac{a}{(1+i)^n - 1}.$$

Where:

"V_0" represents the value at time zero

"i" represents the interest rate (as a percent)

"a" represents the value of the annuity

"n" represents the duration of the investment

Just like in the terminating periodic series, the perpetual periodic series' "n" represents the number of years between each cash flow.

In DCF for urban tree valuation, these formulas are used, and sometimes in combination with one another. As discussed above, the cash flows for urban trees are benefits (positive cash flows) and costs (negative cash flows). Each of these is addressed separately.

DCF Situations in Urban Tree Benefit Valuation

Before digressing into the combinations of DCF formulas that need be applied in urban tree valuation, it is important to reiterate the categories of urban tree benefits that were determined from the literature.

Table 4.1 Categorization of Urban Tree Benefits

PHYSICAL INDIVIDUAL	PHYSICAL GROUP	INTANGIBLE INDIVIDUAL	INTANGIBLE GROUP
Energy Savings	Carbon	Aesthetics	*Aesthetics
Wind Barrier	Air Quality	Recreation	Local Economic Development
Soil Enhancement	Storm Water	Health	District Product Enhancement
Sound Barrier		Privacy	

*Aesthetics is included in both the individual and group since it benefits both categories.

Equations one through six can be used to assess these benefits. It is easiest to think of these equations as functions that fall into the nominal categories of "single sums" (direct calculation of NPV, Eq.1 and Eq. 2), "terminating series" (series that have a distinct stopping point, Eq. 3 and Eq. 4) and "perpetual series" (series that do not have a distinct stopping point, Eq. 5 and Eq. 6). For example, reduction in a heating bill by $2.00 monthly because of the presence of a large shade tree for twenty years of residency is a terminating series assessed on a monthly basis for 240 months. The annual historical value accumulated by a large tree protected under a conservation easement is a perpetual series assessed on an annual basis forever.

Special Constructions in DCF for Benefit and Cost Valuation

Certain situations may occur in DCF benefit and cost valuation that require particular combinations of the DCF equations in order to determine the NPV. These situations are specific to tree valuation because they involve justifying the relationship between tree DBH increase and the time value of money. To ameliorate the process of using equations one through six for these particular situations, these special constructions are indicated and named here, a brief, hypothetical example is given, and a formula provided that should be used to determine the NPV in these situations without too much confusion. These special constructions are labeled as to whether they are specific for benefits, costs, or a combination of both.

1. Minimum Size Delayed Annual Benefits

Many benefits conveyed by urban trees are not relevant until the tree has reached a certain "minimum size." For example, a sapling may not provide substantial heating and cooling benefits until it has reached a size where it has a substantial crown and can create shade on a structure. Therefore the typical "annuity" equation holds, but it needs to be delayed until the tree reaches a minimum size. The annuity as a whole, then can be discounted back to year zero. An example of this construction is used in Chapter five with the Detroit white oak example, but the construction is presented here. If the benefit created annually by the tree is the same, but the benefit does not occur until the tree is a certain number of years old, the following formula should be used:

(Eqn. 11)
$$V_0 = a\frac{(1+i)^{n_a}-1}{i(1+i)^{n_a}(1+i)^{n_v}}.$$

Where:

"V_0" represents the value at year zero
"i" represents the interest rate (as a percent) plus one
"a" represents the annual benefit
"n_a" represents the number of years for which the annuity occurs
"n_v" represents the number of years that the annuity is away from year zero

This structure can also be used for costs. For example, an annual cost of ($10.00) occurring for forty years with the first cash flow occurring in year twenty would appear as (at a five percent interest rate):

$$V_0 = -10\frac{(1.05)^{40} - 1}{0.05(1.05)^{40}(1.05)^{19}}.$$

Notice that the value of ($10.00) is negative here, reflecting the fact that it is a cost. Also, the years that the annuity is away from zero is "19," which is one less than the year in which the annuity begins. The NPV of this cash flow is ($67.94).

2. Fixed Rate Increasing Annuity

Because trees increase in size, often the benefits associated with the tree also increase in magnitude. In some situations, this increase may follow a set pattern. For example, a tree's annual ability to sequester carbon may grow by four-percent per year. The interest rate in this example could be five-percent. In this case, this is an example of "an annuity within an annuity"—there are two "rates" to be concerned with: the interest rate and the growth rate of the annuity. To calculate this the "long way," one would look at the growth of the annuity through equation four (the normal compounding formula) and determine a value for the amount of carbon sequestered at each year (called "C(n)" here) and each and every year's benefits are discounted back to year zero using the summation below:

$$\sum_{i=1}^{n} \frac{C(n)}{(1+i)^n}$$

The index of summation in this case would be "1" for each year, and "n" would be the number of years included. Although writing the formula in summation notation is clean, it is obviously no simpler than calculating out all of the cash flows by hand, so instead the following formula is used:

(Eqn. 12)

$$V_0 = \frac{a}{(i-g)}[1 - (\frac{1+g}{1+i})^n]$$

Where:

"V_0" represents the value at year zero
"a" represents the annual benefit
"n" represents the number of years for which the annuity occurs
"g" represents the rate of growth of the annuity
"i" represents the interest rate

In the carbon example, "g" would be "0.04" and "i" would be "0.05." Putting both formulas together in the Fixed Rate Increasing Annuity construction saves both time and effort. For the carbon example, say that the annual benefit is $10.00 and the number of years to be assessed is fifteen. Using equation twelve, we calculate that the NPV is $133.72.

3. Marginal Analysis

Marginal analysis combines the work of benefit and cost analysis when they occur in the same year. It should be used by those wishing to deal with less cash flows. Calculation of urban tree costs is simpler than calculating urban tree benefits. Determination of the market value of costs is relatively straightforward, and, like benefit valuation, relates to the landowners' objectives. The most important part of urban tree cost calculations is the realization that costs should be input as negative cash flows. This construction entails a method to ease DCF cost valuation. Recall the types of costs that can occur for urban trees:

Table 4.2 Types of Urban Tree Costs

PLANTING	MAINTENANCE	DISEASE	REMOVAL
Costs at Year Zero	Regular Cost Single Sum Costs	Preventative Costs Restorative Costs	Costs of Removal Revenue (sometimes)

From the above nomenclature, as well as from the examples that will be presented in the next chapter, it is easy to see how the six basic DCF equations or the mentioned DCF constructions can be used to determine the NPV for urban tree costs. When calculating costs and benefits together for an urban tree valuation, a third technique can be used.

If a cost and benefit occur in the same year, or over the same periodic sequence (annuity, once every “x” years, etc.), they can be summed and then discounted. For example, if an urban tree provided $15.00 of energy savings per year for its ninety year life on the site and cost $10.00 per year to prune, the marginal benefit from these two cash flows would be: $15.00 + ($10.00) = $5.00 per year for the 90 years.

Running the annuity of the $15.00 benefit at a five percent interest rate gives us the value of $311.28. Running the annuity of the $10.00 cost at the five percent discount rate gives us ($207.53). The sum of these two annuities is $103.75. Calculation of the annuity for $5.00 per year for 90 years at the same discount rate is $103.76. The one-cent difference is due to rounding of the final digits.

The advantage of marginal analysis is that less inputs are needed; the disadvantage is that it complicates itemization. In a complex financial scenario, marginal analysis should be used with caution to ensure no cash flows are forgotten.

4. The Land Expectation Value (LEV) or Urban Tree Site Value (UTSV)

As mentioned previously, NPV is the deciding criterion for investments in forestry, but an additional criterion, the land expectation value (LEV) for timber production or urban tree site value (UTSV) for urban trees can also be used. The LEV or UTSV is calculated by compounding the costs that are incurred during one rotation forward to the final year of the rotation and using that net future value (NFV) as a periodic series (Eqn. 8). In other words, the full LEV or UTSV calculation appears as such:

(Eqn. 13)
$$LEV = \frac{NFV}{(1+i)^n - 1}$$

Where:

"LEV" represents the land expectation value
"i" represents the interest rate (as a percent)
"NFV" represents the net future value
"n" represents the number of years during which the investment occurs

Calculating the LEV or UTSV in this manner requires that the values from each cash flow in the rotation be compounded to the final year of the rotation. However, the ability of the compounding formula (Eqn. 1) saves a user this trouble, and the LEV is written as:

(Eqn. 14)
$$LEV = \frac{NPV(1+i)^n}{(1+i)^n - 1}$$

Where:

"LEV" represents the land expectation value
"i" represents the interest rate (as a percent)
"NPV" represents the net present value
"n" represents the number of years during which the investment occurs

Determining the LEV in this manner allows us to simply calculate the NPV as normally done in DCF and then compound that value to the end of the rotation. Thus, in both the above equations, the variable “n” represents the number of years in the rotation.

The following two examples will show how the concept of “rotations” can be applied in an urban forestry situation in comparison to a timber forest situation. These two examples are displayed at a five percent interest rate. Equations one (single sum) and four (periodic series) were used to calculate the cash flows. The first example displays the calculation of the NPV and LEV. Note that only the LEV is calculated for the TOTAL row, as knowing the LEV for the intermediate cash flows within the timber rotation has little practical application for the context of this document.

Table 4.3 Timber Forest Scenario at a Five-Percent Interest Rate

ITEM	YEAR	AMOUNT	NPV (@ 5%)	LEV(@ 5%)
Plant	0	($100.00/acre)	($100.00)	
Prune	5	($40.00/acre)	($31.35)	
Thinning	15,30,45	($50.00/acre)	($41.19)	
Harvest	60	$4000.00/acre	$214.14	
TOTAL			$41.60	$43.95

After year sixty, the exact same costs are repeated over again, but now this is the second rotation. The “new” year zero for this rotation is year sixty. The theory behind this is that the land expectation value (LEV) assumes that this sixty-year cycle continues on forever. It is assumed that the NPV at year zero for each rotation represents that rotation's value. The LEV never includes the cost of buying and selling the land because this cost is not repeated in each rotation, and the LEV is a method of valuing land; it determines the maximum monetary value of bare land based on the cash flows regarding its productivity (Straka and Bullard, 1998).

The following example shows how to apply the LEV calculation as a UTSV calculation for urban forestry. The same formulas as shown above are used.

Table 4.4 Urban Forest Scenario at a Five-Percent Interest Rate

ITEM	YEAR	AMOUNT	NPV(@ 5%)	LEV (@5%)
Plant	0	($50.00)	($50.00)	
Soil Benefit	10-90	$10.00	$126.44	
Trimming	20, 40, 60	($20.00)	$11.44	
Removal	90	($70.00)	($0.87)	
TOTAL			$87.01	$88.10

In an urban forest, the "rotation" is relative to the life of the tree on the site. The tree's life, in this case, begins at year zero, although the tree may be two years old at that point. It ends with the removal of the tree from the site and the replacement of the tree with a new one, which under the financial assumptions would also be planted at the same relative age. Although the two formulas (LEV and UTSV) are exactly the same mathematically, it is important to understand that many urban forest benefits are not incurred directly after planting, but require the tree to be of a certain size or foliage capacity (McPherson et al., 2005). Although both the LEV and UTSV formulas will yield a value that is slightly greater than the NPV because they represent the worth of future rotations, the LEV will have a more significant difference than the UTSV will. The UTSV formula when applied to urban trees represents the expected value of the tree in perpetual existence on the site, but this value may not have the same magnitude it has in a timber situation because of these delayed benefits and because of the lack of a harvest value. Again, the authors stress that it is important to not include the costs and revenues from buying and selling the land on which the tree is planted in this calculation.

5. Risk Potential Matrices for Decaying or Healing Tree

Many urban trees will not be in "perfect" health. Some trees may be declining (showing symptoms of disease, poor growth or form, or general lack of vigor) while others may appear to be healing (having a larger and healthier crown, reduced bole damage, stronger limbs). Additionally, a tree that looks "ill" now may look healthier later, and a tree that looks "healthy" now may become ill in the future. If a tree is planted in an area where it may become susceptible to disease and its risk potential needs to be evaluated, a transition matrix structure can be used to look at the potential for the tree to be in a healthy or diseased state after a number of years. This can assist the arborist in adjusting current values to reflect decreasing or increasing benefits and costs based on a proportionately accurate future prediction.

If, in year zero, a tree is in either a healthy (denoted "1") or unhealthy (denoted "2") state, and information exists regarding its probability of becoming ill or becoming healthy, a set of transitions can be constructed and then simplified through a risk potential transition matrix. The binary function describing tree health is denoted “$F_k(n)$” where “k=1” denotes the healthy state and “k=2” denotes the ill state. The number “n” describes the year in which the tree is being evaluated.

The structure for health or illness in year one can be described by the partial probabilities from year zero; for example:

$$F_1(1) = p_{11}F_1(0) + p_{12}F_2(0)$$

$$F_2(1) = p_{21}F_1(0) + p_{22}F_2(0)$$

Where:

“p_{11}” designates the probability of a healthy tree staying healthy
“p_{22}” designates the probability of an ill tree staying ill
“p_{12}” designates the probability of an ill tree becoming healthy
“p_{21}” designates the probability of a healthy tree becoming ill

Thus, the probability of the tree staying being in a “healthy” state in year one is the sum of the probability (p_{11}) of a healthy tree from year zero ($F_1(0)$) remaining healthy and the probability (p_{12}) of an ill tree from year zero ($F_2(0)$) healing. Likewise the same principle stands when looking at the probability of having an ill tree in year one. It is the sum of the probability (p_{21}) of having a healthy tree in year one ($F_1(0)$) become ill and the probability (p_{22}) of having an ill tree in year zero ($F_2(0)$) remain ill.

With any more than one year included in this calculation, the interweaving of the probabilities becomes very complex and hard to represent by algebraic notation; the healthy or ill state of trees in each proximal year has a recursive relationship with the trees in the previous year. However, matrix notation can easily denote these probabilities in a comprehensible way:

The above simple situation is noted as:

$$\begin{bmatrix} F_1(1) \\ F_2(1) \end{bmatrix} = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix} \begin{bmatrix} F_1(0) \\ F_2(0) \end{bmatrix}$$

and a two-year scenario is expressed by:

$$\begin{bmatrix} F_1(2) \\ F_2(2) \end{bmatrix} = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix} \begin{bmatrix} F_1(1) \\ F_2(1) \end{bmatrix}$$

The two-year situation can be assayed using the terms from the one year, simple situation, as:

$$\begin{bmatrix} F_1(2) \\ F_2(2) \end{bmatrix} = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix}^2 \begin{bmatrix} F_1(0) \\ F_2(0) \end{bmatrix}$$

The matrix of probabilities is a type of transition matrix, which in this situation represents a “risk potential transition matrix” and is designated “**U**.” It follows then, that for any amount of years, “n,” “**U**” can be used to determine the probability of a tree’s healthiness or illness through the following formula:

(Eqn. 15)
$$\begin{bmatrix} F_1(n) \\ F_2(n) \end{bmatrix} = U^n \begin{bmatrix} F_1(0) \\ F_2(0) \end{bmatrix}$$

Where:

"$F_1(n)$" and "$F_2(n)$" are components in the final vector for tree health

"$F_1(0)$" and "$F_2(0)$" are components in the initial vector for tree health

"$\mathbf{U}^n$" is the risk potential transition matrix raised to the amount of years assessed

It is important to recognize that because of the nature of matrix multiplication, $\mathbf{U}^n$ is not the same as simply raising all the elements in **U** to the power of "n." Rather, sequential dot products are used.

An example proves helpful here. Suppose a healthy dogwood (*Cornus florida*) at year zero has a thirty-percent chance of remaining healthy and a seventy-percent chance of becoming ill with dogwood anthracnose. An ill dogwood at year zero has a ninety-percent chance of remaining ill and a ten-percent chance of healing. An arborist wishes to know the potential that any dogwood planted on the site will be healthy or ill in four years. In other words, he is looking for the "identity" of dogwood health or lack thereof in four years. Then the following matrix would be used:

$$\begin{bmatrix} F_1(4) \\ F_2(4) \end{bmatrix} = U^4 \begin{bmatrix} F_1(0) \\ F_2(0) \end{bmatrix} = \begin{bmatrix} .3 & .1 \\ .7 & .9 \end{bmatrix}^4 \begin{bmatrix} F_1(0) \\ F_2(0) \end{bmatrix}$$

The subsequent calculation reveals that:

$$\begin{bmatrix} F_1(4) \\ F_2(4) \end{bmatrix} = \begin{bmatrix} .3 & .1 \\ .7 & .9 \end{bmatrix}^4 \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} .1264 & .1248 \\ .8736 & .8752 \end{bmatrix}$$

The quantities of interest are the diagonal elements of the transition matrix after it has been raised to the fourth power. The identity matrix is shown above to illustrate the ability to decompose the transition matrix into its respective vectors. It represents the fact that the arborist is looking for the probabilities for both healthy and ill trees in the current state; if he only wished to look at healthy trees he would use the vector $(1,0)^T$ and if he only wished to look at ill trees, the vector $(0,1)^T$ would suffice. Thus, in four years, the chance that a healthy tree will remain healthy is 12.64 %, that a healthy trees will fall ill is 87.36%, that an ill tree will become healthy is 12.48%, and that an ill tree will remain ill is 87.52%. As “n” approaches infinity, in many cases, the risk potential transition matrix will stabilize on a certain set of probabilities. This stabilization, if it occurs within the tree’s feasible lifespan, can help to predict tree conditions. Knowing the tree’s future potential for healthiness or illness helps arborists to assess which future costs to use in financial calculations.

6. Linear Increases in Benefits Relative to Time

In some situations, the benefits conveyed by an urban tree may increase with respect to time. This relationship may be a linear relationship in which an increase in years corresponds with a similar increase in benefits. The relationship between years and benefits can be generally described by the function:

$$B(n) = b_0 + b_1(n)$$

Where:

"B(n)" is the benefits received at time "n"
"b_0" is the "y" intercept
"b_1" is the slope
"n" is the year in which these benefits are received

Because this is a linear relationship that is non-recursive (the benefits from one year are dependent on the benefits from the year before) we can evaluate it in DCF in the context of both a sum and an integral:

$$\sum_{i=a}^{k} \frac{b_0 + b_1 n}{(1+i)^n} = \int_{a}^{k} \frac{b_0 + b_1 n}{(1+i)^n}$$

Where:

"B(n)" is the benefits received at time "n"
"b_0" is the "y" intercept
"b_1" is the slope
"n" is the year in which these benefits are received

“k” is the final year evaluated

“a” is the initial year evaluated

“i” is one plus the interest rate, where the interest rate is expressed as a percent

In the case of the sum (the left side of the above equation), the calculation of the benefits is difficult; each year must be computed separately and added together to get the NPV. The integral, however, can be evaluated in terms of “n” from “a” to “k”

(Eqn. 16)

$$\int_a^k \frac{b_0+b_1 n}{(1+i)^n} = -\frac{b_0(1+i)^{(1-n)}}{(1-n)} - \frac{1}{2}\frac{n^2(1+i)^{(1-n)}}{(1-n)}$$
$$= -\frac{b_0(1+i)^{(1-k)}}{(1-k)} - \frac{1}{2}\frac{k^2(1+i)^{(1-k)}}{(1-k)} + \frac{b_0(1+i)^{(1-a)}}{(1-a)} + \frac{1}{2}\frac{a^2(1+i)^{(1-a)}}{(1-a)}$$

Where:

“B(n)” is the benefits received at time “n”

“b_0” is the “y” intercept

“b_1” is the slope

“n” is the year in which these benefits are received

“k” is the final year evaluated

“a” is the initial year evaluated

“i” is one plus the interest rate, where the interest rate is expressed as a percent

By “plugging in” the values for “k” (final year), “a” (initial year) and “i” (interest rate), to the given equation, the above integrated construction can be used to calculate the NPV of a benefit that has a linear relationship to years. It should be noted that other polynomial relationships between years and NPV can also be calculated using integrals, but recursive equations cannot be calculated in this manner.

Using DCF to Make an Investment Decision

Net present value (NPV) is the deciding financial criterion from DCF that should be used to make an investment decision in an urban tree scenario (Straka and Bullard, 1998). Although it is possible to use the DCF formulas to calculate other values with respect to discounted cash flow (two frequently used values are the benefit-cost ratio and the internal rate of return), and on an “accept or reject” investment basis these criteria will concur with the NPV, these are not sound financial decision-making criteria. The benefit-cost (BC) ratio is all positive discounted cash flows divided by all discounted negative cash flows. It provides the proper “decision” to invest or not invest, but it cannot display the magnitude of an investment’s worth. For example, the ratio between $200,000.00 benefit and $100,000.00 cost is the same as the ratio between $2.00 benefit and $1.00 cost. The internal rate of return (IRR) criterion is even riskier; if any cash flows from the investment are received outside of the market situation (for example, a “gift”), the rate of return will not reflect the lack of “investment” and yields a falsely elevated interest rate. This may cause a landowner or appraiser to view a tree as more profitable than it actually is; when comparing several high value investments this could lead to financial disaster. Additionally, the rate of return is hard to calculate when more than one cash flow is assessed and requires either a financial calculator, computer software, or a lengthy iterative process (Straka and Bullard, 1998).

In this document, NPV is used as the decision-making financial criterion but will also mention another financial criterion specific to forestry, the “land expectation value.” This criterion calculates the value of a site on which a forest is planted and continuously replanted over time. In standard timber production, this represents perpetual “rotation” of the forest on the land and is therefore always greater than the NPV (Straka and Bullard, 1998). In the case of urban forestry, this criterion can be redefined to describe the value of a single tree consistently replanted on a site. This criterion has been named by the authors as the “urban tree site value” or UTSV.

Dealing with Urban Trees in Large Areas

Although the methods discussed are exemplified by single tree situations, it is important to note that DCF can be used to value urban forests over large areas. Calculations of value can be made through discounted cash flow analysis on a per tree basis from as many sample points as desired and then expanded to represent a large area. Expansion of data involves use of basic algebraic equations and statistics. In timber production, this is often done through expansion on a “trees per acre” (TPA) basis. In the simplest, plantation example, if the value of a single tree can be determined to be $200.00 and there are 400 identical trees per acre, the value of that acre could be evaluated by expansion to be ($200.00 per tree times 400 TPA) $80,000.00. This simplification is not practical in urban forestry, however, expansion based on “on the ground” inventories is.

For example, if a street has identical Chinese elms (*Ulmus parvifolia*) planted on its median once every ten feet for a length of five hundred feet, then it is known there are fifty elms on that median. This amount of elms can be called the "trees per resource" or TPR. If each elm has a NPV of $150.00, the total value of that resource is ($150.00 per tree x 50 TPR) $7500.00. A more complicated permutation of this process could be used, for example, to look at the value of all trees in a city. The on-the-ground method of this determination involves the application of traditional forestry techniques to an urban scenario. Arborists and urban foresters aware of appropriate sampling techniques (fixed-area plots or basal area factor points, depending on which method is best for the specific situation); can calculate an estimate of the NPV of plots or points. These values are expanded by basal area factors (denoted "F") or plots per acre (simply the reciprocal of plot size: a one-tenth acre plot denotes ten plots per acre) by the total acreage in the city. Basic confidence intervals can be used to describe an adequate "range" in which the value for the parks could fall. One of the benefits of the use of the National Tree Benefit Calculator is that these mathematics are included in the i-Tree system; anyone wanting to value a large resource need only conduct the inventory and input the plot and resource total size in order to have the expansions calculated automatically.

Many recent computer systems can also provide geographical replications of trees on a large scale, enabling even more precise calculations to be made (Dwyer and Miller, 1999). Information regarding the location of non-tree elements, canopy density, and various partial benefits of trees (storm water, in particular) can be viewed in a more specific context through this method.

Dealing with Irregular Tree Positions

Many values conferred by trees have to do with their relative location to a particular structure or structures. Four basic positions a tree can have relative to a structure impact the monetary nature of the benefits it confers.

1. In front of the structure, centrally located, and visible from a public location.
2. To the side, front corner, or rear corner of a structure, equally between two structures, therefore sharing the value between structures.
3. Behind a structure, centrally located, but not visible from a public location.
4. To the side, front corner, or rear corner of a structure, unequally between two structures, therefore unequally sharing value between two structures.

Different models involve different positions, and when these positions are relevant it is important to consider how the location of the tree affects the magnitude of its cash flows. This affect is proportional. If a tree allots ninety-percent of its shade benefits to one home and ten percent to another, the value of that tree in shade benefits to the first home will be ninety-percent of the total savings, and to the second home, ten percent. These models deal with a single tree, centrally located, conveying values to a single structure. However, it is important to recognize that other tree positions can exist and that valuation must reflect positional discrepancies.

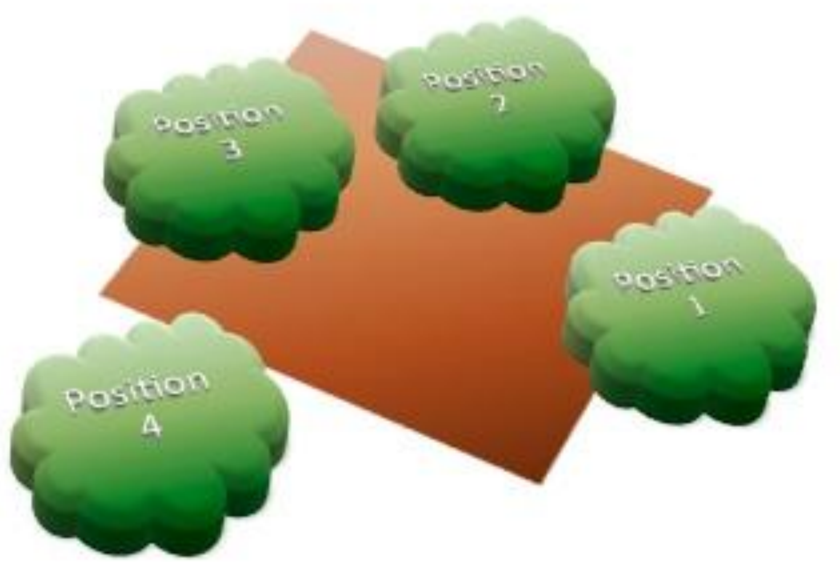


Figure 4.1. Possible locations of trees in reference to a structure

Determination of Tree Life Spans and Planting Rates

The average lifespan and structurally stable lifespan of the trees used in these models, as well as their rates at the age of planting, were determined based on pre-existing figures gathered from literature and online resources (USDAFS, 1990; RMDSI, 2008). To ensure that the models create an accurate picture of reality, nursery rates were researched for the same city that these models discuss. In the discussion of the general method of DCF urban tree valuation, the same meticulous research standards were applied to initial costs or final returns not included in the National Tree Benefit Calculator (Davey). In the context of an actual urban forest situation, both the lifespan of the tree and the landowners' objectives should be taken into account; a landowner may have specific goals in mind for a site that will reduce or increase an urban tree's relative time on the site. These models are designed to be general under the supposition that the user can add in specificities as needed.

The Importance of Diameter at Breast Height (DBH)

As trees get older, they also increase in height and diameter. Benefits conveyed by trees relate directly to their DBH's. Because every tree grows at a different rate, and these growth rates are further affected by a multitude of factors, such as soil, climate, pests, and treatments, it is impossible to accurately "predict" how a tree's DBH will change over the term of its existence (Stoffberg et al., 2009). Models that do attempt these predictions are often mathematically challenging and impractically difficult for urban forestry application. Because the NTBC provides an input for DBH, and values for any tree species at any DBH between one and forty-five inches can be calculated, it is simpler and more practical to use the pre-existing data in the NTBC rather than replicate DBH growth patterns. The data in the NTBC represents many observations and represents a pool of information far larger than would be obtained in a financially feasible appraisal.

In the following discussion, examples are shown from the twelve categories of urban tree benefit calculations and the four categories of urban tree cost calculations based on figures determined in peer-reviewed literature. Appendix C and should be used as a companion to the twelve models provided. However, the literature's figures are taken “one step further” by assessment in the context of discounted cash flow analysis. These models exist to show where the data inside the NTBC comes from. Additionally, simple graphs of the cash flows for each benefit type over the lifespan of a single tree have been created. The graphical models enable the user to observe the benefits as actual cash flows on a time line, as opposed to a series of line items. These cash flow diagrams are found in the appendices. For user application, the NTBC can be used with more simplicity and greater accuracy, and it can be applied over a broader scale. In chapter seven, a tutorial will show how to use the NTBC to determine the value of an urban tree through DCF. FORVAL contains functions for calculating the cash flows mentioned in this chapter. The procedure for this is more explicitly described in chapter eight.

CHAPTER FIVE

DCF MODELS: INDIVIDUAL AND GENERAL

The following models are associated with cash flow diagrams as well as line item reports. The line item reports are presented here, and the cash flow diagrams are presented in Appendix C. These cash flow diagrams reflect the benefits and costs incurred prior to discounting. In the line item reports, the NPV column reflects the net present value of each item of the investment. The "TOTAL" row indicates the total NPV of the tree at the time of removal. The UTSV is provided to the right for a comparison; if the tree will be perpetually replaced on the land, considering the UTSV as an investment criterion is recommended. As mentioned, the UTSV will consistently have a slightly greater magnitude (whether positive or negative) than the NPV because of the nature of the calculation.

Individual Models for Tree Benefits

1. Energy Savings

A study by the American Forests Society (2001) taken in Atlanta, GA, shows that per acre of land, $13.67 dollars are saved per year on natural gas bills due to tree coverage. A commonly planted tree in Atlanta is white oak (*Quercus alba*). It is estimated that a planted white oak has a lifespan of about 120 years, during the first ninety of which it is structurally sound (USDAFS, 1990). White oak saplings are generally planted at age two, and reach a size of significant canopy coverage after about ten years. Thus, the energy savings for the white oak begin at age ten. The nursery price for white oak in 2010 is $70.00. Tree removal is assumed to cost $406.00 for a tree greater than twenty-four inches in diameter (RMDSI, 2008).

The following model represents the discounted cash flow analysis for the energy savings value of a single tree. For the sake of simplicity, this model and all future models are calculated with a discount rate of five-percent.

Table 5.1 Energy Savings Model at a Five-Percent Interest Rate

ITEM	YEAR	AMOUNT	NPV (@ 5%)	UTSV (@ 5%)
Plant tree	0	($70.00)	($70.00)	
Annual Savings	10-90	$13.67	$172.84	
Remove tree	90	($406.00)	($5.03)	
TOTAL			$97.15	$98.37

2. Windbreak Savings

Assume that presence of a large oak on the lawn stops the removal of shingles from a windstorm that occurs once every ten years. An approximation of the cost savings that occurs in this situation is $150.00. Again, it is assumed that the tree begins having a substantial size at age 10 and will need to be removed by age ninety. The interest rate used is five-percent. The following cash flows then apply:

Table 5.2 Windbreak Model at a Five-Percent Interest Rate

ITEM	YEAR	AMOUNT	NPV (@ 5%)	UTSV (@5%)
Plant Tree	0	($70.00)	($70.00)	
Wind Savings	15, 25,35...	$150.00	$183.00	
Remove tree	90	($406.00)	($5.03)	
TOTAL			$106.84	$108.18

3. Soil Enhancement

In this example, assume that a tree can convey soil benefits to at least the area of ground reached by its root mat. For simplicity's sake, assume that the area covered will maximize at one-hundred square feet when the tree reaches forty years of age. Prior to this point, assume the root structure is fifty square feet, except during years two through ten when it should be considered negligible. In reality, the area of root structure could be determined through measurements on the property of root structure or an estimation based on crown diameter. With this information, the costs savings provide a source of benefits:

On tree-less lots, treatments for soil, such as aeration, sod, and fertilization are used to keep the soil lush. Average sod costs are approximately fifty cents per square foot, including cost of transportation and installation. Average cost for aeration is approximately $15.00 per square foot and average cost of fertilization is $7.00 per square foot (Ocone, 2000). Assume the soil (without trees) needs annual fertilization and sodding and aeration once every ten years. This is calculated at a five-percent interest rate. We calculate these cost savings as positive cash flows.

Table 5.3 Soil Enhancement Model at a Five-Percent Interest Rate

ITEM	YEAR	AMOUNT	NPV (@ 5%)	UTSV (@5%)
Plant	0	($70.00)	($70.00)	
Fert	10-30	$25.00	$206.61	
Sod/Aer	10	$1100.00	$675.30	
Sod/Aer 2	20	$1100.00	$414.58	
Sod/Aer 3	30	$1100.00	$254.52	
Fert	30-90	$50.00	$230.55	
Sod/Aer 4	40	$2200.00	$312.50	
Sod/Aer 5	50	$2200.00	$191.85	
Sod/Aer 6	60	$2200.00	$117.78	
Sod/Aer 7	70	$2200.00	$72.35	
Sod/Aer 8	80	$2200.00	$44.40	
Remove	90	($406.00)	($5.70)	
TOTAL			$2444.74	$2475.40

The cost savings from the tree total to $2444.74 after discounting. The costs of planting and removal are still incurred and should be included as such.

4.Privacy Benefits

The following model computes the benefits for privacy. The benefits here represent cost savings (such as that of not buying an alarm) and the hedonic value of increased privacy in daily living. Because privacy benefits from trees can be associated with a “belt effect,” it is important to note that even if this model were to be used on more than one tree, the benefits from privacy would remain the same, however the benefits per tree would decrease. All of the cash flows in this model are calculated at a five-percent interest rate.

Table 5.4 Privacy Benefits Model at a Five-Percent Interest Rate

ITEM	YEAR	AMOUNT	NPV (@5%)	UTSV(@5%)
Plant	0	($70.00)	($70.00)	
Privacy	10-90	$50.00	$632.22	
No alarm	45	$1000.00	$111.29	
Remove	90	($406.00)	($5.03)	
TOTAL			$668.48	$676.86

5. Sound Barrier Benefits

The valuation strategy used to determine sound barrier benefits in this example is comparative. We assume that one layer of R-13 insulation provides the same reduction in sound as the aforementioned tree barrier. Because different insulation brands exist, the efficacy of insulation layers are related to the brand of insulation purchased. Certain types of insulation are geared specifically for acoustic reduction (USEPA, 2009). The square feet covered by a tree’s canopy and the square feet covered by R-13 insulation can be priced comparatively for the same times of duration to determine the value of benefits; the goal is to value the tree based on an equivalent and monetary alternative investment.

In this model, assume insulation costs $40.00 per one-hundred square feet, and that it must be replaced every twenty years. This hypothetical tree reaches one-hundred square feet of crown coverage at age thirty. At age fifty, it achieves two-hundred square feet of coverage. Between ages ten and thirty, it has fifty square feet of coverage. Prior to this time, the coverage is negligible. All cash flows are calculated at five percent interest rate.

Table 5.5 Sound Barrier Model at a Five-Percent Interest Rate

ITEM	YEAR	AMOUNT	NPV (@5%)	UTSV (@5%)
Plant	0	($70.00)	($70.00)	
Insulate	10	$20.00	$12.27	
Insulate 2	30	$40.00	$9.26	
Insulate 3	50	$80.00	$6.97	
Insulate 4	70	$80.00	$2.62	
Remove	90	($406.00)	($5.03)	
TOTAL			($43.91)	($44.47)

In this model, the benefits from a single tree come out negative; that is because 100 to 200 square feet of sound barrier in comparison to a home with significantly larger exterior surface area does not create an effective barrier. If more trees were planted to create a larger amount of coverage, the benefits would increase and the investment would return a positive result. The concept of sound barrier planting is usually associated with tree “belts”—this makes expansion of the cash flow relatively simple; generally trees in sound barriers are very similar to one another, and multiplicative expansion suffices.

6. Carbon Sequestration

The carbon sequestration ability of a tree increases as its size increases; eventually the tree reaches a maximum size, but is still sequestering carbon. The earlier cash flows for this model can be calculated as annuities (Eqn. 3) through the Minimum Size Delayed Annual Benefits construction or, if the rate of sequestration is known, through the Fixed-Rate Growing Annuity Construction. After the tree's growth becomes negligible, we use the same rate to look at the sequestration for the rest of "infinity" (since, even after removal, the tree will still hold a fixed amount of carbon). This is represented in the data as a perpetual annuity; perpetual annuities can be calculated with the perpetual series formula (Eqn. 9). The following model can be used as an example for the determination of a tree's carbon sequestration benefits. This example is calculated with a five-percent discount rate.

Table 5.6 Carbon Sequestration Model at a Five-Percent Interest Rate

ITEM	YEAR	AMOUNT	NPV (@ 5%)	UTSV (@5%)
Plant	0	($70.00)	($70.00)	
Sequester	3-8	$1.82	$8.37	
Sequester 2	9-15	$3.49	$13.66	
Sequester 3	16-22	$5.20	$14.47	
Sequester 4	23-35	$7.32	$23.50	
Sequester 5	36-50	$9.48	$17.83	
Sequester 6	51-70	$11.70	$12.71	
Sequester 7	70 to inf.	$14.12	$282.39	
Remove Tree	90	($406.00)	($5.03)	
TOTAL			$297.90	$301.63

Valuations of carbon sequestration benefits are more applicable to large areas, where carbon sequestration may play a major role in choosing the amount of ground coverage.

7. Air Quality Benefit

Despite applying to many beneficiaries, because of the relative smallness of air quality benefits on a per-tree basis, it is reliable to represent these benefits as an annuity. Obviously the tree is improving the air quality constantly, but the value of the daily or hourly quality increase would be far too small to be calculated easily. Calculations done on the National Tree Benefit Calculator for White Oak in Atlanta, GA, reveal a range of less than $10.00 benefits from air quality enhancement per year between a tree with a DBH of ten inches and a tree with a DBH of forty inches. For this calculation, use the value for DBH of 25 inches. Those desiring greater precision could use as many calculated benefits by DBH as desired to achieve a better valuation. This is the method to be used in the general model discussed later in this chapter.

Table 5.7 Air Quality Model at a Five-Percent Interest Rate

ITEM	YEAR	AMOUNT	NPV (@5%)	UTSV (@5%)
Plant	0	($70.00)	($70.00)	
Air Quality	2-90	$7.72	$145.13	
Remove	90	($406.00)	($5.03)	
TOTAL			$70.10	$70.97

8. Storm Water Benefits

The information calculated by McPherson and Simpson (2002) was discussed in the benefits section of Chapter three. This data set represents an extraction of McPherson's information and the creation of a DCF analysis from it. This produces the following cash-flow model at a five-percent interest rate.

Table 5.8 Storm Water Model at a Five-Percent Interest Rate

ITEM	YEAR	AMOUNT	NPV(@5%)	UTSV (@5%)
Plant	0	($70.00)	($70.00)	
Flood mitigate	20	$195.66	$73.40	
Flood mitigate 2	40	$195.66	$27.79	
Flood mitigate 3	60	$195.66	$10.47	
Flood mitigate 4	80	$195.66	$3.94	
Water Quality	2-90	$0.47	$8.83	
Remove Tree	90	($406.00)	($5.03)	
TOTAL			$49.40	$50.01

9. Recreational and Health Benefits

The following estimation of a cash flow model for the valuation of recreational and health benefits has been proposed here; however, it is important to note that this particular benefit is highly susceptible to change depending on the situation and parties involved. One of the prime advantages of the National Tree Benefit Calculator is that benefits such as recreational and health value are included in the "property value increase" component, giving us reliable information that can be analyzed in a multi-user context. The information from this model comes from opportunity cost valuation and not from the National Tree Benefit Calculator. All cash flows are respective to a five-percent interest rate.

Table 5.9. Recreation and Health Model at a Five-Percent Interest Rate

ITEM	YEAR	AMOUNT	NPV (@5%)	UTSV (@5%)
Plant	0	($70.00)	($70.00)	
No Doc Copay	10-90	$30.00	$379.33	
Work increase	30-60	$1000.00	$3788.21	
Fitness	20-70	$25.00	$181.43	
Remove	90	($406.00)	($5.03)	
TOTAL			$4273.94	$4327.54

In this model, the UTSV valuation provides a useful insight by labeling what physical location of a tree produces the greatest benefits to human health. Further research need be done on this subject, but this could potentially be used to make landscaping decisions.

10. Aesthetic Benefits

The information given about a site's increase in value because of trees (essentially, a comparable sales analysis) can be used to calculate the aesthetic benefit of a single tree or the urban forest resource of the lot, neighborhood, or city. This analysis would need be done in the context of the recreational and health benefit analysis; benefits for those causes, if extant and determinable, would be separated from the aesthetic benefits in the total property value increase situation. The following model represents a single tree.   We will assume that the discount rate in this situation is five-percent, and that the lot is sold in year 25 for the same $300,000.

Table 5.10 Aesthetic Model at a Five-Percent Interest Rate

ITEM	YEAR	AMOUNT	NPV (@5%)	UTSV (@ 5%)
Plant	0	($70.00)	($70.00)	
Site Value up	25	$2640	$779.59	
TOTAL			$709.59	N/A

The increase in site value is calculated by determining 0.88% of the site's sale value. This increase in value occurs at the time of sale, year 25. In this situation, the UTSV cannot be calculated because the increase in site value is relative to the sale of the site.

11. Local Economic Development

Currently, no model has been developed for calculating the actual monetary value of increased urban development. In this situation, we will create arbitrary values to show how this model works for this information on the premise that later research can "fill in" these numbers with veritable ones. This will be done on the scale of ten oak trees. When calculating the value of local economic development for an actual investment, similar cash flows should be used. This model would be generally used on a large-scale basis. It is also important to note that the adjacent structure and beneficiaries from this model could be either residential or commercial. Local economic development models could use used to look at how greenspaces impact community behavior and increase community value as a whole. The model assumes a five-percent interest rate.

Table 5.11 Local Economic Development Model at a Five-Percent Interest Rate

ITEM	YEAR	AMOUNT	NPV (@5%)	UTSV(@5%)
Plant	0	($700.00)	($700.00)	
Enjoyment*	2	$500.00	$453.51	
Crime**	10-90	$60.00	$758.66	
Activity***	35	$1500.00	$271.94	
Activity 2	70	$1500.00	$49.29	
Remove	90	($4060.00)	($50.30)	
TOTAL			$783.10	$792.93

* Could be derived from a fee that volunteers paid to maintain the young sapling or travel expenses spent to tend to it.
** If a police officer paid $15.00 per hour would have policed the scene two times per year for two hours each time to scope out potential crime, and trees prevent this crime by increasing the "residential feel" or other characteristic of the neighborhood, this results in a savings of labor of $60.00 per year
*** Local activities such as town festivals may be held in a tree-lined area. These activities generate revenue for the town.

12. District Sales Increase

For the following model, assume ten white oak trees are present surrounding a store generating five million dollars of annual revenue (before DCF is taken into account). Annually, we estimate that these oaks increase the value of the store by just over eleven-percent. This number is taken in reference to several figures in the literature (Wolf, 2004). All of these cash flows are at a five-percent interest rate.

Table 5.12 District Sales Increase Model at a Five-Percent Interest Rate

ITEM	YEAR	AMOUNT	NPV(@5%)	UTSV (@5%)
Plant	0	($700.00)	($700.00)	
Revenue up	10-90	$450,000.00	$5,689,998.02	
Remove	90	($4060.00)	($50.30)	
TOTAL			$5,689,247.00	$5761363.52

Although these values seem inexplicably high, remember that they are in reference to an entire shopping area, not a single tree or home, and therefore are representative of a greater investment scale than other benefit calculations.

Individual Models for Costs

Although this document primarily focuses on the development of benefit-based valuation models for urban forests, DCF analysis cannot be used for an investment decision without the inclusion of costs. The twelve models include costs necessary in all urban tree-planting operations—costs of planting and removal. However, other costs, as discussed in the previous chapter, exist and effect investment decisions. When conducting an inventory, some tools like the National Tree Benefit Calculator software, i-Tree, include inputs for average costs. These inputs should be use to expand the costs to the scale appropriate for the inventory, but should be assessed through DCF in a manner similar to the following models.

The cost models do not include the UTSV calculation, as these models are partial models and do not reflect any of the benefits of the tree. The UTSV calculation is more relative to full models that contain both benefits and costs.

The easiest error in cost modeling is the simplest error; it is important to enter all costs as negative cash flows. In denoting costs, negative signs, accounting (parenthetical) notation, or nomination as "cost" is one way to negative cash in an itemized list. In these models, we will use accounting notation, but in reference to FORVAL use, FORVAL denotes costs with the "add cost" button:

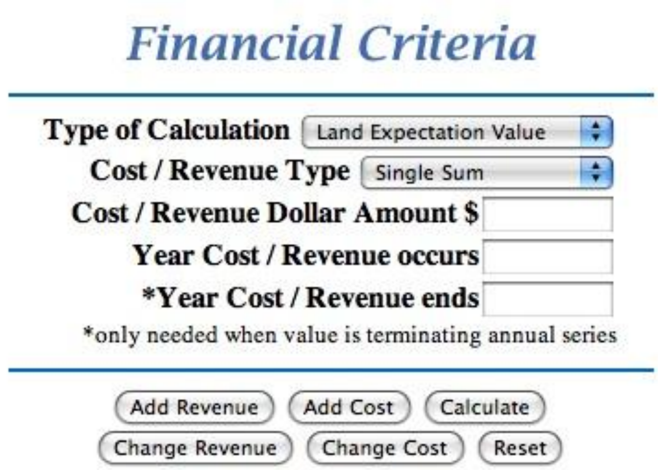


Figure 5.1 The FORVAL "add cost" button.

1. Planting Costs

Planting costs always occur at year zero, the year of NPV, and therefore require no discounting. They are the easiest costs to deal with in DCF method. For example, if a white oak cost $70.00 at the nursery and has been transported twenty miles at a cost of $0.50 per mile, its planting supplemented with a $200.00 irrigation system, and then three hours of labor by two workers earning $10.00 an to hour plant it, the costs for the white oak would appear as follows at a five-percent interest rate.

Table 5.13 Planting Costs Example at a Five-Percent Interest Rate

YEAR	ITEM	AMOUNT	NPV (@5%)
0	Tree	($70.00)	($70.00)
0	Transportation	($10.00)	($10.00)
0	Irrigation	($200.00)	($200.00)
0	Labor	($60.00)	($60.00)
TOTAL			($340.00)

If an entire site is being evaluated with trees that have been planted at different times, a definitive year zero must be chosen in relation to the site. In this instance, trees that were planted at the inception time of the site would share a year zero with the site, whereas trees planted at another time would have their own “year zero” for their lives, but would need to be discounted or compounded to be put on an equivalent basis with the site. This is a more complicated situation.

The graph below depicts how trees of several heights could be at year zero for the site, but at completely different years for themselves.

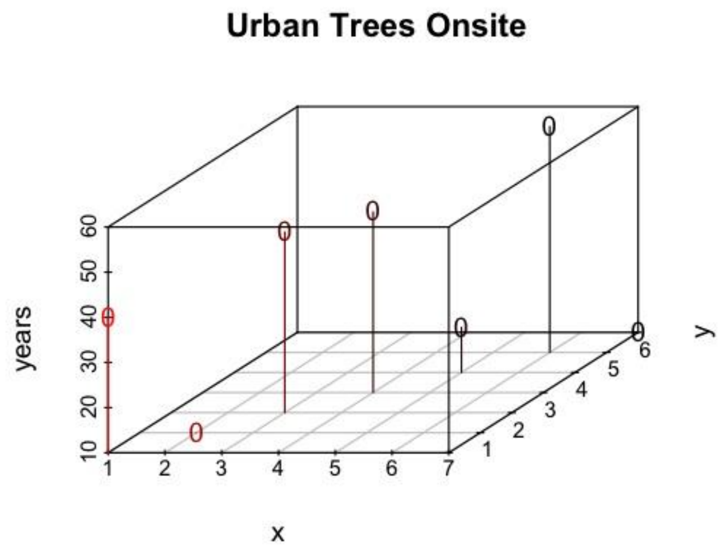


Figure 5.2 Site location (x, y) versus tree age (z). All trees at site year zero.

2. Maintenance Costs

Maintenance costs are the costs to maintain trees on a site. For example, a crew works for five hours with three men (paid $10.00 per hour) pruning a tree once every year. The crew drives 10 miles to get to the tree site at a cost of $0.50 per mile. These regular prunes begin in year 20 and end with tree removal in year 90. Cost per pruning session is therefore five hours times three men times ten dollars ($150.00), plus the cost of transportation to and from the site, 20 miles (10 + 10) at $0.50 per mile, which is ($10.00). Total cost per session is therefore ($160.00). A preliminary cost analysis determines the following about the total cost of pruning at a five-percent discount rate:

Table 5.14a (Regular) Maintenance Costs Example at Five-Percent Interest Rate

YEAR	ITEM	AMOUNT	NPV (@5%)
20-90	Pruning	($160.00)	($1226.72)

At year fifty-three, the tree is struck by lightening and a large branch looms perilously over a home. The crew is called out to remove this branch, an effort that will take them three hours, and they bring in a utility vehicle that costs $100.00 per hour to operate. Two of the men come in the truck, while the third brings out the utility vehicle. This cost is calculated by the addition of the labor costs (three hours times three men times ten dollars: $90.00, plus the cost of the utility vehicle for three hours, which costs $300.00) to the transportation costs (the same $10.00 cost to bring the truck, plus the utility vehicle, which also transports for $10.00, for a total of $20.00 of transportation costs). This single sum cost is as follows at a five percent interst rate:

Table 5.14b (Single Sum) Maintenance Costs Example at Five Percent Interest Rate

YEAR	ITEM	AMOUNT	NPV (@ 5%)
53	Remove	($410.00)	($30.89)

Prior to the planting of the tree, the regular costs can be calculated. After the incident at year fifty-three, the single sum for that particular incident is calculated. Incidents such as this one should be calculated soon after occurrence to determine the change in the benefit-cost ratio and evaluate alternative investment strategies, if necessary.

3. Disease Costs

Whether or not to treat for a disease should be considered as a "mini-investment" in itself; an analysis of the NPV of the tree can determine whether or not it is financially sound to undertake disease costs. For example, suppose that we have determined unless an elm (*Ulmus americana*) receives preventative treatment, it will get Dutch elm disease at age 50 and need removal for ($500.00). The tree has been evaluated for benefits, and benefits per year are $60.00 per year throughout its life. These benefits will be lost when the tree is removed. The cost to prevent Dutch elm disease is $50.00 per year. Evaluation of the removal scenario at a five-percent interest rate shows:

Table 5.15a Disease Cost Example (Year 50) at a Five-Percent Interest Rate

YEAR	ITEM	AMOUNT	NPV (@5%)
50	Removal	($500.00)	($43.61)
50-90	Loss of benefits	($60.00)	($95.02)
TOTAL			($138.62)

Thus, removing the tree will cost ($43.61) in physical removal costs and an additional ($95.02) in benefits not obtained from the tree remaining on the site.

Evaluation of the treatment scenario reveals (at the same five-percent interest rate):

Table 5.15b Disease Cost Example (Year 50) at a Five-Percent Interest Rate

YEAR	ITEM	AMOUNT	NPV (@5%)
0-90	Prevention	($50.00)	($1037.62)

If we know that the tree will get Dutch elm disease at age 50, it is more financially sound to remove the tree at age 50 rather than use preliminary treatment ($138.62 < $1037.62).

If we suspect that disease will occur earlier in the tree's life, however, the balance of disease cost valuation may alter. For example, if the tree were to be stricken with Dutch elm disease at year ten, evaluation of the removal scenario at five-percent interest rate is now:

Table 5.15c Disease Cost Example (Year 10) at Five-Percent Interest Rate

YEAR	ITEM	AMOUNT	NPV (@5%)
10	Removal	($500.00)	($309.96)
10-90	Opportunity cost	($60.00)	($758.67)
TOTAL:			($1065.63)

Removal of the tree at year ten is more costly than lifelong treatment ($1065.63>$1037.62). In this scenario, the investment decision to practice disease control should be made. As can be seen from the above, it is very important to calculate disease costs before making an investment decision, as the NPV of these investments can be sizeable and very sensitive to the time value of money.

4. Tree Removal

Tree removal has both a cost (the cost of removing the tree) and sometimes a benefit (the revenue from processing the tree, if applicable). These benefits need to be included in the tree removal calculation as a positive cash flow; however, because tree removal often occurs many years in the future, these benefits are usually negligible at net present value. Then again, the costs, because of the time value of money, also are a very small amount. Tree removal calculations are simply single sum calculations done at the final year of tree existence, and can be done marginally. Their input to the NPV of the tree value is minimal in urban tree situations because of the diminution of value in the future. A $1000.00 benefit occurring at removal at age 100, for example, is worth only $7.60 today. However, the removal itself will also be heavily discounted, and therefore the cost-benefit ratio at the time of removal may still be favorable.

Figure 5.3 depicts how $1000.00 diminishes in value at a five-percent interest rate over time. This is due to the exponential nature of discounted cash flow analysis, which is depicted in the graph.

Table 5.16 The Decline of Value over Time at a Five-Percent Interest Rate

YEAR	AMOUNT
0	$1,000,00
10	$613.91
20	$376.89
30	$231.38
40	$142.05
50	$87.20
60	$53.54
70	$32.87
80	$20.18
90	$12.39
100	$7.60
110	$4.67
120	$2.87
130	$1.76
140	$1.08

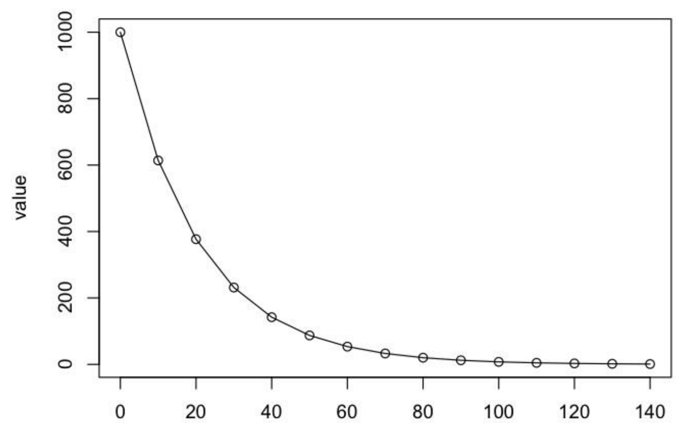


Figure 5.3 Graphical depiction of decreasing value over time.

The General DCF Model for Urban Trees

This section discusses the partial benefits and costs that an urban tree can convey and incur and how to use the DCF formulas to assess these benefits and costs. Alone, this information is interesting, but in the context of an appraisal, it is a vital tool for providing a time-sensitive valuation. Calculation of an urban tree's value requires knowledge of the fiscal return from benefits the tree creates during its lifespan on the site. Assessment of the benefits from an urban forest using DCF presumes that benefits incurred at a future year are discounted back to "year zero" and summed. This is simple to do when we are looking at hypothetical information as presented in the literature, but harder to do in the context of a real urban tree. This is because there are two growths to deal with in urban tree situations; the growth of the money at the bank and the growth of the tree itself. The diagram below shows the biological growth of a tree and the growth of its benefits due to its increase in size. This is an increase exclusive of the discount rate.

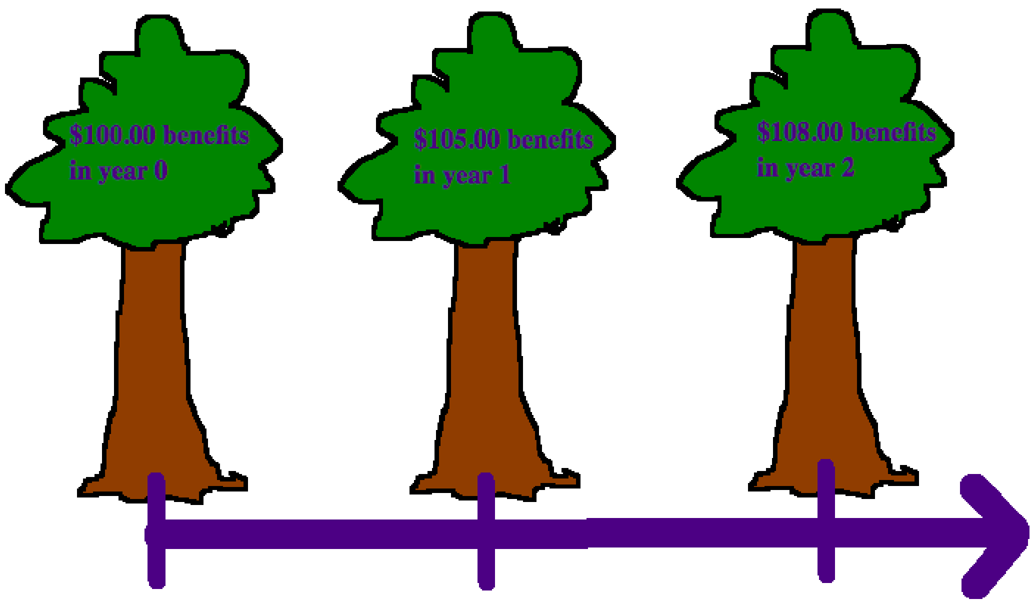


Figure 5.4 Tree Growth and Benefit Growth

In DCF, these benefits are positive cash flows that must be discounted back to year zero. Using equation one (because the rate of growth for these benefits has not been "given"), the value of the diagrammed tree is expressed as:

$$V_0 = \frac{100}{(1+i)^1} + \frac{105}{(1+i)^2} + \frac{108}{(1+i)^3}$$

It follows that if more information about the tree's value in future years existed, we could also discount these values back to year zero. Likewise, if we had any information about the future costs of the tree, these negative cash flows could also be discounted back to year zero (Straka and Bullard, 1998).

In the context of urban forestry, this means that a landowner can determine accurate answers to several questions he or she might have about his or her trees. Some of these questions are listed below, where the general methodology is briefly discussed and used to calculate a net present value for an urban tree, calculate the NPV of an example urban tree, and then show how these questions (which represent various financial permutations of the NPV) can be answered with DCF techniques.

The following questions, and the cash flow technique associated with them (in brackets), pertain to the use of discounted cash flow analysis for urban forests:

1. How much is my tree worth today? (NPV)
2. How much will my tree be worth in X years? (NFV)
3. How much is the site my tree is on worth for the planting of trees? (UTSV)
4. What are the annual benefits I can derive from my tree? (EAI)
5. If I were to place my tree under a conservation easement, how much would it be worth in perpetuity? (Perpetuity)
6. Is it beneficial to use certain treatments on my tree? (B/C ratio)
7. What is my return on investment from an expense regarding this tree? (IRR)

Each of these questions reflects a landowner's particular situation. The urban forester or arborist must understand how specific questions translate into discounted cash flow analysis formulas to provide the preferred financial decision to the landowner. Calculation of the NPV is the basis for answering the other questions and is the focus of the following discussion.

The benefit-based value of an urban forest at any point in time is a function of the aforementioned twelve benefits (energy savings, windbreak savings, soil enhancement, privacy benefit, sound barrier benefit, carbon sequestration, air quality, storm water, recreation and health, aesthetic benefits, local economic development, district sales increase), ten of which (excluding local economic development and district sales increase) apply to personal property. Therefore, for any given moment in time,

(Eqn. 17) $$TotalBenefits = \sum_{i=1}^{n} CategoricalBenefits$$

In some situations less (or more) than the twelve benefit categories may need to be assessed. For example, use of the United States Forest Service Urban Tree Forest Effects Model (UFORE) determines benefits from an urban forest to the city as a whole and considers the universal benefits, such as district sales increase, whereas the National Tree Benefit Calculator determines benefits for an individual tree to a specific person or property, so limited benefits will apply (Nowak et al., 2002). The amount or nature of benefits assessed does not change the way that discounted cash flow analysis is applied to valuation; more benefits simply mean more cash flows.

General models for urban tree benefits can be problematic because of variation in species, location, and condition of trees, as well as unforeseen events in every individual tree's life. McPherson's (1999) valuation of Modesto, California's urban trees created equations for determining categorical tree benefits and then determined the forest's value. These equations were relevant to that particular forest, but could not be used outside of that data's context. Online database technology allows urban foresters to access tree information for any tree in any region and to calculate these tree's benefits without being tied to antiquated or overly specific equations. The discounted cash flow analysis method of valuing urban trees uses the benefit data collected by the Davey Tree Expert Company. The Davey Tree Expert Company uses a user-input system called i-Tree (formerly STRATUM) to collect tree benefit information across the United States that reflects current values specified by location and species. Use of this database (as opposed to sets of predictive equations) allows for variability without sacrificing simplicity and applicability.

The benefits given by the Davey Tree Expert Company are property value increase, storm water protection, carbon sequestration, air quality increase, natural gas savings, and electricity savings.   The benefit "property value" aligns with the benefits labeled as aesthetic value, sound barrier benefits, and recreation and health benefits. For each user input of location, species, and DBH, the tree benefit calculator returns benefit values for each of these categories per year.

As far as the mathematics is concerned, the general model can be viewed as a sum of benefits calculated on an annual basis in the summation form:

(Eqn. 18)
$$NPV_B = \sum_{i=1}^{k} B_n + B_{n+1} + ...B_k$$

Where:

"NVP_B" is the net present value of the discounted benefits
"B_n" represents the discounted benefits for the first year ("n" increases incrementally by the index factor "i" as one)
"B_k" represents the discounted benefits from the final year.

However, the NTBC is based on DBH, so a modified version of this equation, and the version on which the model is based, is:

(Eqn. 19)
$$NPV_B = \sum_{i=1}^{k} n * B_n + n_{(i+1)} * B_{n+1} + ...n_k * B_k$$

Where:

"n" represents the number of years at the initial DBH
"B_n" represents the benefits at the initial DBH
"n_{i+1}" represents the number of years at the subsequent DBH (n+1)
"B_{n+1}" represents the benefits at the subsequent DBH (i+1)
"k" represents the final DBH increment assessed.

To use this model, the arborist performing the inventory must take two measurements: DBH (in inches) and a tree core sample. For accuracy, at least two measurements must be taken with the core sampling technique, preferably from two different locations on the tree. Trees do not grow uniformly in circumference and having two or more samples allow this variability into the model. Samples should be bored at DBH.

The two increment borer samples fulfill the model's requirement of how many years a tree spends at a particular DBH. Because an increment boring measures the radius of the tree (if drilled to the core), and two times the radius represents the diameter, the addition of two increment borer samples measured from core to ring will give us the DBH of the tree at that particular ring. If more than two samples are taken, only two may be used for this method. Determination of the tree diameter at every ring (year) in its history is calculated by simply adding the coinciding distances to each ring together. This should be tabulated in a manner such as the one shown below:

Table 5.17 Sample Ring Tabulation

RING	SAMPLE 1	SAMPLE 2	TOTAL
1	.14 in.	.16 in.	.30 in.
2	.29 in.	.30 in.	.59 in.
3	.45 in.	.45 in.	.90 in.

If only one core sample is available, the measurement of distance from core to ring should be multiplied by two to get the "total" amount of diameter increase. With most tree species, one dark ring is created per year. For the few species that belie this rule, assistance in dendrochronology from a professional is recommended.

The amount of rings in each increment of "total" DBH represents the amount of years the tree spent in that DBH category. In other words, the number of rings per one-inch increment in the "TOTAL" category is "n_i" in the previous equation. In the above table, if the tree reached a total of one inch with ring four, the tree spent four years in the one inch category. To keep track of ring count per one-inch increment in DBH, use a simple table. For the examples in table 5.18 can be found in Appendix D. Remember that the number of rings counted is not the total number of rings from the center of the tree to that particular increment, but only the difference in the amount of rings between one increment and the next:

A layout similar to the following should be used to observe the DBH increments and ring counts. This layout allows us to easily see "n" (number of rings counted) and DBH, both of which are important inputs into the National Tree Benefit Calculator.

Table 5.18 Sample DBH and Ring Counting Table

DBH Increment	Number of Rings Counted
1	5
2	8
3	11

Definition of DBH should be done by one-inch classes to fit with the Davey Tree Calculator data. Assume one-inch classes to represent the range around the integer; that is, the twelve inch class is all DBH's from 11.6 to 12.5 inches.

After determining the trees history by DBH, annual benefits per inch should be calculated. Determination of the annual benefits can be done through the Davey Tree Benefit Calculator as described in the "Using the Davey Tree Benefit Calculator" section. The creation of a table such as:

Table 5.19 Benefits from the Tree Benefit Calculator

DBH	PV	SW	AQ	CO2	NG	EL	TOTAL
1	23.04	0.64	0.64	0.06	3.75	0.72	28.85
2	36.01	1.27	1.16	0.13	6.64	1.32	46.53
3	38.93	1.89	1.58	0.21	8.67	1.80	53.08

facilitates the collection of this information. The acronyms above represent the benefit categories, "PV" is property value, "SW" is storm water, "AQ" is air quality, "CO2" is carbon sequestration, "NG" is natural gas and "EL" is electricity. These numbers are derived from a function created by the Davey Tree Expert Company that is specific to the tree's species and location. For example, the above data represents a white oak (*Quercus alba*) growing in Detroit, Michigan. Using the National Tree Benefit Calculator and the method above, the partial and total benefits for all available DBH's of this particular white oak (up to forty-five inches) were calculated and the total benefits input into the statistical software "R." We then assigned "dbh" to be an independent variable and created a series between one and forty-five. "R" reads this input as a table or matrix so that the information can be analyzed statistically. The input and plot are shown below:

```
> totalben<-c(28.85, 46.53, 53.08, 59.52, 66.53, 73.87, 81.22, 88.57,
95.9, 105.45, 115, 122.54, 134.08, 144.02, 153.17, 162.3, 171.43, 182.58,
189.7, 198.84, 207.98, 217.75, 227.52, 237.29, 247.08, 256.86, 266.63,
276.05, 285.46, 294.87, 302.28, 313.7, 323.12, 332.32, 341.54, 350.75,
359.95, 369.76, 378.37, 386.94, 395.54, 404.12, 412.71, 421.29,429.81)
> # predictive value (dbh)
> dbh <-c(1:45)
> plot(dbh,totalben)
> benefits <-as.data.frame(cbind(totalben,dbh))
> |
```

Figure 5.5 The input of total benefits and DBH in "R." Comma separated values are easiest to use in this particular application.

A ".csv" file can also be used to move the data from Microsoft Excel to the R software. This method is simpler and should be used when several or extremely large data sets need to be analyzed.

That the relationship would be highly correlated was given (since it was derived from the NTBC's internal function), but analysis was needed to confirm the linear shape of this relationship with regression; this statistical analysis proves that the relationship between benefits and DBH is linear for a white oak in Detroit, Michigan. This is not always the case, but it makes this particular example fairly easy to work with for the sake of this explanation Tests to confirm the normalcy of the data were also performed, as well as a calculation of the summary statistics (as expected, since the data comes from a fabricated line, r-squared = 0.9994, discrepancy due to rounding of decimals). These summary statistics and the R commands used to calculate them can be found in Appendix E.

Because it is a linear function, the total benefit function for the Detroit white oak follows the basic linear form:

$$Y = A + BX + e_i$$

where "A" is the intercept, "B" is the slope of the line (or the marginal increase in benefits for every one inch increase in DBH), and "e_i" is the residual error. The following prediction equation results from the interpretation of the Detroit white oak summary statistics into the general model:

$$\hat{y} = 17.57266 + 9.20011x$$

Here, "ŷ" represents the predicted total benefits and "x" represents the input DBH.

If DCF is ignored and a simple calculation of the summation of the benefits from this situation undertaken, the following model would be used:

$$TotalBenefits = \sum_{i=d}^{k} 17.57266 + 9.20011 d * n + 17.57266 + 9.20011 d_2 * n_2 \ldots . 17.57266 + 9.20011 d_k * n_k$$

where “n” is still the number of years at each DBH and “d” is the diameter (in inches) at each successive increment which is the input. The “n” values from the tree ring count to amplify the benefit function for the appropriate number of years. This formula is here only as an intermediate example; it cannot be used for financial decision making because it does not include the time value of money.

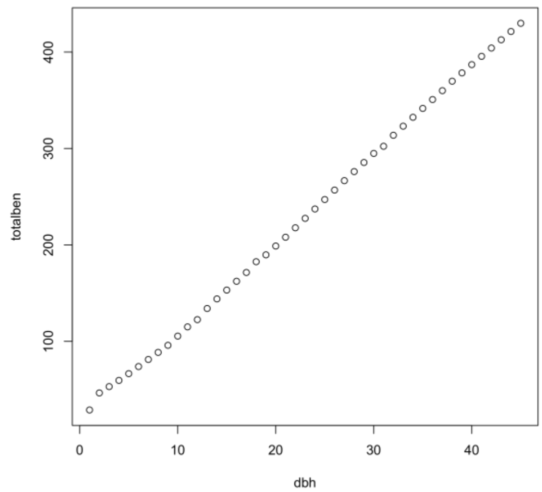


Figure 5.6 The resulting linear relationship between DBH and total benefits

Discounted cash flow analysis “brings back” the total benefits to the present time (year zero) by using the DCF formulas, specifically, equation two and its annual and serial permutations and constructions. For example, suppose the following cash flow diagram represented the benefits accumulated from an urban tree over eleven years (from year zero, today, until ten years from now, year ten).

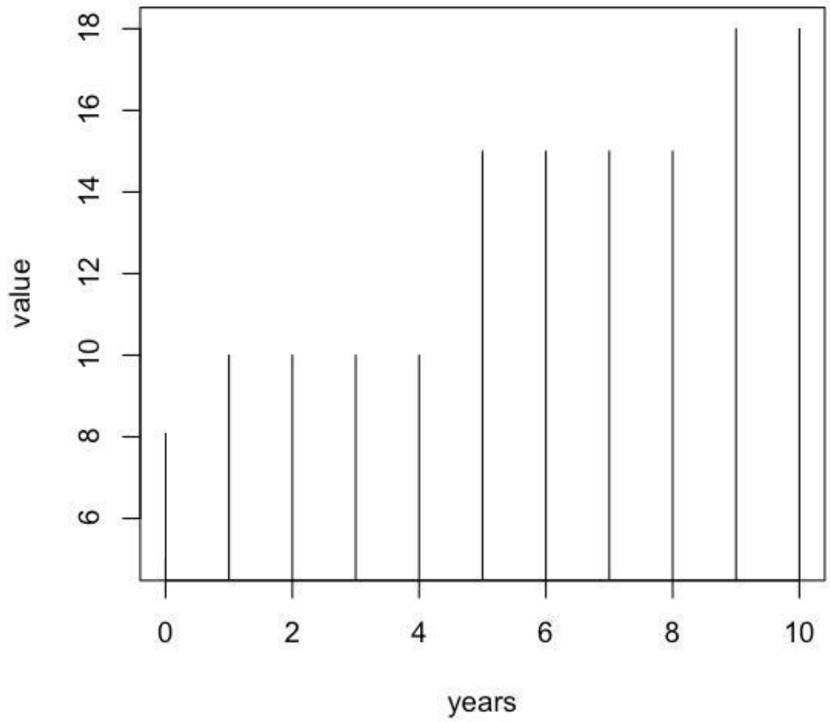


Figure 5.7 Example tree values (y axis) at each year (x axis).

This tree has been in four different DBH classes during this time; at year zero, its DBH corresponds with a benefit value of eight; years one through four, benefit value is ten; years five through eight, benefit value is fifteen, and years nine and ten, benefit value is eighteen. These values can be viewed on the “y” axis. At this point in the model, the actual DBH classes themselves are not relevant to the tree financial decision; they are only valid as inputs into the National Tree Benefit Calculator or the linear equation derived from it (as seen above).

Because there are eleven years in the above diagram, the discounted cash flow analysis uses eleven terms. The mathematics behind the calculation of the NPV from these terms is discussed here, although they can also be easily calculated in FORVAL using the NPV financial criterion options available. Use of FORVAL for calculations is discussed in the "guide to using FORVAL" section and is also further explicated in this section. Unless otherwise noted, the "tree" in Figure 6.6 is used for this explanation.

The net present value of benefits for a tree follows the form:

(Eqn. 20)
$$NPV_B = \sum_{i=1}^{n} \frac{B_d}{(1+i)^n}$$

where "B_d" is the amount of benefits for a certain diameter increment and "n" is the year in which the benefits occur.

For this example, assume an interest rate, or "i", of five-percent. Then, the example is calculated by the following cash flows:

$$NPV = \frac{8}{1.05^0} + \frac{10}{1.05^1} + \frac{10}{1.05^2} + \frac{10}{1.05^3} + \frac{10}{1.05^4} + \frac{15}{1.05^5} + \frac{15}{1.05^6} + \frac{15}{1.05^7} \frac{15}{1.05^8} + \frac{18}{1.05^9} + \frac{18}{1.05^{10}}$$

which are equal to these

$$NPV = 8 + 9.52 + 9.07 + 8.64 + 11.75 + 11.19 + 10.66 + 10.15 + 11.60 + 11.05$$

The NPV of this tree in year zero at a five percent interest rate is $109.86. If the benefits were simply summed without respect to their year, a total of $144.00 would be calculated. However, because of the interest rate, benefits received in the future are worth less "today" and therefore account for less in a NPV summation (recall Figure 5.2). Also, note that if all other terms remain constant, an increase in the interest rate will cause a decrease in the net present value. The same example, at a ten-percent interest rate, would be worth $86.75. The loss of value between these two situations represents the opportunity cost of forgone accumulated interest (Tietenburg and Lewis, 2008).

In the case of the "tree" in Figure 5.6, there are several annuities that can be calculated using the Minimum Size Delayed Annual Benefits construction described in chapter four. Recall that this function is derived from the calculation of an annuity in equation seven as:

$$V_0 = a\frac{(1+i)^n - 1}{i(1+i)^n}.$$

(where "a" is the annual benefits, "i" is the interest rate, and "n" is the number of years during which these benefits are accumulated). The purpose of using the annuity function is to reduce the number of cash flow line items needed. The NPV from this calculation assumes that the first year of benefit accrual is year one; the annuity calculates the value of the repeated future cash flows at year zero. For an annuity that occurs in the future, the "net present value" of that annuity (the value of the total benefits at their first year) must be discounted using discounted cash flow analysis back to the true year zero.

In the previous example, a calculation successive years of $15.00 benefits (from years five until eight) as an annuity at five percent interest follows:

$$V_0 = 15\frac{(1+0.05)^4 - 1}{0.05(1+0.05)^4}$$

$53.19 discounted back four years (because the annuity function computes the value at year 4, the year before the annuity benefits begin):

$$V_0 = \frac{53.19}{1.05^4} = 43.76$$

Or, should the construction for the Minimum Size Delayed Annual Benefits be employed, a calculation of the NPV of this particular size class would appear:

$$V_0 = \frac{(1.05)^4 - 1}{0.05(1.05)^4(1.05)^4}$$

Note that in this example the “4” represents the amount of years that the tree was in this particular DBH class and the amount of years that size class occurred away from zero. Such synchronism will not always be the case.

<u>The Detroit White Oak: A Complete Example</u>

The following example uses the data for the Detroit white oak calculated from the National Tree Benefit Calculator. The growth rate of this tree has been created based on ten-year growth rates for white oak (USDAFS, 1990). The virtual growth data presumes that for the first ten years on the site, the tree grows one-quarter inch in diameter per year. For the subsequent eighty years, assume that the tree grows one-tenth of an inch in diameter per year. The tree is removed at year ninety. This information represents the data provided by the tree core sample. The tree begins its life on the site with a DBH of four inches. This growth data is found in Appendix D. The tree ring-count table fabricated from the *Silvics* information is shown below. The full table of benefits from the Detroit white oak can be found in Appendix F.

Table 5.20 DBH increment and ring count for Detroit White Oak

DBH Increment	Rings Counted
4 in.	3 rings
5 in.	4 rings
6 in.	4 rings
7 in.	10 rings
8 in.	10 rings
9 in.	10 rings
10 in.	10 rings
11 in.	10 rings
12 in	10 rings
13 in.	10 rings
14 in.	10 rings

The benefit table from the Davey Tree Expert Company database can be used to create a line item model for this particular white oak at an interest rate of five-percent. The follow format can be used when organizing cash flows for urban trees is suggested. Itemized listing, combined with cash flow diagrams, makes calculation of cash flows simpler and less prone to error.

Table 5.21 Itemized List of Cash Flows for Detroit White Oak at a Five-Percent Interest Rate

YEAR	ITEM	AMOUNT	NPV (@ 5%)	UTSV
0-2	Benefits (4 in.)	$59.52	$170.19	
3-6	Benefits (5 in.)	$66.53	$213.97	
7-10	Benefits (6 in.)	$73.87	$195.46	
11-20	Benefits (7 in.)	$81.22	$385.02	
21-30	Benefits (8 in.)	$88.57	$257.76	
31-40	Benefits (9 in.)	$95.90	$171.33	
41-50	Benefits (10 in.)	$105.45	$115.66	
51-60	Benefits (11 in.)	$115.00	$77.43	
61-70	Benefits (12 in.)	$122.54	$50.65	
71-80	Benefits (13 in.)	$134.08	$34.02	
81-90	Benefits (14 in.)	$144.02	$22.43	
TOTAL			$1693.77	$1715.01

The benefits from the Detroit white oak over a ninety-year period on the site are $1693.77. Based solely on benefits, the value of planting a four-inch white oak in Detroit on a ninety-year rotation at five-percent interest is $1715.01.

Questions from the Landowner

The preliminary questions a landowner may ask are outlined at the beginning of this chapter. These questions take into account not only the benefits of the tree on the site but costs as well. Explanation of various costs and benefits that apply to an urban tree is in Chapter four. To make a financial decision about an urban tree or a green resource, an appraisal of the urban tree's financial contribution must be undertaken; these questions represent some contexts for which an appraisal might occur.

How Much Is My Tree Worth Today?

Calculation of the benefits from the Detroit white oak is the same as shown above. If costs are incurred as well, these must be included as negative cash flows and discounted accordingly. Let us assume a planting cost of $70.00, annual maintenance cost of $10.00, and removal cost of $400.00, with a $500.00 market value on the wood. The valuation now appears (with a five-percent interest rate):

Table 5.22 Net Present Value for Detroit White Oak

YEAR	ITEM	AMOUNT	NPV (@ 5%)
0	Planting	($70.00)	($70.00)
0-90	Maintenance	($10.00)	($207.53)
0-2	Benefits (4 in.)	$59.52	$170.19
3-6	Benefits (5 in.)	$66.53	$213.97
7-10	Benefits (6 in.)	$73.87	$195.46
11-20	Benefits (7 in.)	$81.22	$385.02
21-30	Benefits (8 in.)	$88.57	$257.76
31-40	Benefits (9 in.)	$95.90	$171.33
41-50	Benefits (10 in.)	$105.45	$115.66
51-60	Benefits (11 in.)	$115.00	$77.43
61-70	Benefits (12 in.)	$122.54	$50.65
71-80	Benefits (13 in.)	$134.08	$34.02
81-90	Benefits (14 in.)	$144.02	$22.43
90	Removal	($400.00)	($4.96)
90	Harvest	$500.00	$6.19
TOTAL:			$1417.47

Because of the costs, the worth of the tree is diminished, as expected. The NPV is the financial criterion that is used to determine how much a tree is worth today.

How Much Will My Tree Be Worth in X years?

In discounted cash flow analysis, the "future value" criterion can be used to express how much a present investment will be worth in the future. This criterion is used to compare investments; for example, is it more profitable to invest in the Detroit white oak with a net present value of $1417.47 at an interest rate of five-percent or a $2000.00 certificate of deposit at the bank with an interest rate of 2.5 percent that will be withdrawn in forty years?

If the interest rate on the Detroit white oak is five percent, its value in forty years can be calculated using the "future value" criterion, which is presented in equation one. In this case, that scenario for the Detroit white oak would be:

$$V_{40} = 1417.14(1.05)^{40}$$

versus the certificate of deposit:

$$V_{40} = 2000.00(1.025)^{40}$$

These two values can be compared because they both occur at year forty. In this case, the Detroit white oak has a NFV of $9978.97 and the certificate of deposit has an NFV of $5370.12. Therefore, it is more profitable to invest in the Detroit white oak than it is to invest in the certificate of deposit ($9978.97 is greater than $5370.12).

How much is the site my tree is on worth for the planting of trees?

The UTSV is the criterion used to determine how much a site is worth for the planting of trees. Determination of the UTSV uses the formula mentioned in Chapter four, or, when using FORVAL, the "land expectation value" criterion with the insertion of cash flows in the same manner as in the NPV calculation (see Chapter eight). The "land expectation value" criterion calculates the value of the tree at the end of its life as a perpetuity; it assumes perpetual replenishment of the same tree on the site. Because of this, the UTSV has a larger magnitude than the NPV. If the NPV has already been calculated, there is no need to reinsert all of the cash flows into FORVAL. Insert the NPV into FORVAL as a single sum that occurs at year zero and calculate the UTSV (land expectation value) from this.

Table 5.23 A Swift Way to Calculate UTSV on FORVAL (Using Previous Data at a Five-Percent Interest Rate and with a Ninety-Year "Rotation")

YEAR	ITEM	AMOUNT	NPV (@5%)	UTSV (@5%)
0	NPV	$1417.47	$1417.17	$1435.24

Additionally, as will be discussed in Chapter eight, FORVAL contains an "all of the above" criterion. If a landowner may need the answer to several of these questions, using the "all of the above" criterion will tell not only the NPV, but several other financial criteria as well.

<u>What is the Annual Income I Can Derive from My tree?</u>

Equivalent annual income (EAI) determines the amount of money that can be earned annually from an investment, in this case, the Detroit white oak. The equivalent annual income is calculated by viewing the future value of the tree at the end of its lifespan as an annuity. FORVAL calculates the equivalent annual income either alone or as part of the "all of the above" criterion. If the NPV has been extracted and the EAI needs to be assessed, compound the NPV to year ninety (the end of the relevant lifespan) and then use FORVAL to determine the EAI of that investment. FORVAL cannot compute the EAI from the NPV alone as a single sum at year zero because it does not understand the length of the investment period. It will give a return answer of "infinity," which is not correct.

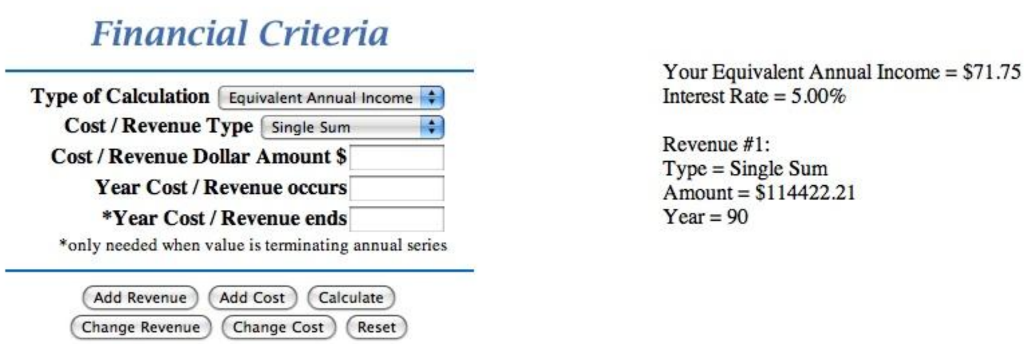


Figure 5.8 The correct way to calculate the EAI in FORVAL

The benefit of using the EAI criterion is that it is easy to look at an investment in the scope of other annual investments. For example, if a landowner wants to compare the costs and benefits of keeping the Detroit white oak after a structural injury versus removing it and replanting a smaller, stable tree, the EAI will tell, on an annual basis, what loss or revenue the landowner will incur.

If I were to place my tree under a conservation easement, how much would it be worth in perpetuity?

This calculation assumes that the same tree will continue to grow on the site perpetually; without information about the future growth of the tree (beyond what is gathered from the tree core sample and the Davey Tree Benefit Calculator). It is impossible to adequately predict this value; however, calculation of the EAI as a perpetuity, or its equivalent, the UTSV, will give us a baseline approximation.

(Eqn. 21)

$$PerpetualValue = \frac{EAI}{i}$$

In this case $71.75 divided by 0.05 calculates the UTSV as $1435.00 (difference from the UTSV calculated previously is due to rounding by the computer).

Because calculation of a perpetuity relies on the principle of limits and the exponential decline of net present value, benefits of the tree far enough into the future are very negligible. Examination of the Detroit white oak with the same one-inch per ten years growth pattern into the future reveals that its benefits after year ninety are very small in terms of net present value even though they are significantly "large" in the context of that year.

Table 5.24 Perpetual Approximation for the Detroit White Oak at a Five-Percent Interest Rate

YEAR	ITEM	AMOUNT	NPV (@5%)
91-100	Benefits (15 in.)	$153.17	$14.65
101-110	Benefits (16 in.)	$162.30	$9.53
111-120	Benefits (17 in.)	$171.43	$6.17
121-130	Benefits (18 in.)	$182.58	$4.04

Even these estimates are falsely hopeful, since the tree will not continue growing at a linear rate and will begin to spend longer and longer time periods in each DBH class. In fact, for some of the other tree species on NTBC, for example, a southern magnolia (*Magnolia grandiflora*) tree growing in Phoenix, Arizona, certain values, such as property value, appear to decline over time after the tree reaches a certain size (in this case, sixteen inches). Questioning the Davey Tree Expert Company about this revealed that the growth of the tree at this point has slowed to such an extent that the annual benefit decreases to reflect the enormous period of time that the tree spent in these DBH classes. This explanation seems feasible, but must be taken into account for valuation of trees with large DBH's; in some cases the value of a particularly large tree may be underestimated because of this method in the NTBC's construction. It is important to be aware of the mechanisms which underlie this system.

The table below displays the "property value" benefit category from the National Tree Benefit Calculator; the property value "declines" over time because of the DBH principle mentioned above.

Table 5.25 Declining Property Values Returned by the National Tree Benefit Calculator for a Growing Magnolia in Phoenix, Arizona

DBH	PROPERTY VALUE $
12	$28.19
13	$28.71
14	$29.23
15	$29.75
16	$25.90
17	$22.05
18	$18.02
19	$14.38

In fact, with some trees, the Davey Tree Benefit Calculator will actually stop returning new results after a certain DBH, indicating that a tree of that size is beyond the range of the data. In these situations, the tree will return the same amount of benefits for the rest of its relevant life. Because of the exponential nature of discounting, the benefits from these trees will decline quickly as time moves further into the future.

Is it beneficial to use certain treatments on my tree?

An urban tree may need certain treatments, such as disease control, thinning, pruning, or fertilization. Likewise, the tree's surroundings (sidewalks, windows, mailboxes) may also need to be altered to accommodate for the tree. A landowner may want to know whether it is more profitable to remove the tree, use one of these treatment alternatives, or retain the tree and risk damage. The benefit-cost ratio can be used for this calculation. Determination of the benefit-cost ratio involves calculating the NPV for all the positive cash flows associated with a decision and the NPV of all the negative cash-flows associated with that decision and comparing them as a ratio (B/C). If B/C > 1, then the investment is financially sound; if the B/C <1, then the investment is not financially sound.

For example, a landowner compares assisting the Detroit white oak on his site by sidewalk grinding (to alleviate root stress) for a cost of $100.00 in years fifty, sixty, seventy, and eighty with the benefits earned from the trees during that period of years. The comparison is done at an interest rate of five-percent.

Table 5.26a Costs of Grinding at a Five-Percent Interest Rate

YEAR	ITEM	AMOUNT	NPV (@ 5%)
50	Grind	($100.00)	($8.73)
60	Grind	($100.00)	($5.36)
70	Grind	($100.00)	($3.29)
80	Grind	($100.00)	($2.02)
TOTAL:			($19.40)

Table 5.26b Benefits from Grinding at a Five-Percent Interest Rate

YEAR	ITEM	AMOUNT	NPV (@ 5%)
51-60	Benefits (11 in.)	$115.00	$77.43
61-70	Benefits (12 in.)	$122.54	$50.65
71-80	Benefits (13 in.)	$134.08	$34.02
TOTAL			$162.10

The calculation of the B/C Ratio is found by dividing the benefits by the costs. Note that since this calculation is a ratio, the costs do not need to be expressed as a "negative" value. The B/C ratio is only an analysis to see whether or not the ratio is greater or smaller than one. In this case, the B/C ratio is defined by \$162.10/\$19.40 = 8.35 and it is concluded that it is beneficial to grind the sidewalks. The B/C ratio is often falsely used in the current literature for urban tree valuations; benefits and costs that have not been discounted are compared through the B/C ratio. As has been discussed, this may lead to improper investment decisions.

What is My Return on Investment from an Expense Regarding This Tree?

Internal rate of return (IRR) or return on investment (ROI) calculates the percent return a landowner gets from an initial expense. In other words, IRR looks at the future benefits of a decision as the "future value" and the initial expense as the "net present value" and over the number of years solves for an "interest rate."

There are many situations where IRR may be used, such as fertilization, pruning, or disease control measures. IRR is a common method for evaluating "when" to undertake investments; however, NPV is a more valid financial criterion because it considers all costs and benefits instead of a single selected situation. An IRR can be difficult to calculate in a complex situation, and may not account for certain cash flows, such as gifts, that incur no initial rate of investment. In many situations, when the NPV of an investment is compared with the IRR, the comparison is done through comparing the maximum NPV with the maximum IRR, and the maximum NPV will predict an earlier investment time to reflect greater returns on an interest rate. It is therefore considered the preferred financial criterion.

CHAPTER SIX

MATHEMATICAL PRINCIPLES OF BENEFIT VALUATION

Determination of the benefits of an urban tree requires the creation of a function that uses physical measurements to weigh economic valuations. Both physical measurements and economic valuations are highly variable. Physical measurements on urban trees include DBH, leaf area, root spread, rainfall interception, and carbon storage (Xiao and McPherson, 2003). Economic valuations are often either implied or contingent valuations indicating a willingness-to-pay or percent participation in alternative scenarios (Levert et al., 2009; Sinden and Worrell 1979). For example, McPherson (1999) valued the air quality benefits from Modesto's urban forests by simulating the implied value of air quality in Modesto and distributing this to the urban forest by DBH and leaf area.

The benefits conveyed by an urban tree and calculated by the National Tree Benefit Calculator are property value, storm water benefits, air quality benefits, carbon sequestration, natural gas savings, and electricity savings. Each of these benefits is a partial benefit; the sum of these partial benefits is the total benefit, which indicates the financial value of the tree prior to costs. This value can be viewed as the intangible "revenue" from the tree; it is the market value of the benefit times the amount of benefit conveyed. The components of this revenue (market value, amount conveyed) can be predicted by the variables of species, DBH, and location using equations that account for variation in other factors (condition and climate as examples on the physical side; cost-of-living and human preference as examples on the economic side). These equations are built into tree benefit calculators like UFORE or the National Tree Benefit calculator;

however, they can be calculated for individual situations, such as Nowak's (2002) compensatory valuation of the urban forests in the United States' largest cities.

The relationships between these partial benefits and DBH are not necessarily linear, nor are they independent. For example, the relationships between DBH and the benefits value for a white oak in Galveston, Texas individually produce graphs indicating nonlinear relationships between all partial benefits and DBH. The functional results for the upper ends of the data range (DBH greater than forty inches) for each partial benefit also demonstrate interesting patterns. The method of benefit calculation for very large trees forces the appearance of decreasing value. As was discussed in the previous section, Davey Tree Expert Company responded to a query on this issue by explaining that since large trees grow at a slower rate than smaller, comparable trees, the tree benefit calculation functions assume that a benefit calculated for a certain tree size is distributed over the total numbers of years that the tree remains in that age. Thus, annual benefit calculations for very large trees may undervalue the actual benefits the tree creates per year. Although diminishing marginal returns are feasible and even expected, a devaluation of tree with a purely benefit-based calculation is impossible because factors such as risk and cost that would normally decrease the value of a tree are not included. On the margin, most tree benefits always either remain the same or increase because they are calculated as a positive function of DBH. This blanket statement excludes changes to the tree's conditions that might cause devaluation; an oak in oak decline no longer undergoing leaf out is not going to convey the same benefits as a living oak of the same size. These problems, however, are situational, and should be therefore considered as a reduction on a situational basis.

The graphs on this page and the next show the values for the partial benefits for a white oak in Galveston, Texas. Notice how the upper end of the data shows a strange pattern of "drop off" due to the method of calculation. In the property value graph on the upper left, property value benefits has "straight-line" initial acceleration that soon tapers, creating a monotonically convex graph. Storm water reductions, on the other hand, continue a rapid initial acceleration until the maximum benefit is achieved, creating a monotonically concave graph. The carbon sequestration benefit appears to have two points of concavity, indicating both rapid acceleration and tapering benefit structure.

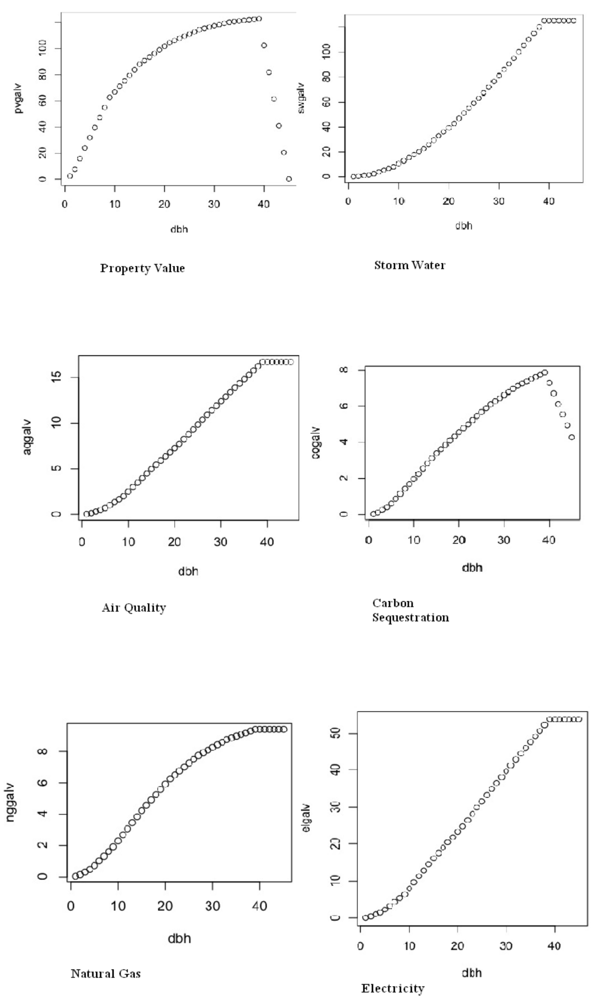


Figure 6.1 Graphs of partial benefits for a white oak tree in Galveston, Texas.

Inventories of municipalities reveal certain relationships between partial benefits and tree characteristics, but the relationships are not consistent between different municipalities and different species (McPherson et al. 1998; AFS 2001). Trees in different locations and trees of different species have different 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 (property value, storm water, air quality, carbon sequestration, natural gas, and electricity) does not follow a pattern across species and location. Additionally, many of these benefits are autocorrelated; a tree that has a high property value rating will probably also have a full crown creating significant energy savings. Two analyses of urban tree value data were conducted in order to draw out any existing patterns by controlling for species and location. Understanding these patterns allows us to see the implications of DCF when basic variables within the valuations are altered.

An effective way to look at variation between multiple components in data sets is principal component analysis (PCA). This technique uses a covariance matrix to determine the components of greatest variation. Further decomposition of the matrix into its eigenvectors and eigenvalues allows an orthogonalization of the data onto a component of greatest variation. The "principal component" is identified as an artificial component with the greatest eigenvalue from the original matrix. Reduced expressions onto that single parameter (or any number of reduced parameters) can be produced to simplify the data set without losing significant variation (unlike some reduced linear regression techniques). That is, the first eigenvalue represents the principal component of greatest magnitude; it holds the most variation from the original data. In other words, given the similarity matrix (the matrix of eigenvectors), the entire original set of data could be retrieved from the eigenvalues of PCA. Because the full equations for tree value exist within databases such as Davey's, providing reduced expressions here is not necessitated; the existing data can be retrieved without sorting through the PCA mathematics. However, a better understanding of the component variability between tree locations and species elucidates the relationship between value and physical characteristics. Additionally, determining if reduced expressions can be produced may lead to hypotheses that could be tested in further field inventories; can certain intangible values be expressed adequately by the components of the matrix?

In this section, principle component analysis is first used to explain the benefit components of a southern magnolia (*Magnolia grandiflora*) in Phoenix, Arizona. This text acknowledges that this example is limited, but understand the importance of describing the method of PCA used (covariance method rather than factor analysis) and assessing the implications of components' eigenvalues. Control for species was then conducted by looking at only white oaks in their seven possible growing regions in the United States and examining the principle components, overall functional form, partial benefit functions, and discounted cash flow analyses. Then, control for location was conducted by examining the patterns inherent in all trees growing in Atlanta, Georgia. Classifications of trees into benefit "classes" as obtained by the model reveals a particular valuation preference for trees in certain growth "classes" which are included in the appendices.

Single Tree Scenario: *Magnolia Grandiflora* in Phoenix, Arizona

The technique of principal component analysis was used to assess the annual benefits of the magnolia tree in Phoenix, Arizona. Although PCA is normally used for the analysis of very large datasets, this investigation of the Phoenix magnolia shows realistically how PCA creates combination "variables" from the linear equations that define a particular data set. It is a proper method here due to its very clear explanation. By explaining the matrices behind principal component analysis, the means by which patterns in data emerge is explained, and the ability of the principle components to conflate the influence of inputs is exemplified. The benefit of matrices in this situation is that they organize the data in a way that reflects the original complex system but without the length and frustration of linear notation. In PCA theory, rotation of the matrix of data points onto an orthogonal plane for the component that shows the most variance allows less variable components to be viewed in the context of this highly-variable orthogonal. As a method, this keeps the complexity of the original, multi-dimensional system intact but expresses the situation in a reduced-dimensional context. Use of PCA instead of factor analysis is employed here because it accounts for more variance between components and uses data structure that innately minimizes least squares. The full calculated benefits from the magnolia tree are available in Appendix G.

Expression of this data as a six-column matrix with twenty-seven rows allows each column to represent a dimension from which the magnolia conveys value. Summation of the mean-subtracted data in each dimension and computation of the pooled variances between each of the components creates the elements for a covariance matrix.

This step is absolutely necessary, as it centers the data in the appropriate range and prevents false parameter equality due to distant intercept variables. As an intermediary step, the covariance matrix was graphed. Value categories were labeled from one to six for the ease of the "R" system and graphed (property value as one, storm water as two, carbon dioxide as three, air quality as four, natural gas as five, and electricity as six). The graph shows the categories both across the x-axis and as floating indicators on the y-axis; the height of the number above the corresponding category indicates the magnitude of the covariance. Property value (1) had the highest variance and also had high covariance with other categories. In the category of electricity (6), which has a mean sum of squares of 0.65 for itself, the covariance with property value also has a large magnitude. Other categories, such as carbon dioxide (3) and natural gas (5) showed very little variance. The variance for these categories was small, and did not influence other categories significantly. Intuition of an interesting link between trees with high property values and trees that are conducive to electrical savings (both categories would favor trees with large leaf surface area or crown size) can be suggested here and so the mathematical analysis has a simple, real-world, application.

In Figure 6.2, the vertical distance between numbers indicates the magnitude of variance between them; their distance from the horizontal axis indicates their difference from zero.

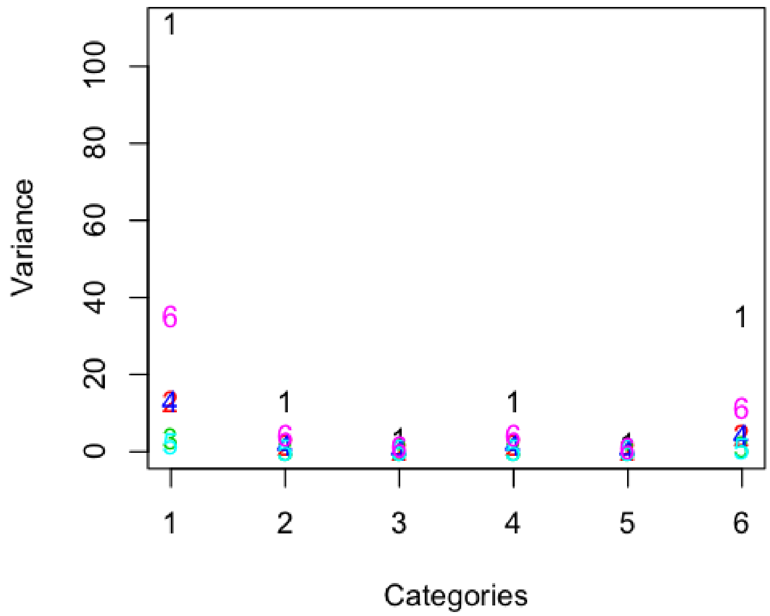


Figure 6.2 Covariance of the Phoenix magnolia.

The covariance matrix was then decomposed into its eigenvalues and eigenvectors to find the component with the greatest variance and the orthogonal translation of the data with respect to these components. In PCA, the component with the greatest eigenvalue is the component of greatest influence. As expected from above, property value was a great influencer, and because of this, much of the variation within the data could be explained by the first principal component (PC1). PC1 has a much greater magnitude than the subsequent components. It would therefore be possible to express the other variables well with relation to PC1. The purpose of this expression would be to determine a rotated equation for the description of the Phoenix magnolia's benefits with reduced autocorrelation between variables.

Table 6.1 Eigenvectors from PCA of Phoenix Magnolia

PV	SW	CO2	AQ	NG	EL
0.94176	-0.1765	0.3007	-0.18381	0.2138	0.03964
0.10894	0.4914	-0.54108	-0.34705	-0.1958	-0.54319
0.02643	-0.4357	0.39942	0.09808	-0.3113	-0.73719
0.11023	0.6602	0.47906	0.37698	0.3584	-0.22783
0.01156	-0.2585	-0.55743	0.64444	0.3931	-0.22893
0.2968	0.1886	-0.08106	0.52796	-0.7332	0.23582

Table 6.2 Eigenvalues for the Principal Components of the Phoenix Magnolia

PC1	PC2	PC3	PC4	PC5	PC6
1.249×10^{-2}	1.603×10^{-2}	9.122×10^{-3}	7.952×10^{-3}	3.149×10^{-3}	5.599×10^{-4}

This scenario affirms that PCA is an effective technique for looking at the partial benefits conveyed by urban trees. The partial benefits of urban trees are highly correlated, and this correlation can be reduced for better predictive and descriptive equation making with the PCA technique.

Location as Variable

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; trees grow faster in certain climates than in others. Second, consumers value different aspects of trees in different regions; 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 (Timmer, 2007). Third, regional markets differ; costs of labor or services vary because of market conditions and these affect benefit values (Jim and Chen, 2008). For example, Table 6.5 shows the values determined by the NTBC for a sixteen- inch magnolia tree in Phoenix, Arizona, Buffalo, New York, and Seattle, Washington.

Table 6.3 Values of Categorized Benefits in Three 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

This study used PCA to examine the components of value of a white oak tree in Atlanta, Detroit, Omaha, Seattle, Wichita, Helena, and Galveston. These cities represent the "South," "North," "Pacific Northwest," "Midwest," "Temperate Interior," and "Coastal Plain" regions of the country according to the Davey Tree Expert Company; certain areas of the United States, such as the Southwest and Coastal California, were not suitable for white oak growth and did not produce values. The correlation matrices for the white oaks' values in all locations indicate high levels of correlation (up to $R^2 > .94$) between the values; this suggests that multicollinearity between the partial benefits and could influence the total value. However, the interaction is not consistent between partial benefits in different locations because of the aforementioned regional differences. PCA is very useful in this situation because it enables us to reduce the multicollinearity while still maintaining the data complexity. The benefit of PCA is that the orthogonalization represents artificial components that are not tied to a specific variable.

Assessment of the principal components between these trees by DBH class was conducted to see how many eigenvalues were significant. As tree DBH increases, the amount of principal components retained in order to account for variability also increases. In other words, white oaks with larger DBH's have several principal components with similar and significant eigenvalues, whereas white oaks with smaller DBH's may have only one or two significant principal components. This suggests that smaller trees' abilities to convey benefits are more strongly influenced by a particular combination of factors while larger trees have more leeway in how they make benefits. It was found that as the DBH increases, the magnitude of the first principal component also increases. This suggests that the first principal component is accounting for greater variability in larger DBH classes, which logically fits the concept of increasing benefits with increasing size.

Table 6.4 Principal components of White Oaks

DBH	Eigenvalue of PC1	# of PC with order > 10^{-4}
7	9.623×10^{-2}	2
14	3.419×10^{-3}	3
21	3.790×10^{-3}	4
35	3.107×10^{-3}	4
42	4.948×10^{-3}	4

Although not determined from the PCA, it was also interesting to notice that in all DBH classes, the partial benefit with greatest variance was the property value benefit.

The abilities of the data to reduce towards a single eigenvalue in both the smaller DBH classes suggests more complex variation exists in larger trees than in smaller ones. In other words, the alignment of limited variability and extreme variance in the property value category suggests that the consumer demand for green properties has great impact on urban tree values, especially in deciding which trees to plant (Zhu and Zhang, 2008). Financial decisions made in favor of property value for urban trees will impact other benefits most significantly; urban tree investment decisions should mind property value first.

Total benefits for white oaks in various cities differed significantly; the nature of the total benefits equation (as a function of DBH) also differed. In Pittston, white oak reaches a maximum annual value of $429.81 at a DBH of forty-five inches. In Seattle, the maximum value for annual benefits from white oak is $344.77 at a DBH of thirty-four inches. White oaks in Galveston have a maximum value of $335.90 at a DBH of forty inches and in Omaha 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 a “drop off” after a peak in the data). Analysis of the partial benefits for oaks in each location was used to determine the reason for these varying total benefit equation shapes.

In Figure 6.3, the total benefit equations for the white oaks in four cities have been graphed. Figure 6.4 shows the differing shape of the “property value” benefit for three of these cities. As discussed above, property value is the most influential component of the total benefit, and it affects the magnitude of other benefits. A comparison of the situations for the white oak in Seattle and in Pittston (Figure 6.5) 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 6.5 compares the property value benefit equations with the storm water equations).

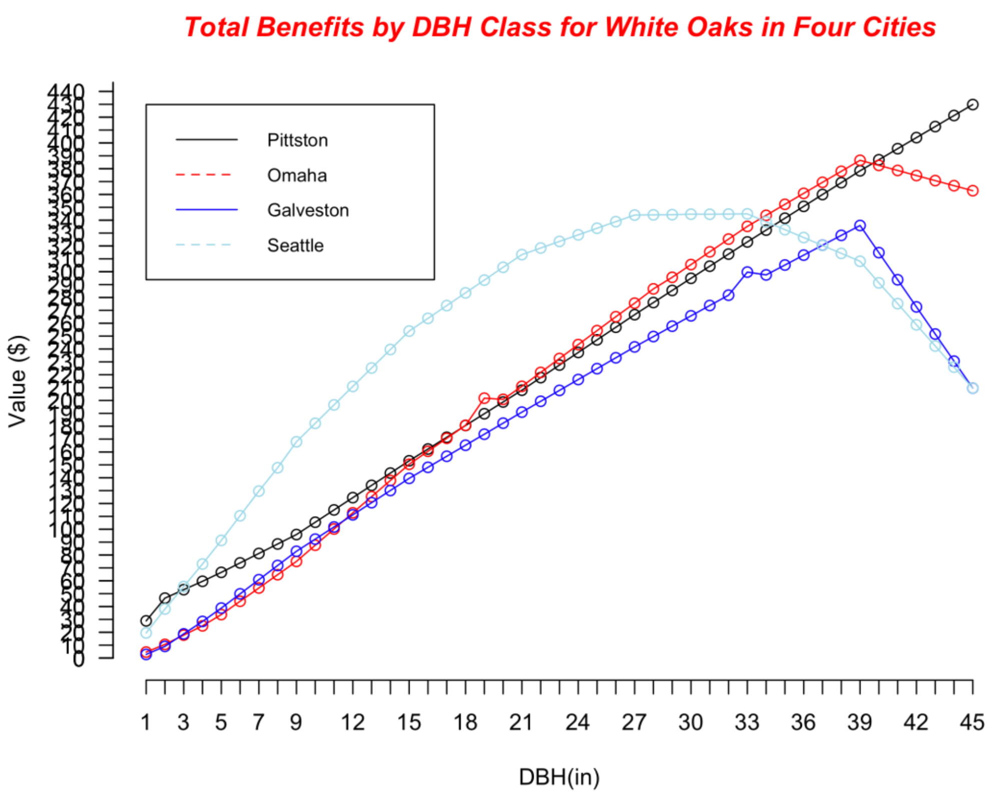
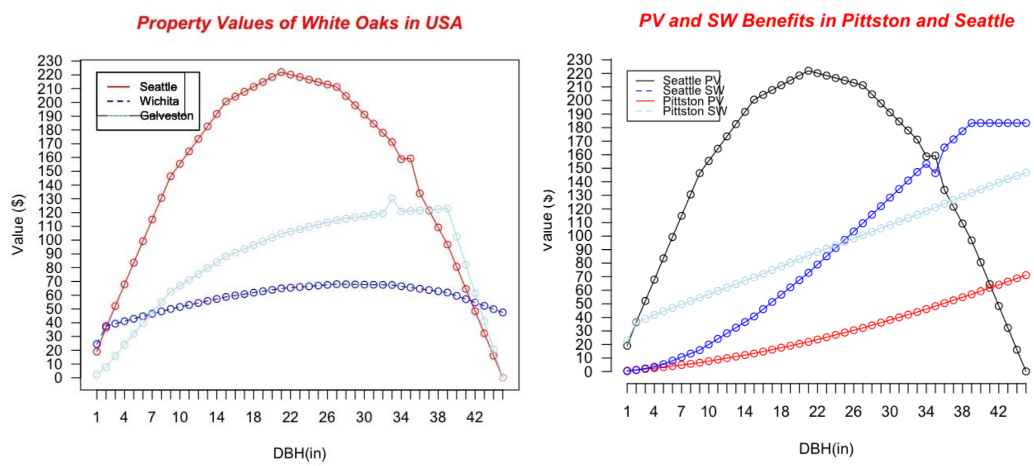


Figure 6.3 Total benefits by DBH class for white oaks in four cities



Figures 6.4 and 6.5. Property values for white oaks in four cities; a comparison of property values and storm water benefits in Seattle and Pittston.

In a discounted cash flow analysis situation, however, the benefits received during the earlier years have a greater impact on the total value due to the time value of money. Setting basic growth parameters on the data allows us to use the discounted cash flow analysis method to compare the NPV's of white oaks in Seattle and Pittston after many years of growth. Assume for this example that white oaks grow at a rate of one inch every four years for the first one-hundred years of its life (for the sake of calculation's simplicity, the data set assimilated here includes 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 discounted cash flow analysis calculations for annuities to determine the NPV of the two trees.

The set up of such calculation as a line-item assessment to be used in FORVAL would appear as follows. This itemized list represents the cash flows from the Pittston white oak. In this example (Table 6.5) the interest rate is five-percent.

Table 6.5 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			$1466.15

A white oak growing for 260 years and achieving forty-five inches of DBH growth in Pittston, PA, is worth $1466.15. The same set up (itemized list of cash flows) is used on a white oak in Seattle, WA. If the growth pattern and interest rate are the same, then the white oak in Seattle will be worth $1986.99 today. This result differs from the result without discounted cash flow 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; with the information from DCF it is apparent that the Seattle white oak actually is more profitable. The graph in Figure 6.6 shows the discounted cash flows for the white oaks in Seattle (black) and Pittston (blue). The integrals under the curves represent the NPV. The benefits from the white oak in Seattle are obviously greater, even though it's 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. This analysis could be extended to any comparison of trees using the same methodology.

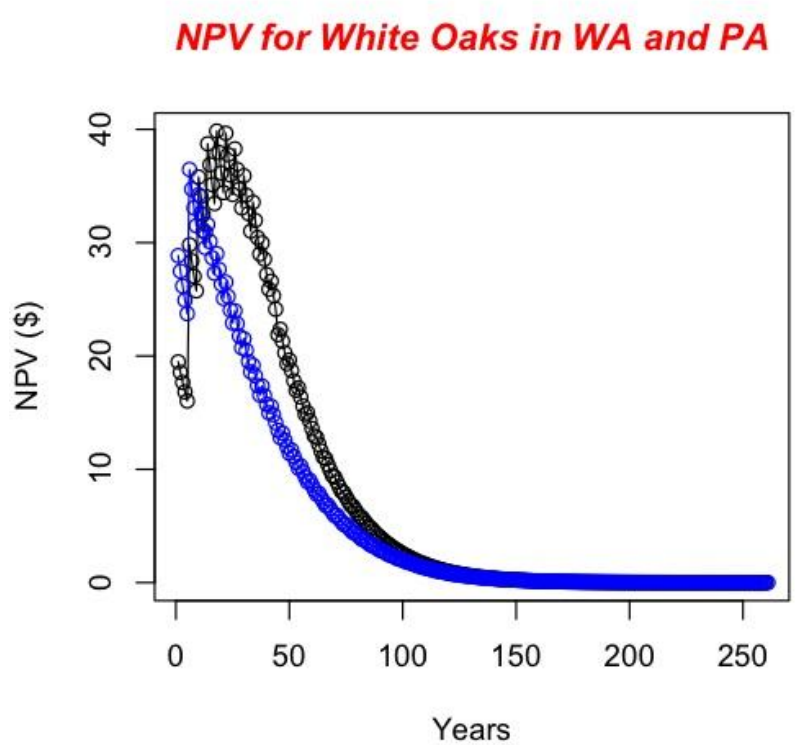


Figure 6.6 Discounted values for white oaks in Pittston and Seattle. The integral under the curve is the NPV

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 $601.40) than the Pittston white oak (NPV at ten-percent $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.

A final conclusion for the assessment of the discounted cash flows 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). Calculation of the exact point of marginal irrelevance could be done by fitting a non-linear curve to the NPV functions and setting the second derivative with respect to years equal to zero. This finds the points of minimum concavity; a logical assessment of the original function eliminates invalid solutions (local minimums or maximums versus a global minimum). Minimum concavity could be calculated for any interest rate. Knowing the point of marginal irrelevance allows us to reduce the volume of cash flows in a discounted cash flow analysis. For an investment period that extremely long, different strategies for discounting may be appropriate. These long run strategies for resource economics have been discussed by Gollier (2008) and include using reduced interest rates for forecasted investments in the far future. Using an estimate of the interest rate based on the US Census rate for the past 110 years suffices for the mathematics presented in this paper.

Species as Variable

Analysis of the benefits and partial benefits for all trees in Atlanta, Georgia, reveals that trees of particular genuses tend to follow the same benefit patterns. That is, there are twenty-three benefit models in the Atlanta section of the National Tree Benefit Calculator. With more than two hundred trees in the Atlanta inventory region, it is hypothesized that these classes are included in the model to make up for the lack of data for less common trees. Data on the National Tree Benefit Calculator is obtained for every tree in Atlanta at every size between one and forty-five inches to determine the existence of these "classes," which are found in Appendix H. 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. It appears 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 intangible valuation, how to value long-term benefits that will end up contributing to other generations; in this case, the choice to benefit future generations is preferable today.

A creation of histograms of eleven common tree genuses, including one "other" category was useful in viewing the results. These genuses were *Ilex*, *Prunus*, *Pinus*, *Quercus*, *Acer*, *Magnolia*, *Carya*, *Juglans*, *Fraxinus*, and *Cornus*. The results determined were that generally trees considered to be less valuable in timber production, nursery prices, or CTLA basic value, or trees with a reputation of being "small," had a lower value than trees considered to be valuable for timber or "large" (Nowak et al., 2002). The use of terminology "small" and "large" is informal here since these measurements are taken with respect to DBH; a five-inch cherry and a five-inch oak obviously have the same DBH, but will have significantly different forms. One result from the histograms, for example, was that many trees in the genus "*Prunus*" (cherries) have a lower initial value (less than $13.00 for a 5 inch tree) and follow a benefit growth curve that grows at a slower rate and with lesser magnitude than trees in the genus "*Pinus*" (pines) that have a medium initial value (benefits greater than $14.00 but less than $25.00 for a five-inch tree) and follow a benefit curve of a medium size. On the other end of the spectrum, the majority of trees in the genus "*Quercus*" (oaks) and "*Fraxinus*" (ashes) have fall into classes with greater initial value (benefits greater than $25.00 for a five-inch tree).and follow benefit curves that produce greater values that increase more rapidly over time.

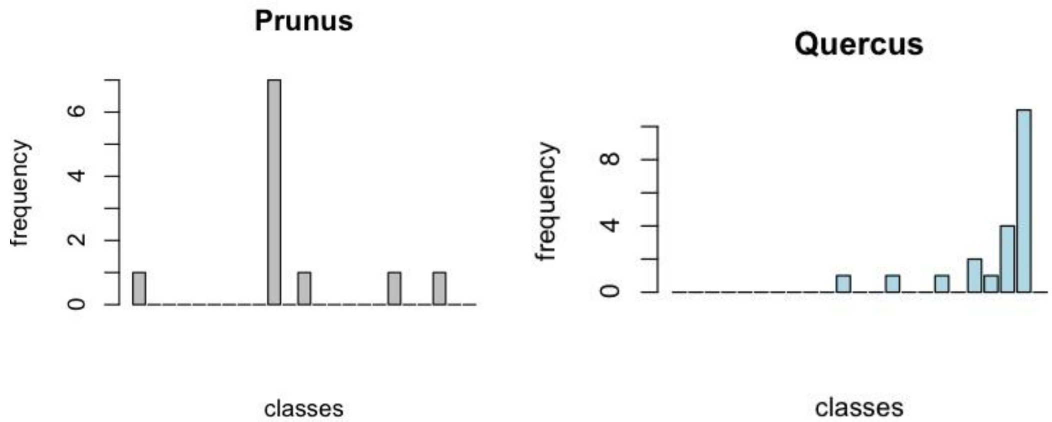


Figure 6.7 Histograms of the frequency of genuses Prunus and Quercus in five-inch benefit classes

The implication of this assessment is that certain tree genuses 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 genuses that are "preferred" accumulate additional benefit in the form of "property value." In figure 6.7, the benefit curves for oak (*Quercus*) and holly (*Ilex*) are contrasted (oak in black and holly in blue). Even though holly has an initially greater slope, relative to its scale, its benefits do not have the same magnitude as the benefits for oak. This initial increasing slope is due to the faster growth of the holly and its ability to create more physical benefits, such as carbon sequestration, which are tied 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 Ilex tree in Atlanta has too poor of magnitude early of a to possibly achieve equality with the *Quercus*, even after discounting. To maximize an urban tree investment, choosing trees with greater potential growth and longer life spans proves highly important.

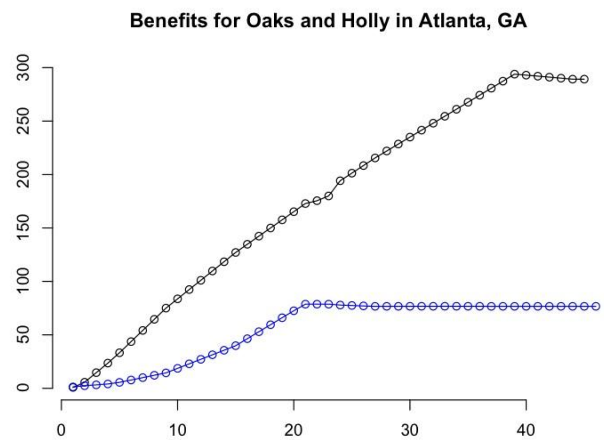


Figure 6.6 Benefit curves for genuses Quercus (oak) and Ilex (holly) in Atlanta, GA. Quercus is black and Ilex is blue.

An observation of partial benefits reveals more about this pattern. An interesting effect of the model used is that 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 (Table 6.6). For larger trees, the partial benefits from property value (as a percentage of total benefits) increase initially and then decrease 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 become more valuable relative to the site.

Table 6.6 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

Table 6.7 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

When observing percent value from partial benefits, it can be time-saving to determine the “class” the tree fits into on the benefit calculator to have the best idea of the trees overall financial capabilities.

CHAPTER SEVEN

USE OF THE DAVEY TREE BENEFIT CALCULATOR

Inventory Office Work

One can perform an inventory based on the stipulations clearly outlined on the Davey Tree Expert Company's website, which also includes a link to Davey's manual for the use of the i-Tree Streets inventory software (Davey, 2009). Although paper based inventories can be performed, Davey recommends computerized inventories using personal data assistants (PDA) with Windows-based operating systems years 2003 or later. Contacts to Davey regarding the release of a Macintosh or Linux based application inform us that this application is not and will not be available.

Figure 7.1 Davey Tree Expert Company Contact Form (available online)

From the Davey Tree Expert Company's manual (available at the website given above), a basic outline of the three main input categories for an inventory can be determined and a replication of their tables created. These tables are the "Define City Information Table," the "Define Costs Information Table" and the "Define Benefit Prices Table," and they can be found in Appendix I. For the sake of simplicity, this appendix puts the phrase "(input)" into the area where user-defined input would appear.

The information given in Define City Information Table is not related to cash flows but instead to setting a spatial background in which these cash flows occur. Therefore, this data can be used as a background for a discounted cash flow analysis view of urban tree valuation as well. This table contains demographic information about the urban area and provides description about the scope of the inventory project.

The Define Costs Information Table specifies city-wide costs associated with management; it allows i-Tree to determine the benefit-cost ratio. Note that this benefit-cost ratio does not reflect discounted costs and therefore is not the same as the benefit-cost ratio calculated with FORVAL. This table represents the input needed to the i-Tree application. Because the i-Tree application does not use DCF, input of annual costs reflect only the costs from the fiscal year in which the inventory is being collected.

The Define Benefit Prices Information Table specifies regional values for certain benefits to reflect a specific market. Benefit prices also may vary over time as market conditions change. With any financial analysis, it is important to continuously monitor market conditions over the assessed period and conduct frequent analyses reflecting any substantial changes in order to ensure that investment decisions are not made erroneously.

Inventory Field Work

Sampling intensity using the Davey Tree Expert Company's method is based on the population size of the urban area. It is suggested to conduct a six percent sample for populations under 50,000, a five percent sample for populations between 50,000 and 150,000, a four percent sample for populations 150,000 to 250,000 and a three percent sample for populations 250,000 and above (Davey, 2009). These inventories should be stratified by streets in order to minimize variance (since similar trees may be planted along a corridor).

Required information for the Davey Tree Expert Company inventory can also be collected through the same software mentioned above; the following lists the information that must be collected:

1. Species
2. DBH (values or ranges by one-inch class)
3. Tree ID (a sorting number, can be generated by i-Tree)
4. Segment (identifies the strata for a stratified sample)

Additionally, other information (management zone, municipal management, pest damage, condition, maintenance, land use, site type) may also be collected on the i-Tree software to further specify the results. The newest version of i-Tree includes a specific application called "beta" that collects information about the signs and symptoms from pests and performs basic diagnostics. Worksheets are available on the software for organizing the DBH values into ranges, defining management zones, defining conditions, describing maintenance, describing land use, defining site type, and reporting conflicts. Because these categories are not essential to the function of the inventory, they are not included here, but can be found on the i-Tree section of the Davey website and should be used to increase the specificity of the inventory if desired (Davey, 2009). Additional technical user information can also be found at the above website as well.

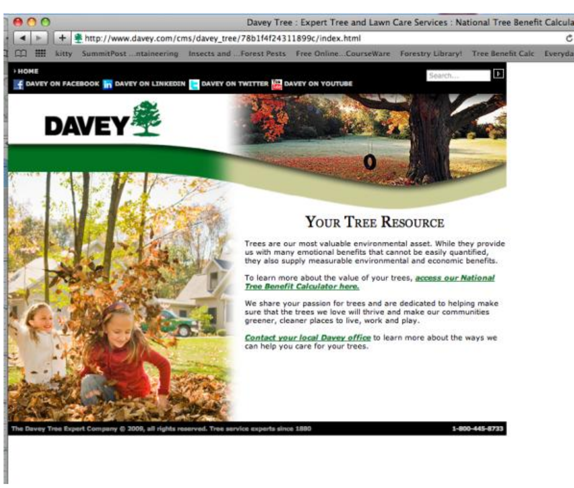
Use of the Tree Benefit Calculator

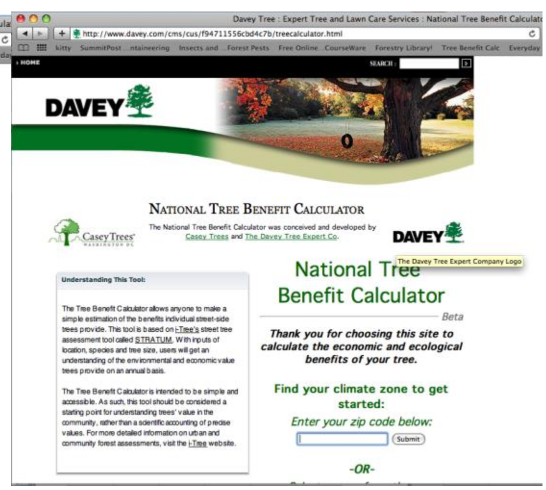
The National Tree Benefit Calculator determines the value of an individual tree. Statistical techniques can be used to magnify individual tree calculations to a larger scale if necessary. The following screen shots detail the procedure for conducting an individual tree calculation on the National Tree Benefit Calculator.

The tree benefit calculator can be accessed from the main Davey Tree Expert Company webpage.

Figure 7.2 The main webpage of the Davey Tree Expert Company

From the webpage depicted in figure, click on the green subtitle "What are my trees worth?" (located beneath the tan banner) to access the following:





Figures 7.3 and 7.4 Your Tree Resource on left, Tree Benefit Calculator on right

The Your Tree Resource page will appear first, and the first linked statement "access our National Tree Benefit Calculator" will direct the user to the National Tree Benefit Calculator. To return to the main Davey Tree webpage, one can simply click on the Davey Tree Expert Company Logo in the upper right hand corner of the screen.

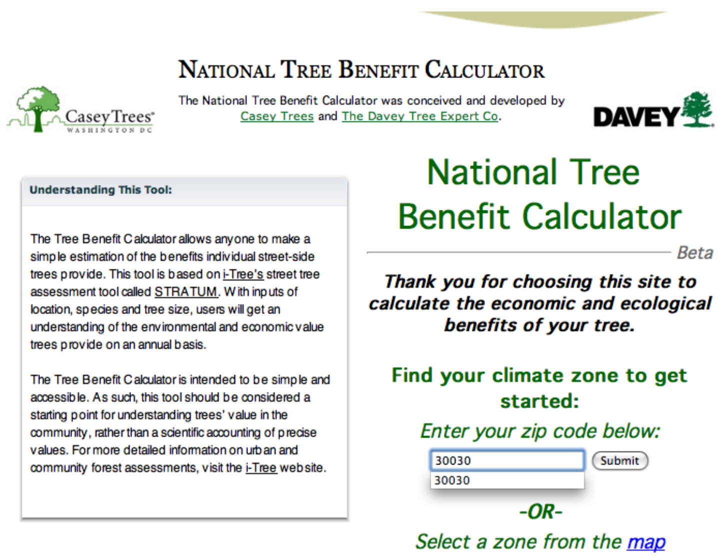


Figure 7.5 Using the National Tree Benefit Calculator, zip code input

On the left side of the tree benefit calculator, a flash window details the background of the tree benefit calculator application. On the right side, a prompt to enter a zip code or select a map zone exists. Here, is entered the zip code "30030," which corresponds with Decatur, Georgia. Note that the Tree Benefit Calculator works with MAC OS X Keychain and will save frequently used zip codes. Other internet browsers and operating systems will provide comparable assistance.

Clicking on the "map" option will reveal the image in Figure 7.6. The United States is sorted into sixteen climactic regions, identified by color. These colors somewhat correspond with the stereotypical hydrology of these regions, although no formal link should be made between color and annual precipitation. The selection of Decatur, Georgia, for example, would put us in the teal-colored region ranging from Texas to Maryland, which the legend dictates as "south."

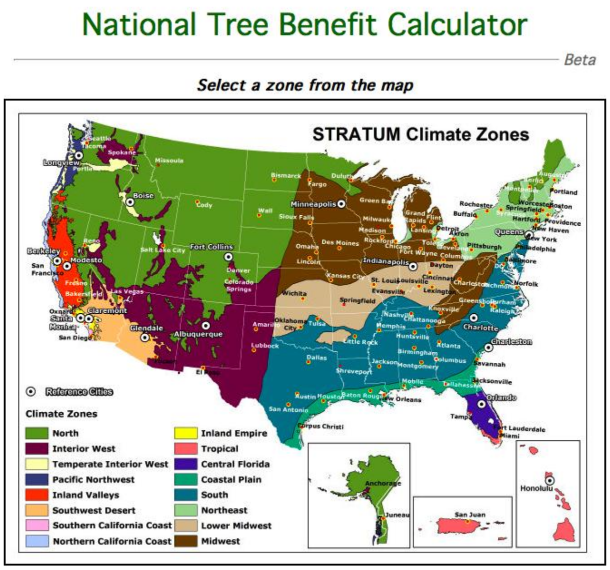


Figure 7.6 Using the National Tree Benefit Calculator- Map Option

No matter the input method, submitting the location of the tree produces the following window. In figure 7.7 we show the submission of a specific zip code, which produces a city name as well as a climactic zone.

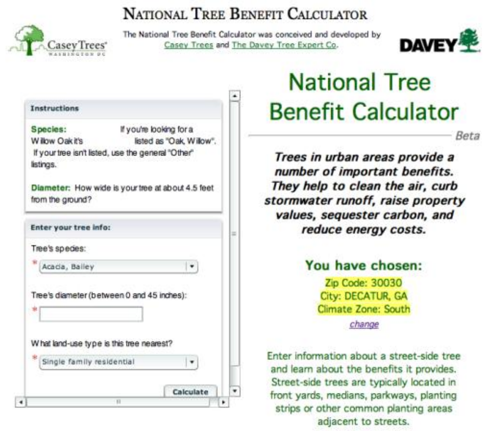
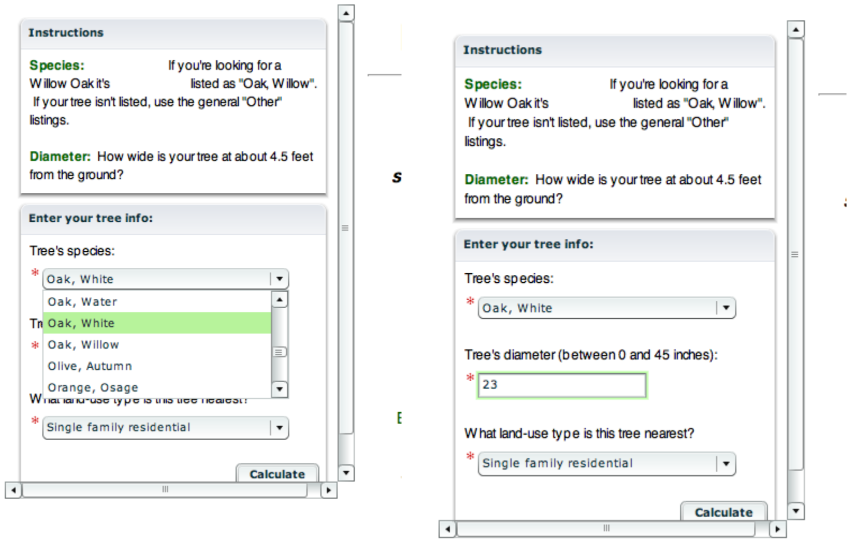


Figure 7.7 Using the National Tree Benefit Calculator- Tree Selection Window

Note the highlighted text on the java side (right) in Figure 7.7. This reminds us of the location. This information can be changed by simply choosing the "back" option on the web browser to submit another location. On the flash side (left) in Figure 7.8, three queries appear: species, diameter, and land use.

To select a species, click on the drop down window for "Tree's species." Note that many major trees are organized by genus as opposed to species. Thus, white oak is found under "oak, white." Selection of a different climatic will generate a list of species found in that region. Thus, while some species (such as white oak) may be found in many regions, other species (such as blue spruce) may be found only in locations conducive to its growth.



Figures 7.8 Selection of species and DBH

After a species has been selected, select the tree's diameter by inputting the diameter of the specific tree from your inventory, in inches. The input "23" is shown here. Note that although the tree diameter input asks for a value "between 0 and 45 inches," an input of zero inches will return an error message of "please enter a non-zero number between 0 and 45 inches."

If desired, the "land use" component of the window can be changed by selecting various types of residential, commercial or recreational use. These selections are found on the third text box on the flash side of the Tree Benefit Calculator. For this particular analysis, the "single-family residential" option was selected.

After the Tree Benefit Calculator has determined the benefits of the tree, it will return the following screen shown in Figure 7.9. This is a framed Flash application with seven different tabs available. Switching tabs will not result in the loss of input information.

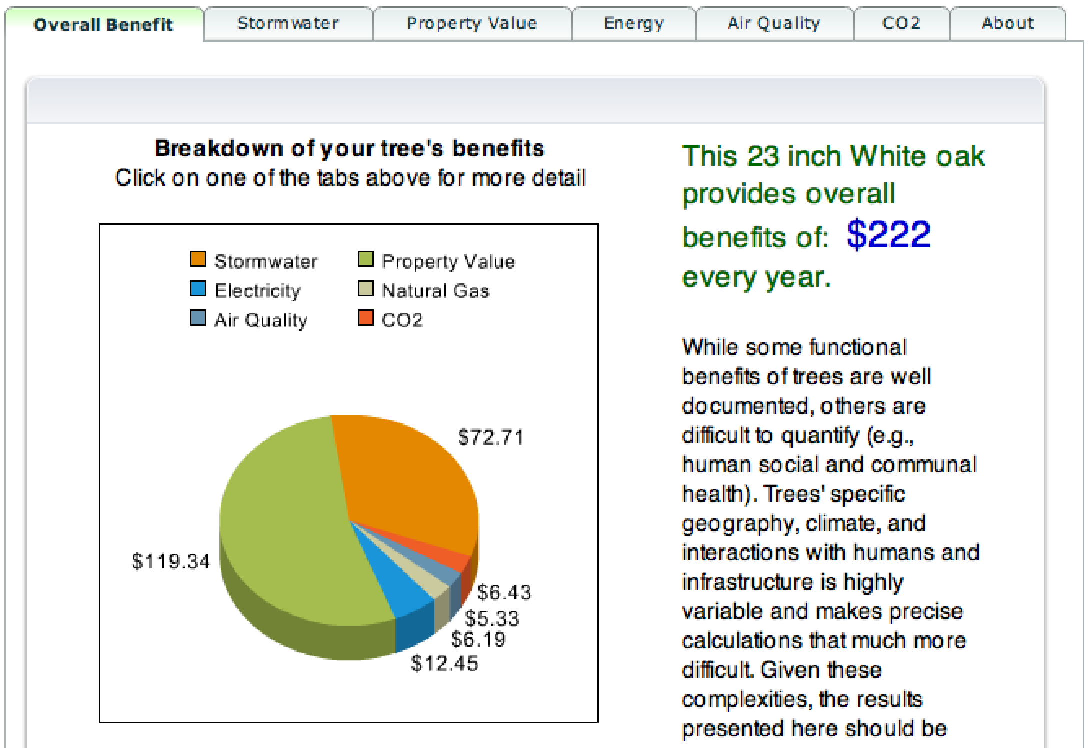


Figure 7.9 Tree Benefit Calculator output

The pie chart on the left side of the window describes the benefits created per year by the submitted tree in the submitted region. The sum of all of these partial benefits equals the total benefit written in blue on the right, in this case $222.00 dollars. Colored pie "slices" assist in visualizing the partial contributions of each benefit to the total value. Note that on some trees it may be difficult to view the value associated with each slice; if one value contributes significantly to the overall benefits, the other slices appear proportionately small. It is suggested that the user "mouse over" the slices to reveal the corresponding values in these situations, or explore these benefits further with the tabs at the top of the window. The tab for "energy" in this example is shown in Figure 7.10.

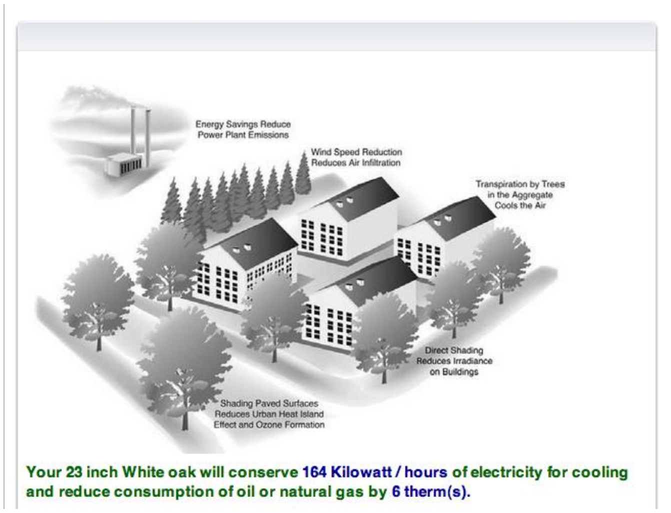


Figure 7.10 Electricity and natural gas tab

Notice that this tab displays the kilowatt-hours and therms saved by the specific tree (23 inch white oak in Decatur, Georgia) and provides a helpful diagram of how trees, in general, reduce energy costs. The same type of user-friendly detail is found in the other tabs, as well.

<u>Collection of the data from the National Tree Benefit Calculator</u>

Spreadsheets, such as those on Microsoft Excel, are the easiest way to collect and organize data from the National Tree Benefit Calculator. A column of "DBH" should be created in the spreadsheet. This can be facilitated by typing the nominative "DBH" in cell A1, the numeric “1” in cell A2, and copying the command “=A2+1” into cells A3 and beyond (depending on the DBH range of your tree). Subsequent columns can be used to record the partial benefits from the calculated categories by Davey, and a “total” column can be used with a row summation (“=sumB2:G2” – notice that the first column, A, is the DBH, and should not be included in the summation- copy this notation for all DBH values, i.e. in row 3, input “=sumB3:G3” and in row 4, type “=sumB4:G4”). If partial benefits are not desired, simply copy the total benefits (as written in blue) into a column proximal to the DBH column. Other data recording methods, such as using a text file or comma separated value file, may also be used, but Microsoft Excel is very user-friendly and provides outlined cells to improve visual structure.

It is important to note that “data-mining” (automated) processes are very difficult to run on the National Tree Benefit Calculator. Although no explicit barriers against automated data collection exist in the file sources, inputs in both Flash and Java windows, combined with the retrieval of text from a chart, increase the difficulty of creating and encoding an automated process. Attempts by the authors to use python scripts through the MAC OS X terminal were futile; however, this does not mean that automated data collection is impossible, but merely that it was found it much easier to collect the data by hand. A plethora of open source information is available online for perusal and can be found through basic search engine queries.

CHAPTER EIGHT

A GUIDE TO FORVAL

FORVAL is a forestry valuation software that follows the trend of 1987's FOR-TRAN software but with two major improvements: 1) it is free and 2) it is easy-to-use. FORVAL was originally created as a teaching tool. It can be either accessed online or downloaded from the location given in the references (Bullard et al., 2001)

We will briefly discuss FORVAL's use here. FORVAL-online's home screen appears as such:

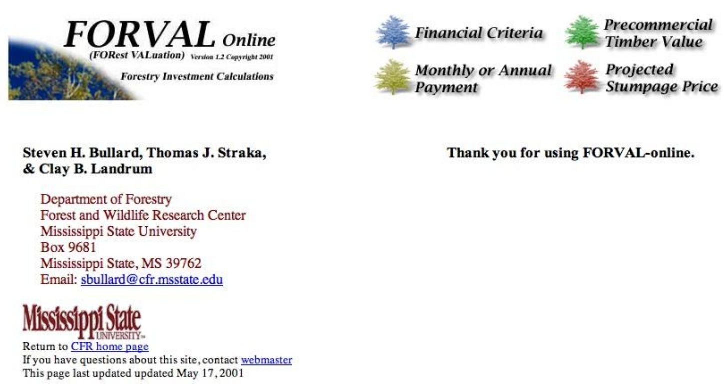


Figure 8.1 FORVAL-online homepage

At the upper right corner of the screen, four choices exist:

1. Financial Criteria
2. Monthly or Annual Payment
3. Precommercial Timber Value
4. Projected Stumpage Price.

We will only be using items 1 (financial criteria) and 2 (monthly or annual payment). Because of the use of many tabs, it is recommended that the user keep a scrap paper beside you while doing calculations in order to write down any information you may need to transfer.

Clicking on "Financial Criteria" (the blue tree), displays the following screen:

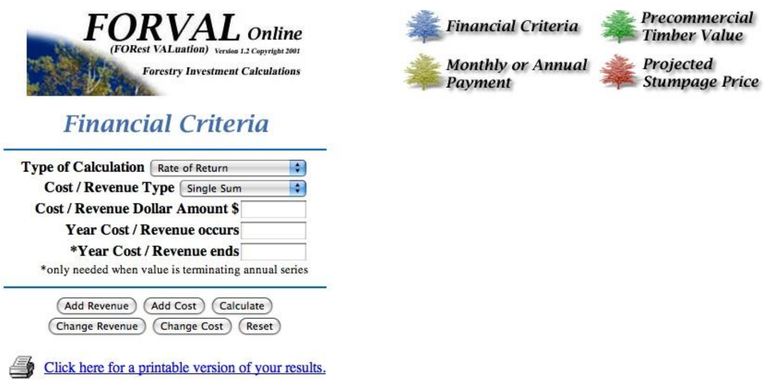


Figure 8.2 FORVAL Financial Criteria Screen

Notice how the four options still appear in the upper right hand corner. On the left side of the screen is the FORVAL Financial Criteria. There are two drop-down menus, three entry blocks, six calculators, and a link to a printable screenshot. Let us examine the Types of Calculation FORVAL can do:

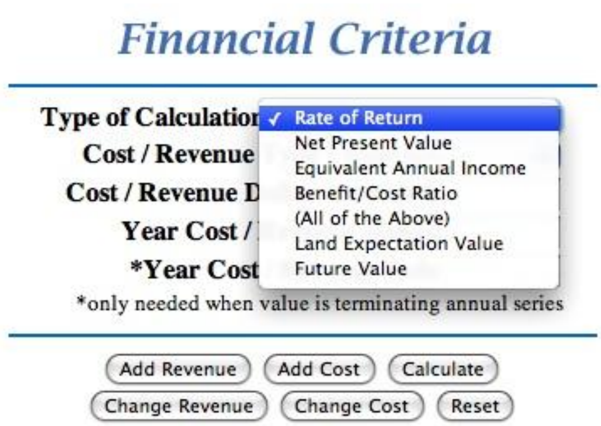


Figure 8.3 Types of Calculations FORVAL can do

FORVAL has seven options for calculation.

1. Rate of Return- Calculates the percent rate of return on an initial investment. This can be used for giving the "go or no go" on a particular forestry investment, but is not necessary for urban forestry models.
2. Net Present Value (NPV)- Discounts a cash flow from a given time (or an annuity) to year zero.
3. Equal Annual Income (EAI)- Calculates the NPV as an annuity. EAI is used to determine whether or not an investment is financially preferable in comparison to another investment that earns annual returns.
4. Benefit/Cost ratio—Determines the ratio of benefits (positive cash flows) to costs (negative cash flows). The valuations are designed for benefits; however, investment decisions should be made in the context of costs as well.
5. All of the Above
6. Land Expectation Value (LEV)—Calculates the net present value as a perpetuity. That is, the LEV assumes that the NPV will be repeated forever on a periodic basis of a "rotation" of X years in length at a given interest rate. Use this tab to calculate the UTSV. It is important to remember NOT to include the cost of purchasing or selling the site when calculating the LEV or UTSV.
7. Future Value—Compounds an cash flow to a future time. Essentially, this is the opposite of NPV.

For benefit-based valuation of urban trees, we primarily used the criterions 2, 5, 6, and 7 (NPV, All of the Above, and LEV).

Net Present Value

To calculate a net present value using FORVAL, select the net present value option under the "Type of Calculation" menu.

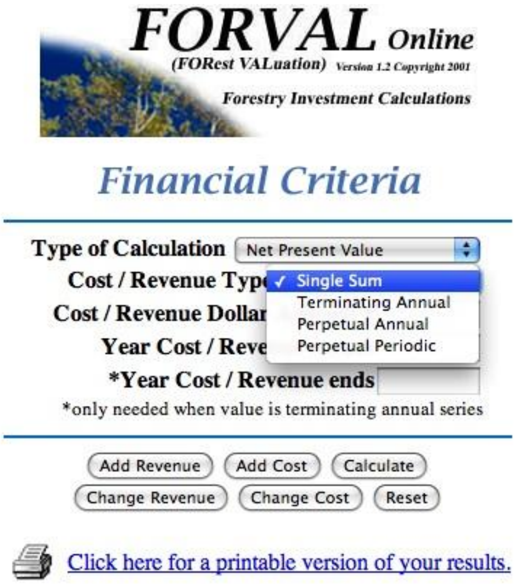


Figure 8.4 FORVAL Net Present Value Operation

With NPV selected, choose the type of revenue or cost to be calculated. There are four choices: single sum, terminating annual, perpetual annual, or perpetual periodic. This choice should be made based upon the predicates given in the models. An explanation of each choice is given below:

1. Single sum: Calculates the value in year zero of a one-time cost or revenue.
2. Terminating annual: Calculates the value in year zero of a regular payment occurring on an annual basis. The "end of the year assumption" holds true for these annual payments, meaning that the first payment occurs at the end of year one and the final payment occurs at the end of the terminal year. If an initial

payment need be calculated, it can be calculated as a single sum occurring at year zero with the single sum option.

An example clarifies this: the annual benefit of $2.00 stormwater damage reduction between years twenty and sixty-five could be calculated as a terminating annuity on FORVAL as follows:

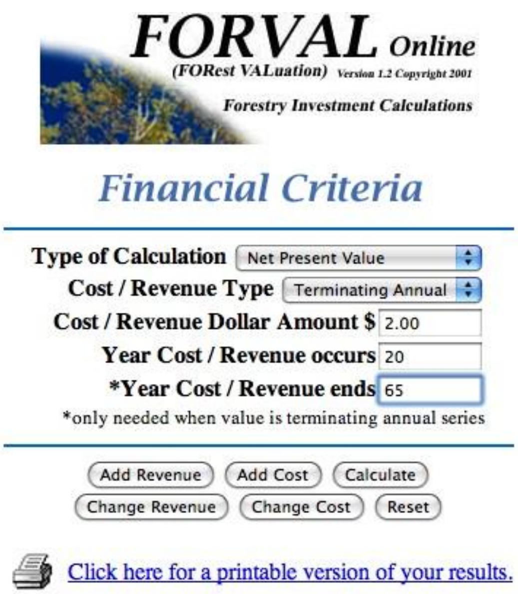


Figure 8.5 Example of data entry for terminating annual payment on FORVAL

3. Perpetual Annual: Calculates the value in year zero of a cashflow occurring on an annual basis that will occur "forever."
4. Perpetual Periodic Series: Calculates the value at year zero of a series of cash flows that occurs "forever" at regular intervals.

An Example: Calculating the NPV of Crape-Myrtle with Limited Benefits and Costs

If one were considering planting crape-myrtle (*Lagerstroemia indicata*) and wanted to know the value of that tree over its forty-five year lifespan, assuming the discount rate is five percent, use FORVAL's NPV criterion to calculate the value.

Let us assume the following cash flows apply at a discount rate of 5%:

Table 8.1 FORVAL Entries for Crape-Myrtle Example at a Five-Percent Interest Rate

ITEM	AMOUNT	YEAR	NPV (@ 5%)
Plant	($100.00)	0	($100.00)
Electric	$10.00	12-45	$94.67
Aesthetic	$70.00	30	$16.19
Stormwater	$2.00	1-45	$35.54
Pruning	($10.00)	15,30	($7.13)
Removal	($50.00)	45	($5.57)

The FORVAL calculations would look like this on FORVAL's output.

Your Net Present Value = $33.73
Interest Rate = 5.00%

Revenue #1:
Type = Terminating Annual
Amount = $10
Year = 12
Ends in Year = 45

Revenue #2:
Type = Single Sum
Amount = $70
Year = 30

Revenue #3:
Type = Terminating Annual
Amount = $2
Year = 1
Ends in Year = 45

Cost #1:
Type = Single Sum
Amount = $100
Year = 0

Cost #2:
Type = Single Sum
Amount = $10
Year = 15

Cost #3:
Type = Single Sum
Amount = $10
Year = 30

Cost #4:
Type = Single Sum
Amount = $50
Year = 45

Figure 8.6 Costs on FORVAL of crape-myrtle example

After entering these costs and revenues, click on the “calculate” button and FORVAL prompts entry of the “interest” rate. This is the “discount rate.” The interest rate should be entered in the form of a percent, and not as a decimal. Thus a five-percent discount rate is entered as “5” not as “.05.” This is crucial, else FORVAL will compute the data at a very low interest rate! The interest rate screen is as follows:

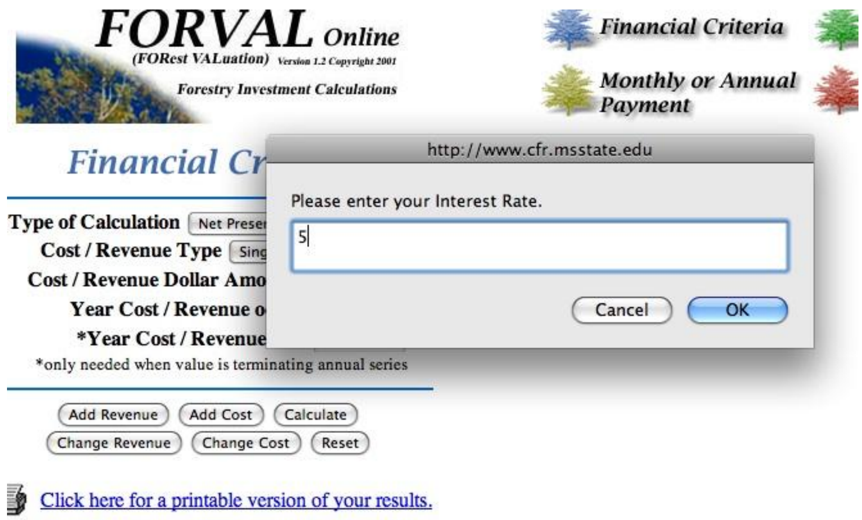


Figure 8.7 FORVAL interest rate prompt

The solution to the NPV query, in this case, was $41.12. This result is displayed directly below the four colored trees on the right-hand side of the page:

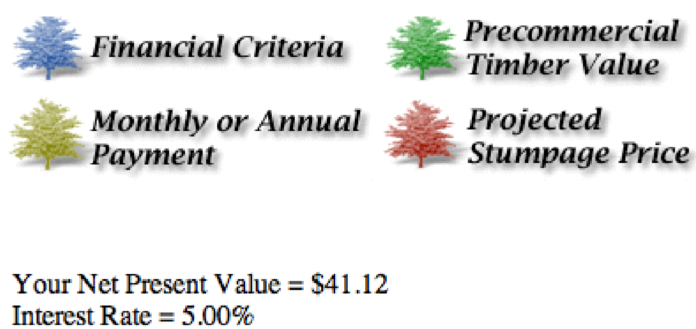


Figure 8.8 Solution for the Crape-Myrtle Example (NPV)

Because the NPV is positive, it is financially feasible and advisable to invest in the crape-myrtle at an interest rate of five-percent. With any investment, however, frequent recalculations of NPV should be done throughout the life of the tree due to fluctuations in the discount rate, service market rates, or tree health.

To know the value of the site on which the tree is growing (UTSV), do not change your cash flows, but select the LEV criteria from the drop down menu and click calculate.

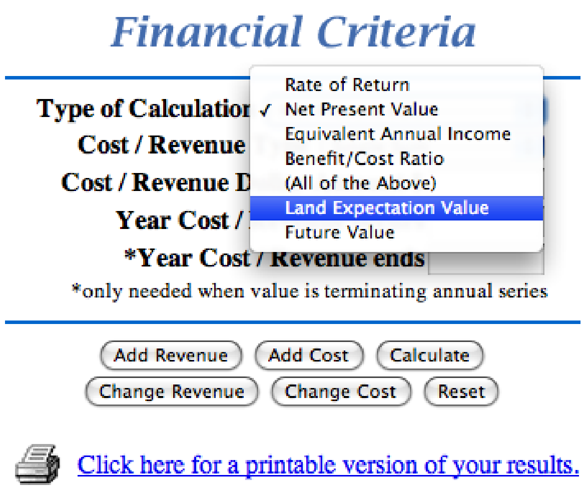


Figure 8.9 Choosing Land Expectation Value

Again insert the interest rate when prompted. The next pop-up screen will ask for a rotation age. In the calculations, this is the profitable life of the tree on the site.

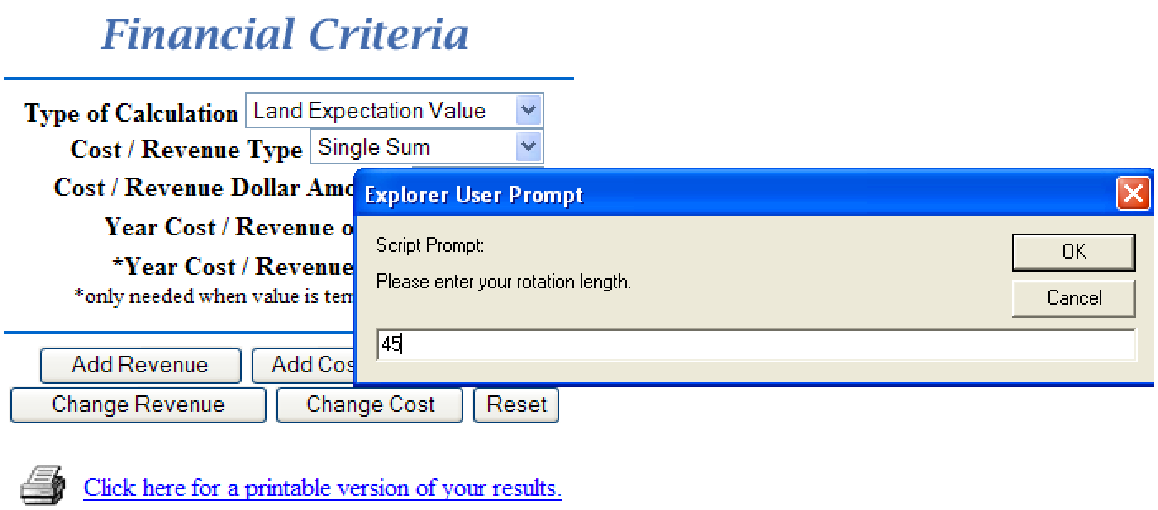


Figure 8.10 Prompt for Rotation Age (Windows Application)

CHAPTER NINE

ADDITIONAL RESEARCH PERSPECTIVES

Valuation through discounted cash flow analysis is a valid alternative for urban forestry. Unfortunately, there is a severe lack of research towards the financial propensities of urban trees as discountable investments. While this document served to highlight the absence of discounted cash flow analysis from the urban forestry scene, it by no means accomplished the full goals of really creating a well-rounded view of how urban forest investments would respond to DCF as opposed to other viable methods of time-accumulated assessment such as real options analysis or a formula approach that used discounting in combination with other standard procedures.

Specifically, it appears that more study needs to be done on the financial aspects of urban forestry investment. Determining how urban forestry businesses are currently performing valuations, looking at arborists' willingness to learn discounted cash flow analysis, and seeing the effect that a long-term, interest based approach will take on city and municipal policy remains to be studied.

Additionally, the development of sound computerized models needs to be sustained. Several models exist for finding urban trees or mapping urban landscapes, others exist for valuing trees without discounts, and still a third set of models exists for discounted valuation, but a synergistic model to do all three would be especially promising.

Finally, a further look into the probability distributions of long-term interest rates and risks particularly associated with urban trees (pests, storms, development) need to also be assessed so that a risk management component of this data may be analyzed. Long term theoretical models could be developed to look at the general nature of urban forest investments over time; constant study using these models in comparison with field inventories would prove their use.

Overall, DCF should be viewed as a supplementary appraisal method for valuation of urban trees that should be used in conjunction with other popular methods. Increased time and study will show whether or not DCF could be considered the premier method of urban tree analysis, and, if so, the method of DCF analysis proposed herein is a simple, accurate, and economic method designed for arboricultural and urban forestry usage.

APPENDICES

Appendix A

Financial Terminology Used in This Document

Discount Rate: The alternative rate of return, possibly from other investments, that provides the criteria for financial decision-making. Can also be called the interest rate, internal rate of return, or return on investment.

Discounted Cash Flow Analysis: A method of valuation that involves looking at an investment as a series of cash flows occurring over time with respect to an interest rate.

Forest: A group of trees. An urban forest is considered to be smaller than a standard group of trees in a timber situation.

Net Present Value: The value of an asset at year zero. Also known as NPV.

Opportunity Cost: The value of a choice not made or a missed opportunity. In valuation, expressed as a pecuniary value.

Urban: An area not being used for agricultural, timber, or wildlife benefits. This area may be commercial, residential, municipal or some portion of all of these. In an urban area the land is considered to have value, but not to create it.

Appendix B

The Tree That Owns Itself, Athens, Georgia

Figure B-1: “The Tree That Owns Itself” grows in the middle of the intersection of North Finley Street and Spring Street in Athens, Georgia. A protective chain and honorary placard denote the tree as its own property.

Appendix C

Cash Flow Diagrams to Accompany the Twelve Models

In all of the following diagrams the x-axis represents time in years and the y-axis represents money (cash flows) in dollars.

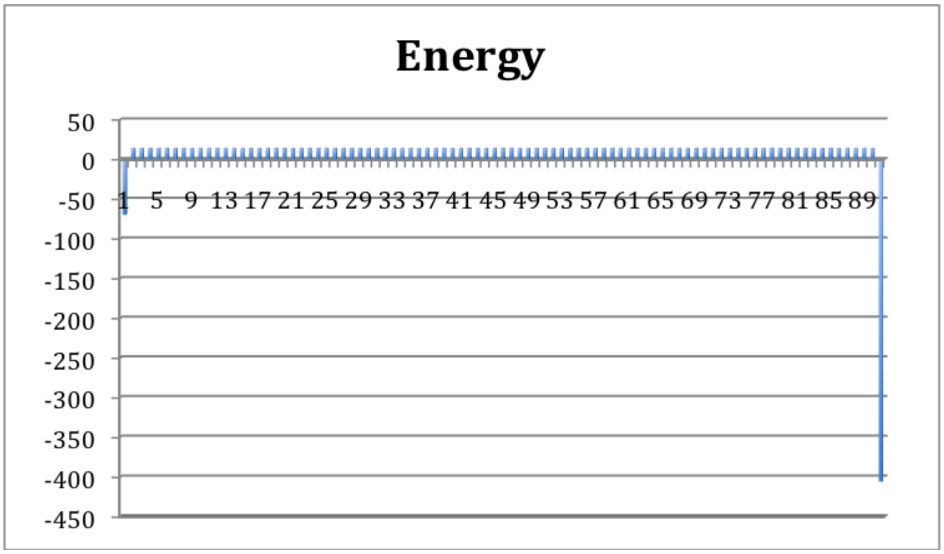


Figure C-1. Energy Savings Model

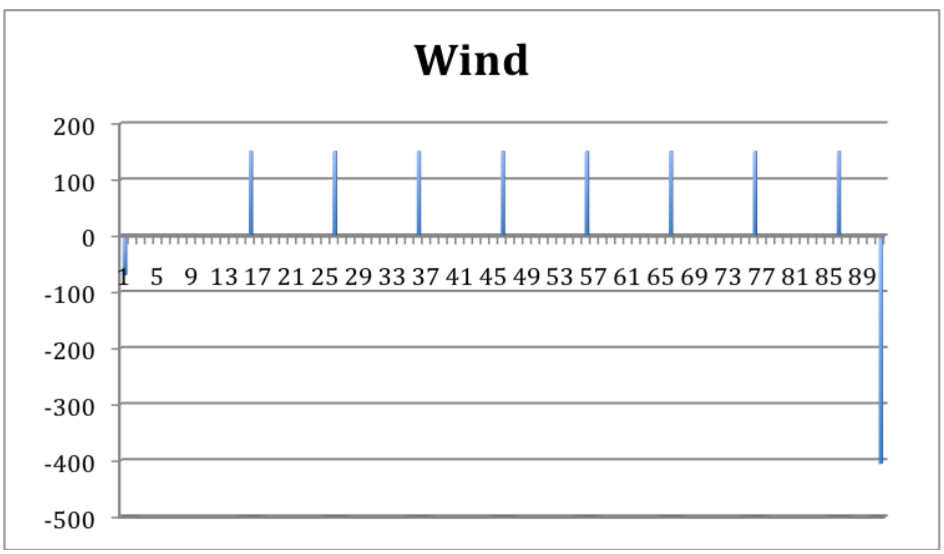


Figure C-2: Wind Model

Appendix C continued

Cash Flow Diagrams to Accompany the Twelve Models

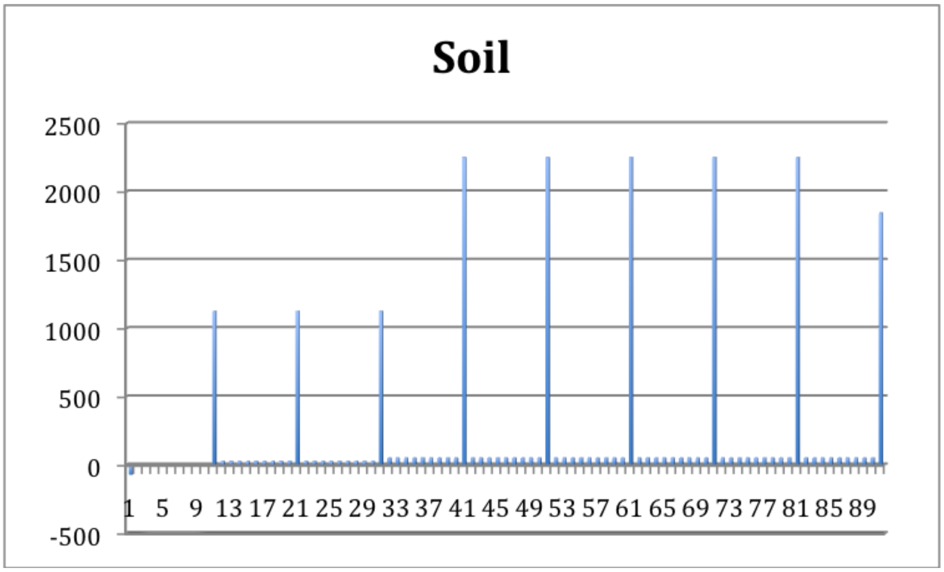


Figure C-3: Soil Enhancement Model

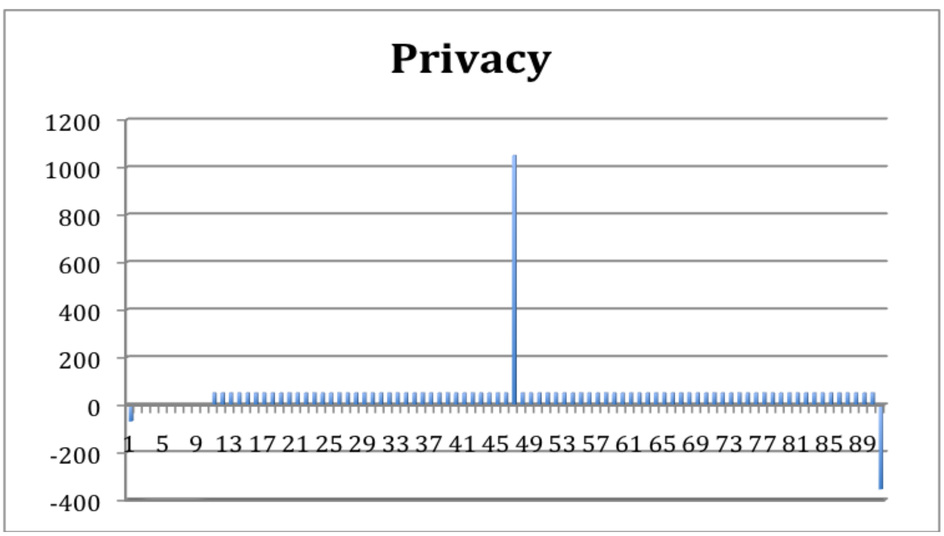


Figure C-4: Privacy Benefit Model

Appendix C continued

Cash Flow Diagrams to Accompany the Twelve Models

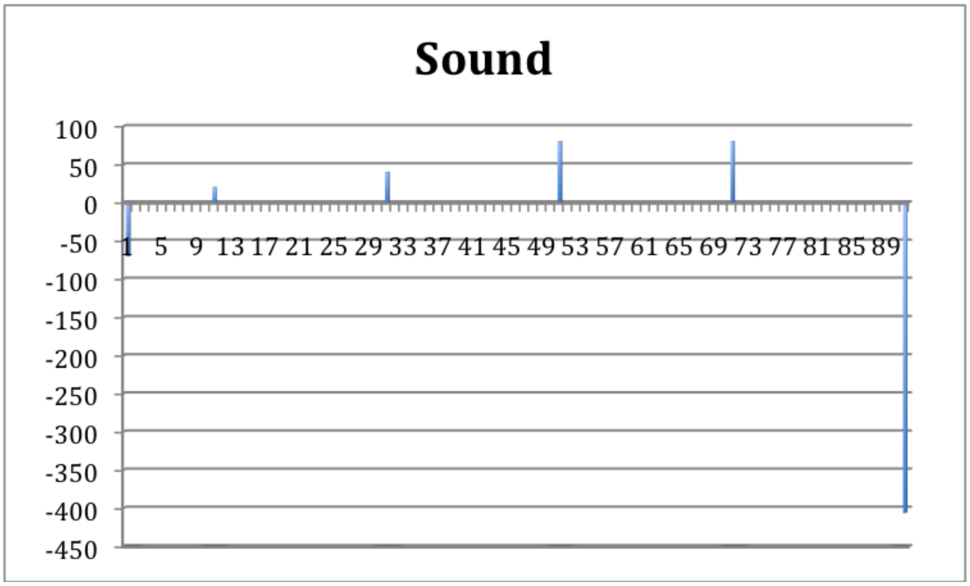


Figure C-5: Sound Barrier Model

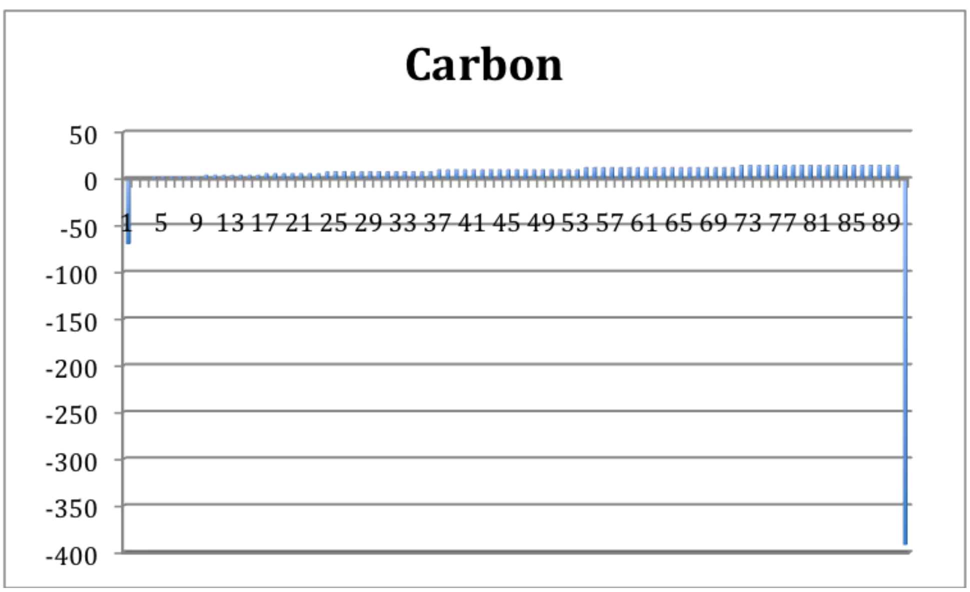


Figure C-6: Carbon Sequestration Model

Appendix C

Cash Flow Diagrams to Accompany the Twelve Models

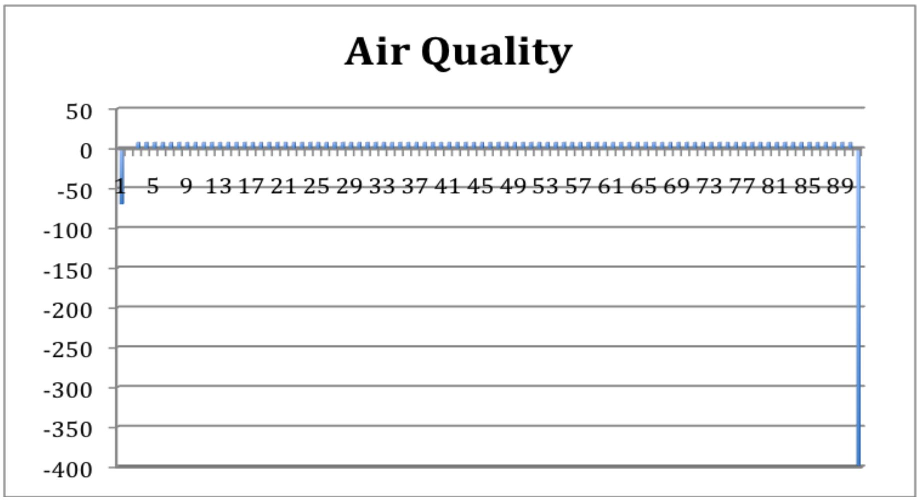


Figure C-7: Air Quality Model

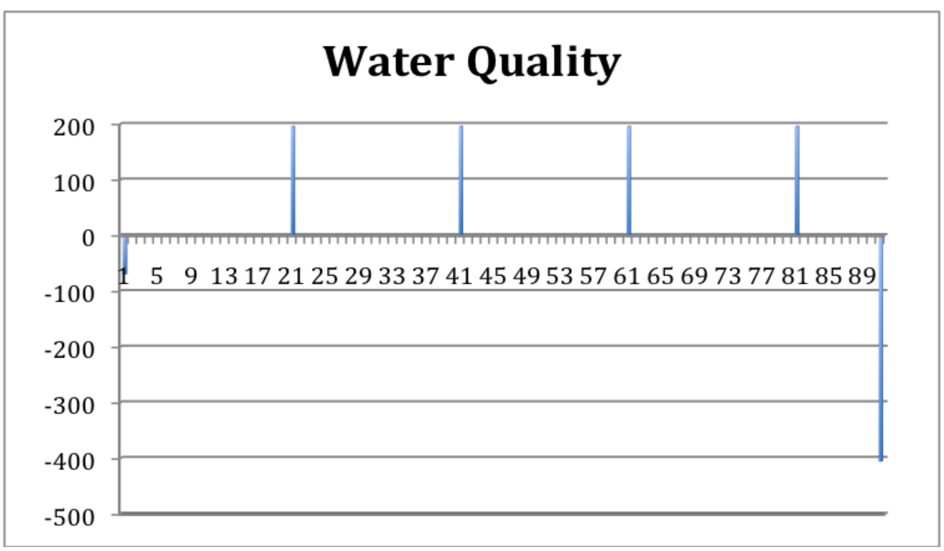


Figure C-8: Water Quality Model

Appendix C

Cash Flow Diagrams to Accompany the Twelve Models

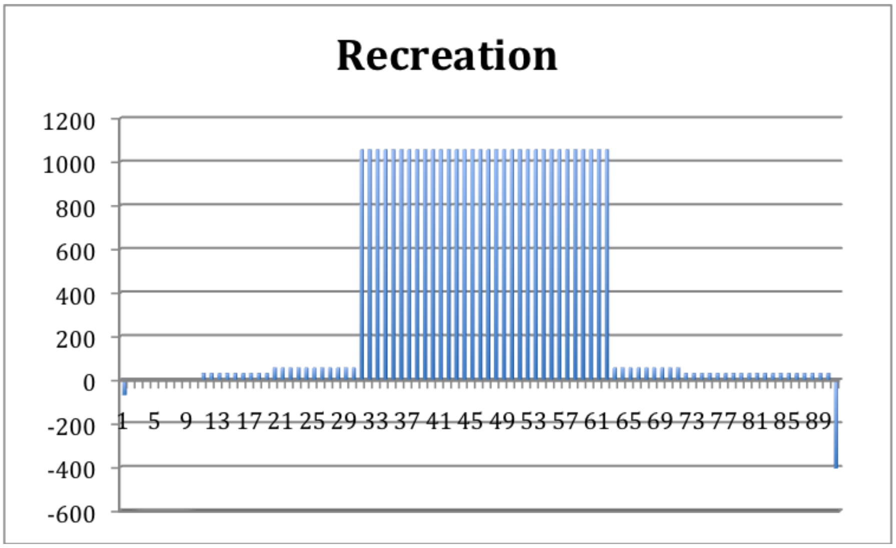


Figure C-9: Recreation Model

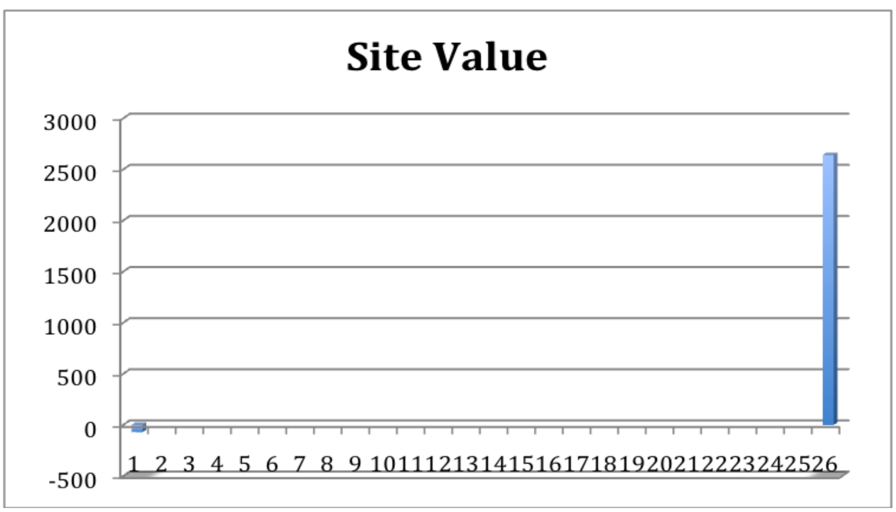


Figure C-10: Site Value Model

Appendix C

Cash Flow Diagrams to Accompany the Twelve Models

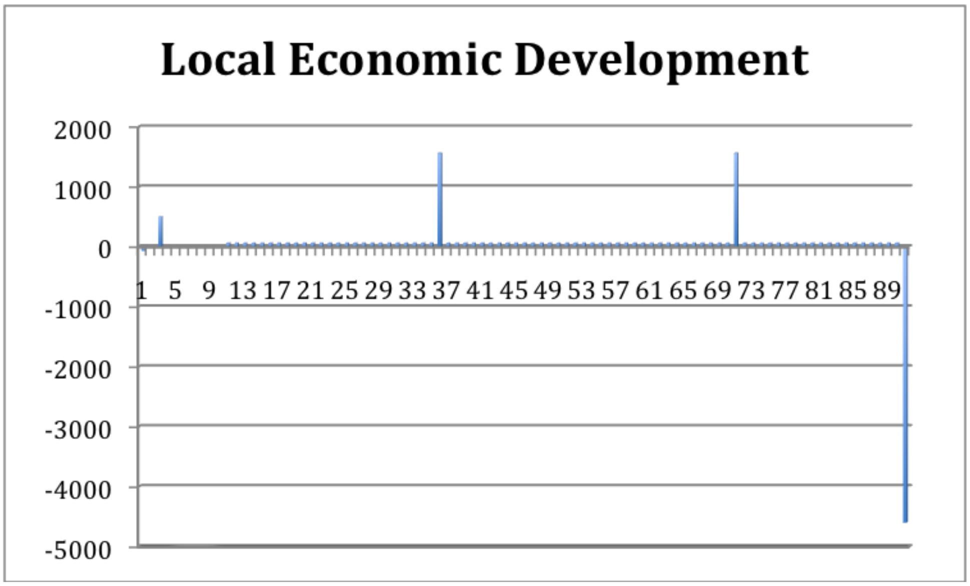


Figure C-11: Local Economic Development Model

* A model for "District Product Enhancement" is not provided because the scale of the final cash flow exceeds the reasonable scale for the model.

Appendix D

Growth Data for The Detroit White Oak

Year	**DBH (in.)**
0	4.00
1	4.25
2	4.50
3	4.75
4	5.00
5	5.25
6	5.50
7	5.75
8	6.00
9	6.25
10	6.50
11	6.60
12	6.70
13	6.80
14	6.90
15	7.00
16	7.10
17	7.20
18	7.30
19	7.40
20	7.50
21	7.60
22	7.70
23	7.80
24	7.90
25	8.00
26	8.10
27	8.20
28	8.30
29	8.40
30	8.50
31	8.60
32	8.70
33	8.80
34	8.90
35	9.00

Appendix D continued

Growth Data for The Detroit White Oak

Year	**DBH (in.)**
36	9.10
37	9.20
38	9.30
39	9.40
40	9.50
41	9.60
42	9.70
43	9.80
44	9.90
45	10.00
46	10.10
47	10.20
48	10.30
49	10.40
50	10.50
51	10.60
52	10.70
53	10.80
54	10.90
55	11.00
56	11.10
57	11.20
58	11.30
59	11.40
60	11.50
61	11.60
62	11.70
63	11.80
64	11.90
65	12.00
66	12.10
67	12.20
68	12.30
69	12.40
70	12.50
71	12.60
72	12.70
73	12.80

Appendix D continued

Growth Data for The Detroit White Oak

Year	**DBH (in.)**
74	12.90
75	13.00
76	13.10
77	13.20
78	13.30
79	13.40
80	13.50
81	13.60
82	13.70
83	13.80
84	13.90
85	14.00
86	14.10
87	14.20
88	14.30
89	14.40
90	14.50

Appendix E

Summary Statistics for Detroit White Oak

```
> totalben<-c(28.85, 46.53, 53.08, 59.52, 66.53, 73.87, 81.22, 88.57, 95.9, 105.45, 115,
122.54, 134.08, 144.02, 153.17, 162.3, 171.43, 182.58, 189.7, 198.84, 207.98, 217.75, 227.52,
237.29, 247.08, 256.86, 266.63, 276.05, 285.46, 294.87, 302.28, 313.7, 323.12, 332.32, 341.54,
350.75, 359.95, 369.76, 378.37, 386.94, 395.54, 404.12, 412.71, 421.29,429.81)
> # predictive value (dbh)
> dbh <-c(1:45)
> plot(dbh,totalben)
> benefits <-as.data.frame(cbind(totalben,dbh))
> benefits.lm <-lm(totalben~dbh, data=benefits)
> summary(benefits.lm)

Call:
lm(formula = totalben ~ dbh, data = benefits)

Residuals:
   Min     1Q Median     3Q    Max
-5.434 -2.404 -0.467  1.944 10.557

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 17.57246    0.93888   18.72   <2e-16 ***
dbh          9.20011    0.03555  258.83   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.097 on 43 degrees of freedom
Multiple R-squared: 0.9994, Adjusted R-squared: 0.9993
F-statistic: 6.699e+04 on 1 and 43 DF,  p-value: < 2.2e-16

> |
```

Figure E-1: This command system was used to calculate the summary statistics for a white oak in Detroit, Michigan.

Appendix F

Benefits for Detroit White Oak

PV = present value, SW = storm water, AQ = air quality, CO2 = carbon dioxide, NG= natural gas, EL = electricity, SUM = total

DBH	PV	SW	AQ	CO2	NG	EL	SUM
1	23.04	0.64	0.64	0.06	3.75	0.72	28.85
2	36.01	1.27	1.16	0.13	6.64	1.32	46.53
3	38.93	1.89	1.58	0.21	8.67	1.80	53.08
4	41.84	2.5	1.99	0.21	10.70	2.28	59.52
5	44.54	3.23	2.50	0.37	13.01	2.88	66.53
6	47.04	4.06	3.11	0.47	15.60	3.59	73.87
7	49.54	4.90	3.72	0.57	18.19	4.30	81.22
8	52.04	5.74	4.34	0.66	20.78	5.01	88.57
9	54.53	6.57	4.95	0.76	23.37	5.72	95.90
10	57.03	7.70	5.96	0.91	26.69	7.16	105.45
11	59.53	8.83	6.97	1.07	30.00	8.60	115.00
12	62.02	9.96	7.99	1.22	31.31	10.04	122.54
13	64.52	11.09	9.00	1.37	36.62	11.48	134.08
14	67.02	12.21	10.02	1.92	39.93	12.92	144.02
15	69.51	13.34	11.03	1.68	43.25	14.36	153.17
16	72.22	14.78	11.88	1.77	46.65	15.00	162.30
17	74.92	16.21	12.72	1.87	50.06	15.65	171.43
18	77.63	17.64	13.57	1.97	55.47	16.3	182.58
19	80.33	19.08	14.41	2.07	56.87	16.94	189.70
20	83.04	20.51	15.26	2.16	60.28	17.59	198.84
21	85.74	21.95	16.11	2.26	63.69	18.23	207.98
22	88.24	23.66	17.20	2.52	66.74	19.39	217.75
23	90.74	25.36	18.30	2.79	69.79	20.54	227.52
24	93.23	27.07	19.40	3.05	72.84	21.7	237.29
25	95.73	28.78	20.50	3.32	75.89	22.86	247.08
26	98.23	30.49	21.60	3.58	78.95	24.01	256.86
27	100.72	32.20	22.70	3.84	82.00	25.17	266.63
28	103.22	34.16	23.83	4.03	84.50	26.31	276.05
29	105.72	36.11	24.97	4.22	87.00	27.44	285.46
30	108.21	38.07	26.10	4.41	89.50	28.58	294.87
31	110.71	40.03	27.23	4.59	90.00	29.72	302.28

Appendix F continued

Benefits for Detroit White Oak

PV = present value, SW = storm water, AQ = air quality, CO2 = carbon dioxide, NG= natural gas, EL = electricity, SUM = total

DBH	PV	SW	AQ	CO2	NG	EL	SUM
32	113.21	41.98	28.37	4.78	94.50	30.86	313.70
33	115.71	43.94	29.50	4.97	97.00	32.00	323.12
34	118.41	46.11	30.62	5.17	98.96	33.05	332.32
35	121.12	48.29	31.74	5.37	100.92	34.10	341.54
36	123.82	50.46	32.87	5.57	102.88	35.15	350.75
37	126.53	52.63	33.99	5.76	104.84	36.20	359.95
38	129.83	54.81	35.11	5.96	106.8	37.25	369.76
39	131.94	56.98	36.23	6.16	108.76	38.30	378.37
40	134.43	59.34	37.32	6.34	110.26	39.25	386.94
41	136.93	61.70	38.41	6.53	111.77	40.20	395.54
42	139.43	64.06	39.49	6.71	113.28	41.15	404.12
43	141.93	66.42	40.58	6.89	114.79	42.10	412.71
44	144.42	68.78	41.67	7.08	116.29	43.05	421.29
45	146.89	71.12	42.75	7.26	117.79	44.00	429.81

Appendix G

Benefits for Phoenix Magnolia

PV = present value, SW = storm water, AQ = air quality, CO2 = carbon dioxide, NG= natural gas, EL = electricity,

DBH	PV	SW	CO2	AQ	NG	EL
1	6.41	0.08	0.02	0.04	0.02	0.22
2	11.10	0.18	0.06	0.08	0.03	0.51
3	14.07	0.32	0.13	0.14	0.05	0.86
4	17.04	0.45	0.19	0.19	0.07	1.22
5	19.43	0.64	0.27	0.30	0.10	1.76
6	21.23	0.88	0.36	0.46	0.13	2.48
7	23.03	1.13	0.45	0.62	0.17	3.19
8	24.83	1.38	0.54	0.78	0.20	3.91
9	26.63	1.63	0.63	0.94	0.24	4.63
10	27.15	2.05	0.74	1.44	0.30	5.98
11	27.67	2.47	0.86	1.94	0.36	7.33
12	28.19	2.89	0.97	2.44	0.42	8.68
13	28.71	3.31	1.08	2.94	0.48	10.03
14	29.23	3.74	1.20	3.44	0.55	11.38
15	29.75	4.16	1.31	3.94	0.61	12.73
16	25.90	4.80	1.28	4.85	0.69	13.69
17	22.05	5.45	1.24	5.77	0.77	14.65
18	18.20	6.09	1.20	6.68	0.85	15.61
19	14.35	6.74	1.17	7.60	0.93	16.56
20	10.51	7.38	1.13	8.51	1.01	17.52
21	6.66	8.03	1.09	9.43	1.09	18.48
22	5.55	8.03	1.11	9.78	1.09	19.37
23	4.44	8.03	1.14	10.14	1.09	20.26
24	3.33	8.03	1.16	10.49	1.09	21.15
25	2.22	8.03	1.18	10.85	1.09	22.04
26	1.11	8.03	1.20	11.21	1.09	22.93
27	0.01	8.03	1.22	11.56	1.09	23.92

Appendix H

Trees in Atlanta, Georgia, by Benefit Class

The following "classes" indicate trees in Atlanta, Georgia that follow the same benefit patterns over the course of their growth. The class labels indicate the total benefits the trees convey at DBH= 5 in. The order of the classes is based on the property value the benefits convey at DBH=5 in. Species are organized by category alphabetically according to the common name of their genus; for example, "leyland cypress" precedes "eastern white pine."

Class 1: DBH 5= $5.57
Bailey Acacia (*Acacia baileyana*)
Acuba (*Aucuba japonica*)
Southern Bayberry (*Morella caroliniensis)*
Boxwood (*Buxus spp.*)
Camelia (*Camelia spp.*)
Laurel Cherry (*Prunus caroliniana*)
Chokeberry (*Aronia spp.*)
Dahoon (*Ilex cassine*)
Firethorn (*Pyracantha spp*.)
Formosa firethorn (*Pyracantha koidzumii*)
Hakea (*Hakea spp*.)
American Holly (*Ilex opaca*)
Chinese Holly (*Ilex cornuta*)
European Holly (*Ilex aquifolium*)

Class 2: DBH 5=$6.11
Small Palms (fam. *Arecaceae*)

Class 3: DBH 5=$10.62
Apple (*Malus spp.*)

Class 4: DBH 5= $8.77
Crapemyrtle (*Lagerstroemia indicata*)

Class 5: DBH 5= $10.50
California Palm (*Washingtonia filifera*)
Saw Palmetto (*Seronea repens*)
Medium Palms (fam. *Arecaceae)*
Yucca (*Yucca spp*.)

Appendix H continued

Trees in Atlanta, Georgia, by Benefit Class

Class 6: DBH 5= $9.75
Atlantic White-Cedar (*Chamaecyparis thyoides*)
Atlas Cedar (*Cedrus atlantica*)
Eastern Redcedar *(Juniperus virginiana*)
Northern White-Cedar (*Thuja occidentalis*)
Eastern Hemlock (*Tsuga canadensis*)
Juniper (*Juniperus spp.*)
Austrian Pine (*Pinus nigra*)
Virginia Pine (*Pinus virginiana)*
Blue Spruce (*Picea pungens*)
White Spruce (*Picea glauca*)

Class 7: DBH 5= $12.40
Loblolly Pine (*Pinus taeda*)

Class 8: DBH 5= $13.07
Callery Pear/ Bradford Pear (*Pyrus calleryana*)

Class 9: DBH 5= $14.02
Deodar Cedar (*Cedrus deodara*)
Japanese Red Cedar (*Cryptomeria japonica*)
Port Orford Cedar (*Chamaecyparis lawsonia*)
Leyland Cypress (*x Cupressocypris leylandii*)
Western Red Cedar (*Thuja plicata*)
Blue Chinese Fir (*Cunninghamia lanceolata*)
Douglas Fir (*Pseudotsuga mensiezii*)
White Fir (*Abies concolor*)
Monkeypuzzle Tree (*Araucaria araucana*)
Eastern White Pine *(Pinus strobus*)
Longleaf Pine (*Pinus palustris*)
Red Pine (*Pinus resinosa*)
Scotch Pine (*Pinus sylvestris*)
Shortleaf Pine (*Pinus echinata)*
Lodgepole Pine (*Pinus contorta*)
Norway Spruce (*Picea abies*)
Sugarberry (*Celtis laevigata*)

Class 10: DBH 5= $12.96

Appendix H continued

Trees in Atlanta, Georgia, by Benefit Class

Mountain Ash (*Sorbus americana*)
Blackhaw (*Viburnum prunifolium*)
Red Buckeye (*Aesculus pavia)*
Buckthorn (*Rhamnus cathartica*)
Orange-eye Butterflybush (*Buddleja davidii*)
Chaste Tree (*Vitex agnus-castus*)
Cornelian Cherry (*Cornus mas)*
Higan Cherry (*Prunus subhirtella*)
Kwanzan Cherry (*Prunus serrulata*)
Manchu Cherry (*Prunus tomentosa*)
Taiwan Cherry (*Prunus campanulata*)
Crabapple (*Malus spp.*)
Common Crabapple (*Malus sylvestris)*
Alternate Leaf Dogwood (*Cornus alternifolia*)
Flowering Dogwood (*Cornus florida*)
Kousa Dogwood (*Cornus kousa*)
Common Fig (*Ficus caricara*)
Forsythia (*Forsythia spp.)*
Chinese Fringe Tree (*Chionanthus retusus*)
Harlequin glorybower (*Clerodendron trichotomum*)
Goldenrain (*Koelreuteria paniculata*)
Hawthorn (*Crategus spp.*)
Green Hawthorn (*Crategus viridis*)
Washington Hazel (*Corylus spp.)*
Witch-hazel (*Hamamelis virginiana*)
Lilac (*Syringa spp.*)
Japanese Lilac (*Syringa reticulata*)
Chinese Magnolia (*Magnolia x soulangiana*)
Star Magnolia (*Magnolia stellata*)
Amur Maple (*Acer ginnala*)
Japanese Maple (*Acer palmatum*)
Paperback Maple (*Acer griseum)*
Purple Blow Maple (*Acer trancatum*)
PawPaw (*Asimina triloba*)
Peach (*Prunus persica*)
Cherry Plum (*Prunus ceracifera*)
Eastern Redbud (*Cercus canadensis*)
Banksian Rosebush (*Banksia lutea*)

Appendix H continued

Trees in Atlanta, Georgia, by Benefit Class

Downy Serviceberry (*Amalanchier arborea*)
Rose-of-Sharon (*Hibiscus syricus*)
Smoketree (*Cotinus coggygria*)
Snowbell (*Styrax japonica*)
Chinese Tallowtree (*Triadica sebifera*)
Virburnum (*Viburnum spp.)*
Pussy-willow (*Salix discolor*)

Class 11: DBH 5= $16.33
Southern Magnolia (*Magnolia grandiflora*)
Darlington Oak (*Quercus hemispaerica*)
Sumac (*Rhus spp.*)
Sweetbay (*Magnolia virginiana*)

Class 12: DBH 5= $18.91
Yoshino Cherry (*Prunus x yedonensis*)

Class 13: DBH 5= $17.43
Sawara False Cypress (*Chamaecyparis pisifera*)
Bolander Beach Pine (*Pinus contorta*)
Sweet Mountain Pine (*Pinus mugo*)
Florida Torreya (*Torreya taxifolia*)

Class 14: DBH 5= $20.53
Northern Red Oak (*Quercus rubra*)

Class 15: DBH 5= $25.40
Silver Maple (*Acer saccharinum*)

Class 16: DBH 5= $21.70
Sweetgum (*Liquidambar styraciflua*)

Class 17: DBH 5= $24.57
White Oak *(Quercus alba*)

Class 18: DBH 5= $24.66
Red Maple (*Acer rubrum*)
Plum (*Prunus prunus*)

Trees in Atlanta, Georgia, by Benefit Class

Class 19: DBH 5= $24.64
Eucalyptus (fam. *Myrtaceae*)
Live Oak (*Quercus virginiana*)
Water Oak (*Quercus nigra*)

Class 20: DBH 5= $25.73
Willow Oak (*Quercus phellos*)

Class 21: DBH 5=$32.40
Black Ash (*Fraxinus nigra*)
Asian White Birch (*Betula platyphylla*)
Black Birch (*Betula lenta*)
European White Birch (*Betula pendula*)
Indian Paper Tree (*Betula bhojpatra*)
Paperbirch (*Betula papyrifera*)
River Birch (*Betula nigra*)
Boxelder (*Acer negundo*)
Northern Catalpa (*Catalpa speciosa*)
European Bird Cherry (*Prunus padus*)
Chinese Chestnut (*Castanea mollissima)*
Amur Corktree (*Phellodendron amurense*)
Chinese Elm (*Ulmus parvifolia)*
Slippery Elm (*Ulmus rubra*)
Ginkgo (*Ginkgo biloba)*
Eastern Hophornbeam (*Ostraya virginiana*)
European Hophornbeam (*Ostraya carpinifolia*)
Littleaf Linden (*Tilia cordata*)
Black Locust (*Pseudoacacia robinia*)
Hedge Maple (*Acer campestre*)
Blackjack Oak (*Quercus marilandica*)
Chinquapin Oak (*Quercus muehlenbergii*)
Overcup Oak (*Quercus lyrata*)
Sawtooth Oak (*Quercus acutissima*)
Osage Orange (*Maclura pomifera*)
Parasoltree (*Firmiana simplex*)
Royal Pauwlonia (*Paulownia tomentosa*)
Common Pear (*Pyrus communis*)
Common Persimmon (*Diospyros virginiana*)

Trees in Atlanta, Georgia, by Benefit Class

Chinese Pistache (*Pistacia chinensis*)
Black Poplar (*Populus nigra*)
Pride-of-India (*Lagerstroemia speciosa*)
Sassafras (*Sassafras albidum*)
Japanese Pagoda Tree (*Sophora japonica*)
Snowdrop Tree (*Halesia tetraptera*)
Black Tupelo (*Nyssa sylvatica*)
English Walnut (*Juglans regia*)
Black Willow (*Salix nigra*)
Weeping Willow (*Salix babylonica*)
Yellowwood (*Cladrastis kentukea)*

Class 22: DBH 5= $32.26
Blue Ash (*Fraxinus quadrangulata*)
Green Ash (*Fraxinus pennsylvanica*)
White Ash (*Fraxinus Americana*)
Bald-Cypress (*Taxodium distichum*)
American Basswood (*Tilia americana*)
American Beech (*Fagus grandifolia*)
European Beech (*Fagus sylvatica*)
Ohio Buckeye (*Aesculus glabra*)
Yellow Buckeye (*Aesculus flava*)
Black Cherry (*Prunus serotina*)
American Chestnut (*Castanea dentata*)
Kentucky Coffeetree (*Gymnocladus dioicus*)
Eastern Cottonwood (*Populus deltoides*)
American Elm (*Ulmus Americana*)
Siberian Elm (*Ulmus pumila*)
Northern Hackberry (*Celtis occidentalis*)
Tree-of-Heaven (*Alianthus altisima*)
Bitternut Hickory (*Carya cordiformis*)
Mockernut Hickory (*Carya tomentosa*)
Pignut Hickory (*Carya glabra*)
Shagbark Hickory (*Carya ovata*)
Honey Locust (*Glenditsia tricanthos*)
Horsechestnut (*Aesculus hippocastanum*)
European Larch (*Larch decidua*)
Bigleaf Maple (*Acer macrophyllum)*
Black Maple (*Acer nigrum*)

Appendix H Continued

Trees in Atlanta, Georgia, by Benefit Class

Freeman Maple (*Acer x freemanii*)
Norway Maple (*Acer platanoides*)
Sugar Maple (*Acer saccharum*)
Black Oak (*Quercus velutina*)
Bur Oak (*Quercus macrocarpa*)
English Oak (*Quercus robur*)
Northern Pine Oak (*Quercus ellipsoidalis*)
Pin Oak (*Quercus palustris*)
Post Oak (*Quercus stellata*)
Scarlet Oak (*Quercus coccinea*)
Shingle Oak (*Quercus imbricata*)
Shumard Oak (*Quercus shumardii*)
Southern Red Oak (*Quercus falcata)*
Swamp Chestnut Oak (*Quercus michauxii)*
Swamp White Oak (*Quercus bicolor*)
Pecan (*Carya illinonensis*)
London Plaintree (*Platanus x hispanica*)
Balsam Poplar (*Poplulus balsamifera*)
White Poplar (*Poplulus alba)*
Dawn Redwood (*Metasequoia glyptostroboides)*
American Sycamore (*Platanus occidentalis*)
Cucumber Tree (*Magnolia acuminata*)
Katsura Tree (*Cercidiphyllum japoncium*)
Yellow-Poplar (tulip-poplar) (*Liriodendron tulipifera*)
Black Walnut (*Juglans nigra)*
Zelkova (*Zelkova serrulata*)

Class 23: DBH 5= $36.34
Winged Elm (*Ulmus alata*)

Appendix I

Three Tables for Inventory

FIELD	UNIT	YOUR DATA
Total Municipal Budget	$	(input)
Population	persons	(input)
Total Land Area	Square miles	(input)
Average sidewalk width	Feet	(input)
Total linear miles of streets	Miles	(input)
Average Street width	Feet	(input)

Table C-1: The Define City Information Table

FIELD	UNIT	YOUR DATA
Annual planting	$	(input)
Annual pruning	$	(input)
Annual tree and stump removal and disposal	$	(input)
Annual pest and disease control	$	(input)
(cont’d on next page)		

Annual establishment and irrigation	$	(input)
Annual price of repair or mitigation of infrastructure damage	$	(input)
Annual cost of litter and storm clean up	$	(input)
Annual litigation and settlements	$	(input)
Annual expenditure for program administration	$	(input)
Annual expenditures for inspection	$	(input)
Other annual tree related expenditures	$	(input)

Table C-2: The Define Costs Information Table

FIELD	UNIT	YOUR DATA
Electricity	$/kWh	(input)
Natural gas	$/therm	(input)
CO_2	$/lb	(input)
PM_{10}*	$/lb	(input)
NO_2	$/lb	(input)
SO_2	$/lb	(input)
VOC	$/lb	(input)
Storm water interception	$/gallon	(input)
Median Home Resale Value	$	(input)

Table C-3: The Define Benefits Prices Table.

*PM_{10} is a commonly used measurement of particulate matter

REFERENCES

Abbott, Richard E. and Kenneth C. Miller. “Estimating Tree Care Jobs.” *Journal of Arboriculture* 13(1987): 118-120.

[ACC] Athens-Clarke County Online. “Virtual Tour of Athens Landmarks: The Tree that Owns Itself.” Athens-Clarke County. http://www.athensclarkecounty.com/tour/tour10.html. Accessed on 10 March 2009.

[AFS] American Forest Society. “Urban Ecosystem Analysis, Atlanta Metro Area: Calculating the Value of Nature.” http://www.americanforests.org/downloads/rea/AF_Atlanta2.pdf. 2001. Accessed on 10 March 2009.

Anderson, L.M. and H.K. Cordell. “Residential Property Values Improve by Landscaping with Trees.” *Southern Journal of Applied Forestry* 9(1985): 162-166.

Anthon, Signe, Bo Jellesmark Thorson, and Finn Helles. “Urban Fringe Afforestation Projects and Taxable Hedonic Values.” *Urban Forestry and Urban Greening* 3(2005):79-91.

Arenas, Jorge P. “Potential Problems with Environmental Sound Barriers When Used in Mitigating Surface Transportation Noise.” *Science and the Environment* 405(2008): 173-179.

Ayers, F., H. Steltzer, S. Berg, M.D. Wallenstein, B.L. Simmons, D.H. Wall. “Tree Species Traits Influence Soil Physical, Chemical, and Biological Properties in High Elevation Forests.”*Plos One* 4(2005): 5964e.

Bernatzky, A. “The Contribution of Trees and Green Spaces to a Town Climate.” *Energy and Buildings* 5(1982): 1-10.

Bourassa, SC, M. Hoesli, and J. Sun. “A Simple Alternative House Price Index Method.” *Journal of Housing Economics* 15(2006):80-97.

Brookshire, D.S. and D.L. Coursey. “Measuring the Value of a Public Good: An Empirical Comparison of Elicitation Procedures.” *American Ecnomic Review* 77(1987): 554-566.

Bullard, Steven H., T.J. Straka, and C. B. Landrum. “FORVAL. Online Forestry Investment Calculations.” Mississippi State University. http://www.cfr.msstate.edu/forval/.2001. Accessed on 14 April 2010.

Buresh, R.J. and G. Tian. “Soil Improvement by Trees in Sub-Saharan Africa.” *Agroforestry Systems* 38(2004): 51-76.

Burger, J. A. “Management Effects on Growth, Production, and Sustainability of Managed Forest Ecosystems.” *Forest Ecology and Management* 258(2009): 2335-2346.

Burns, Gary Allen. “Urban Tree Appraisal: The Formula Approach.” *Journal of Forestry* 84(1986):18-49.

City of Atlanta. “Atlanta Tree Ordinance.” Atlanta Government. http://www.atlanta.gov/government/planning/newarborist012706.aspx. Accessed on 08 September 2009.

Cho, S.H., N.C. Poudyal, and R.K. Roberts. “Spatial Analysis of the Amenity Value of Open Greenspace.” *Ecological Economics* 66(2008): 403-416.

Church, Roger J. and P.J. Daugherty. “Considering Intergenerational Equity in Linear Programming-Based Forest Planning Models with MAXMIN Objective Functions.” *Forest Science* 45(1999): 366-373.

Contato-Carol, M.L. “A Comparative Analysis of Methods for the Valuation of Urban Trees in Santiage del Estero, Argentina.” *Spanish Journal of Agricultural Research* 6(2008): 341-352.

Diaz-Baltiero, Luis, and Carlos Romero. “Valuation of Environmental Goods: A Shadow Value Perspective.” *Environmental Economics* 64(2007): 517-520.

[Davey] Davey Tree Expert Company. “I-Tree: Applications.” Davey Tree Expert Company. http://itreetools.org/street_trees/introduction_step1.shtm. 2009. Accessed on 24 December 2009.

[Davey] Davey Tree Expert Company. “National Tree Benefit Calculator.” Davey Tree Expert Company.http://www.davey.com/cms/cus/f94711556cbd4c7b/treecalculator.html.

Davis, Lawrence S. and K. N. Johnson. *Forest Management*. Third Edition. New York: McGraw-Hill. 1987.

Dwyer, John F., G.L. Peterson, and A.J. Darragh. “Urbanites Willingness to Pay for Trees and Forests in Recreation Areas.” *Journal of Arboriculture* 15 (1989): 182-195.

Dwyer, John F., H.W. Schroeder, P.H. Gobster. “The Significance of Urban Trees and Forests: Towards A Deeper Understanding of Values.” *Journal of Arboriculture* 17(October 1991): 276-284.

Dwyer, John F., E.G. McPherson, H.W. Schroeder, and R.A. Rowntree. “Assessing the Benefits and Costs of the Urban Forest.” *Journal of Arboriculture* 18(1992): 227-235.

Dwyer, John F. and R. W. Miller. “Using GIS to Assess Urban Tree Canopy Benefits and Surrounding Greenspace Distributions.” *Journal of Arboriculture* 25(1999): 102-107.

Fang-Fang, Chih and Der-Lin Ling. “Guidance for Noise Reduction Provided by Tree Belts.” *Landscape and Urban Planning* 71(2005): 29-34.

Gamble, H.B. and R.J. Downing. “The Effect of Nuclear Power Plants on Residential Property Values.” *Journal of Regional Science* 22(1982): 457-478.

Gollier, Christian. “Declining Discount Rates: Economic Justifications and Implications for Long-Run Policy.” *Economic Policy* 56(2008). http://idei.fr/doc/wp/2008/declining_discount.pdf.

Graves, A.R., P.J. Burgess, F. Liagre, J.P. Terreaux, and C.U. Dupraz. “Development and Use of a Framework for Characterizing Computerized Models for Silvorable Economics.” *Agroforestry Systems* 65(2005): 53-65.

Hamada, Shuko and Takeshi Ohta. “Seasonal Variations in The Cooling Effect of Urban Green Areas on The Surrounding Urban Areas.” *Urban Forestry and Urban Greening* 9(2010): 15-24.

Hardin, Perry J. and R.R. Jensen. “The Effect of Urban Leaf Area on Summertime Urban Surface Kinetic Temperatures: A Terra Haute Case Study.” *Urban Forestry and Urban Greening* 6(2007): 63-72.

Harrje, D.T., C.E. Buckley and G.M. Heisler. “Building Energy Reductions- Windbreak Optimization.” *Journal of Energy*. 108(1982): 143-154.

He, Jiang and A. Hoyano. “The Effects of Windbreak Forests on the Summer Thermal Environment in a Residence.” *Journal of Asian Architecture and Building Engineering* 8(2009): 291-298.

Heisler, G.M. “Effectiveness of a White-Pine Windbreak for Reducing Fuel Use for Space Heating.” *Bulletin of the American Meteorological Society* 59(1978): 1508.

Heisler, G.M. “Plantings that Save Energy.” *American Forests* 90(1984):13-16.

Heisler, G.M. “Effects of Individual Trees on the Solar Radiation Climate of Small Buildings.” *Urban Ecology* 9(1986): 337-359.

Hollis, Adam. (a) “Can Trees Be Depreciated Like (Mechanical) Plant? A Depreciated Replacement Cost Solution to the Adjusted Trunk Formula Anomaly in CTLA’s Trunk Formula Method.” *Arboricultural Journal* 32(2009): 97-110.

Hollis, Adam. (b) “Could a More Disciplined Approach to Tree Appraisal Inform Development Site Surveys and Tree Preservation Decisions—And Vice Versa?” *Arboricultural Journal* 32(2009): 19-32.

Huang, C.H. “Economics of Northern Bobwhite and Timber Management in the Southeastern United States.” *Journal of Wildlife Management.* 73(2009): 1355-1361.

[ISA] International Society of Arboriculture. “Tree Care Information.” Trees Are Good. http://www.treesaregood.com/treecare/tree_benefits.aspx.

Jim, C.Y. “Formula Method to Integrate Evaluation and Valuation of Heritage Trees in A Compact City.” *Environmental Monitoring and Assessment* 116(2005): 53-80.

Jim, C.Y. and Wendy Chen. “External Effects of Neighborhood Parks and Landscape Elements on High Rise Residential Value.” *Land Use Policy* 27(2008): 662-670.

Jim, C.Y. and Wendy Chen. “Ecosystem Services and Valuation in Urban Forests in China.” *Cities* 26 (2009): 187-194.

Johnson, B.E. “Nature, Affordability, and Privacy as Motivations for Exurban Living.” *Urban Geography* 29(2008):705-723.

Joye, Yannick, K. Williams, M. Brengman, K. Wolf. “The Effects of Urban Retail Greenery on Consumer Experience: Reviewing the Evidence from a Restoration Perspective.” *Urban Forestry and Urban Greening* 9(2010): 57-64.

Kanniainen, Juho. “Can Properly Discounted Projects Follow Geometric Brownian Motion?” *Mathematical Methods of Operations Research*. 70(2009): 435-450.

Kim, Yeon-Su and Aaron Wells. “The Impact of Forest Density on Property Values.” *Journal of Forestry* 103 (2005): 146-151.

Leonard, Raymond E. and Sally B. Parr. “Trees as A Sound Barrier.”*Journal of Forestry*. 68(May 1970): 282-283.

LeVert, Micheal, T. Stevens, and D. Kitteredge. “Willingness-to-Sell Conservation Easements: A Case Study.” *Journal of Forest Economics* 15(2009): 261-275.

Lin, X.J., Barrington, S., Choiniere, D., Prasher, S. “Simulation of the Effects of Windbreaks on Odour Dispersion.” *Biosystems Engineering* 3(2007): 347-363.

Leuschner, W.A. and R.L. Young. “Estimating the Southern Pine Beetle’s Impact on Resevoir Campsites.” *Forest Science* 24 (1978): 527-537.

Martin, Clay W., R.C. Maggio, and D.N. Appel. “Contributory Value of Trees to Residential Property in Austin, Texas Metropolitan Area.” *Journal of Arboriculture* 15(1989): 72-75.

Matsuoka, Rodney H. and Rachel Kaplan. "People's Needs in the Urban Landscape: Analysis of *Landscape and Urban Planning* Contributions." *Landscape and Urban Planning* 84(2008): 7-19.

Maurer, U., T. Peschel, and S. Schmitx. "The Flora of Selected Urban Land-Use Types in Berlin and Potsdam with Regard to Nature Conservation in Cities." *Landscape and Urban Planning* 46(2000). 209-215.

McPherson, E. Greg. "Accounting for the Benefits and Costs of Urban Greenspace." *Landscape and Urban Planning* 22(1992): 41-51.

McPherson, E. Greg and R. Rowntree. "Energy Conservation Potential of Urban Tree Planting." *Journal of Arboriculture* 19(November 1993): 321-331.

McPherson, E. Greg, K.L. Scott, and J.R. Simpson. "Estimating Cost Effectiveness of Residential Yard Trees for Improving Air Quality in Sacramento, California, Using Existing Models." *Atmospheric Environment*. 32(1998): 75-84.

McPherson, E. Greg. "Benefits-Cost Analysis of Modesto's Municipal Urban Forest." *Journal of Arboriculture* 25(1999): 235-248.

McPherson, E. Greg and J.R. Simpson. "A Comparison of Municipal Forest Benefits and Costs in Modesto and Santa Monica, California." *Urban Forestry and Urban Greening* 1(2002): 62-74.

McPherson, E. Greg, J.R. Simpson, P.J. Peper, S.E. Maco, and Q. Xiao. "Municipal Forest Benefits and Costs in Five US Cities." *Journal of Forestry* (2005): 411-416.

Min, Zhao, Zheng-Hong Kong, F.J. Escobedo, and J. Gao. "Impacts of Urban Forests on Offsetting Carbon Emissions in Hangzhou, China." *Journal of Environmental Management* (2009). Article in Press.

Myeong, Soojeong, D.J. Nowak, and M.J. Duggin. "A Temporal Analysis of Urban Forest Storage Using Remote Sensing." *Remote Sensing and the Environment* 101(2006): 277-282.

Nair, P.K.R., V.D. Nair, B.M. Kumar, S.G. Haile. "Soil Carbon Sequestration in Tropical Agroforestry Systems: a Feasibility Appraisal." *Environmental Science and Policy* 12(2009): 1099-1111.

Neilsen, Anders Busse and Fanny Møller. "Is Coppice a Potential for Urban Forestry? The Social Perspective." *Urban Forestry and Urban Greening* 7(2008): 129-138.

Nordh, H., T. Hartig, C.M. Hagerhall, G. Fry. “Components of Small Urban Parks that Predict the Possibility for Restoration.” *Urban Forestry and Urban Greening 8*((2009): 225-235.

Nowak, David J. and D.E. Crane. “The Urban Tree Forest Effects Model: Quantifying Urban Forest Structure and Function.” Integrated Tools Proceedings. 2000. http://www.ufore.org/about/files/NowakCrane_UFORE.pdf.

Nowak, David. J. and D.E. Crane. “Carbon Sequestration by Urban Trees in the USA.” *Environmental Pollution* 116(2002):381-389.

Nowak, David J., D.E. Crane, and J.F. Dwyer. “Compensatory Value of Urban Trees in the United States.” *Journal of Arboriculture* 28(2002): 194-199.

Nowak, David J., J.T. Walton, J.F. Dwyer, L.G. Kaya, and S. Myeang. “The Increasing Influence of Urban Environments on US Forest Management.” *Journal of Forestry* 103 (2005): 377-382.

Nowak, David J., D.E. Crane, and J.C. Stevens. “Air Pollution Removal by Urban Trees and Shrubs in the United States.” *Urban Forestry and Urban Greening* 4(2006):115-123.

Oates, Wallace B. “The Effect of Property Taxes and Local Spending on Property Values: An Empirical Study of Tax Capitalization and the Tiebout Hypothesis.” *The Journal of Political Economy* 77(1969): 957-971.

Ocone, Lynne. “Ruling over The Lawn in Winter.” Los Angeles Times. 2000. http://articles.latimes.com/2000/jan/15/home/hm-54297.

Panagopolos, T. “Linking Forestry, Sustainability, and Aesthetics.” *Ecological Economics* 68 (2009): 2485-2489.

Payton, Seth, G. Lindsey, J. Wilson, J.R. Ottensman, and J. Man. “Valuing the Benefits of the Urban Forest: A Spatial Hedonic Approach.” *Jounral of Environmental Planning and Management* 51(2008): 717-736.

Peters, Andy S. “Architects Eye Stricter Protection For Trees.” Holding Atlanta City Government Accountable. June 2, 2009. http://holdingcitygovernmentaccountable.blogspot.com/2009/07/architects-eye-stricter-protection-for.html.

Poudyal, N.C. “A Hedonic Analysis of the Demand for and Benefits of Urban Recreational Parks.” *Land Use Policy* 26(2008): 975-983.

Præstholm, Søren, F.S. Jensen, B. Hesler, C. Damgaard, and E. Erichsen. "Forests Improve Qualities and Values of Local Areas in Denmark." *Urban Forestry and Urban Greening* 1(2002):97-106.

Price, Colin. "Quantifying the Aesthetic Benefits of Urban Forests." *Urban Forestry and Urban Greening* 1(2003): 123-133.

[RMDSI] Risk Management Disaster Services Incorporated. "Atlanta Trees at Cost." Risk Management Disaster Services Online. http://www.atlantatreesatcost.com. 2008. Accessed 14 March 2009.

Rowntree, R.A. "Forest Canopy Cover and Land Use in Four Eastern US Cities." *Urban Ecology* 8(1984): 55-67.

Sæbø, Arne and F. Ferrini. "The Use of Compost in Urban Green Areas." *Urban Forestry and Urban Greening* 4(2006):159-169.

Sanders, Ralph A. "Some Determinants of Urban Forest Structure." *Urban Ecology* 8(1984): 13-27.

Sanders, Ralph A. "Urban Forest Vegetation Impacts on the Urban Hydrology of Dayton, Ohio." *Urban Ecology* 9(1989):361-376.

Sherwood, Stephen C. and D.R. Betters. "Benefit-Cost Analysis of Municipal Dutch Elm Disease Control Programs in Colorado." *Journal of Arboriculture* 7(November 1981): 291-298.

Silva, Felipe Omar Tapia, Wehrmann, A., H.J. Henze, N. Model. "Ability of Plant-Based Surface Technology to Improve the Urban Water Cycle." *Urban Forestry and Urban Greening* 4(2006): 145-158.

Sinden, John A. and A.C. Worrell. *Underpriced Values*. New York: Wiley-Interscience, 1979.

Smith, V. Kerry, C. Poulos, H. Kim. "Treating Open Space as an Urban Amenity." *Resource and Energy Economics* 24(2002): 107-129.

Straka, T.J. and S.H. Bullard. *Basic Concepts in Forest Valuation and Investment Analysis*. Jackson: Forestry Suppliers: 1998.

Stenger, Anne, P. Harou, and S. Navrud. "Valuing Environmental Goods and Services Derived from Forests." *Journal of Forest Economics* 15 (2009): 1-14.

Stoffberg, G.H., M.W. van Rooyen, M.J. van der Linde and H.T. Groeneveld. "Modelling Dimensional Growth of Street Tree Species in the Urban Forest of Tshwane, South Africa." *Southern Forests* 71(2009): 273-277.

Tait, Roger J., T.J. Allen, N. Sherkat, M.D. Bellett-Travers. “An Electronic Tree Inventory for Arboriculture Management.” *Knowledge-Based Systems* 22(2009): 552-556.

Templeton, Scott R. and G.E. Goldman. “Urban Forestry Adds $3.8 Billion in Sales to California Economy.” *California Agriculture* 50(1996): 6-10.

Timmer, R.P. and P.J. Lamb. “Relations between Temperature and Residential Natural Gas Consumption in the Central and Eastern United States.” *Journal of Applied Meteorology and Climatology* 46(2007): 1993-2013.

Thompson, Richard, R. Hanna, J. Noel, D. Plito. “Valuation of Tree Aesthetics on Small Urban-Interface Properties.” *Journal of Arboriculture* 25(September 1999): 225-233.

Tietenburg, Thomas H. and L. Lewis. *Environmental and Natural Resource Economics*. Reading: Addison-Wesley. 2008.

Tyrväinen, Lissa and Antti Miettenen. “Property Prices and Urban Forest Amenities.” *Journal of Environmental Economics and Management* 39(2000) 205-223.

Tyrväinen, Lissa, H. Silvennoinen, and O. Kolehmainen. “Ecological and Aesthetic Values in Urban Forest Management.” *Urban Forestry and Urban Greening* 1(2003)135-149.

Ulrich, R.S. “View through a Window May Influence Recovery from Surgery.” *Science* 224(1984): 420-421.

US Census Bureau. “The 2010 Statistical Abstract: Historical Statistics.” United States Census Bureau. 2010. http://www.census.gov/compendia/statab/hist_stats.html. Accessed 3 January 2010.

[USDAFS] United States Department of Agriculture Forest Service. *Silvics of North America*. Agriculture Handbook 654. Washington DC: 1990.

[USEPA] United States Environmental Protection Agency. “Recommended Levels of Insulation.” Energystar.gov. 2009. http://www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_insulation_table. Accessed on 18 December 2009.

Velande, M.D., G. Fry, and M. Tveit. “Urban Forestry for Human Health and Well-Being.” *Urban Forestry and Urban Greening* 6(2007): 195-197.

Walsh, R.G., F.A. Ward and J.P. Olienyk. “Recreational Demand for Trees in National Forests.” *Journal of Environmental Management* 28(1989): 255-268.

Weng, Qihao. “Thermal Remote Sensing of Urban Areas: An Introduction to the Special Issue.” *Remote Sensing and The Environment* 104(2006):119-122.

Wolf, Kathleen. “What Could We Lose? The Economic Value of Urban Forests.” Sixth Annual Canadian Forest Conference Proceedings. University of Washington 2(2004): 1-8.

Wu, Chunxia, Q. Xiao, and E. G. McPherson. “A Method for Locating Potential Tree-Planting Sites in Urban Areas: A Case-Study of Los Angeles.” *Urban Forestry & Urban Greening* 7(May 2008): 65-76.

Xiao, Qingfu, E. G. McPherson. “Rainfall Interception by Santa Monica’s Urban Forest.” *Urban Ecosystems.* 6(2003): 291-302.

Yang, Jun, J. McBride, J. Zhou, and Z. Sun. “The Urban Forest in Beijing and Its Role in Air Pollution Reduction.” *Urban Forestry and Urban Greening* 3(2005): 65-78.

Zeiss, Christopher and James Atwater. “Waste Facility Impacts on Residential Property Values.” *Journal of Urban Planning and Development.* 115(1989): 64-80.

Zhu, Peng-yu and Yaoqi Zhang. “Demand for Urban Forests in United States Cities.” *Landscape and Urban Planning* 84(2008): 293-300.