A METHOD TO ESTIMATE CITY STREET TREE POPULATION USING GIS TO DETERMINE OPTIMUM SAMPLE SIZE

By

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ABSTRACT

This paper provides an introduction to urban forestry as a discipline and its evolution from its beginnings to the present day. As a discipline, urban forestry has grown and evolved into a recognized field of practice, in part, because of its ability to place dollar values on benefits provided by trees. This paper had two objectives: develop a unique sampling method for estimating a street tree inventory and develop a benefit/cost ratio methodology using this inventory data. The sampling method establishes an estimated street tree inventory using a Geographical Information System (GIS). Also, it will be demonstrated how using GIS software can enhance a municipality's street tree management. As important, it was shown how this new inventory method can be tied to a benefit/cost analysis computer program (e.g., STRATUM) which can provide a municipality with an economic guideline for decisionmaking involved in street tree management. Case studies show how, by creating either a complete or partial inventory in a GIS, the methodology can provide users access to other digital data that can be used in conjunction with a tree inventory. The use of these elements together can make decisionmaking for the purposes of urban forestry more thorough and cost effective for communities.

INTRODUCTION

Historical Background

Street trees have been valued as an important element of the urban forest since the European Renaissance period (Lawrence 1995). From the sixteenth century promenades of Antwerp, Belgium to the boulevards of nineteenth century France, trees have been planted and maintained for the benefit of those who live, work, and recreate in cities and towns.

While efforts to nurture trees within communities can be traced back to the dawn of urbanism, the birth of urban forestry as a distinct scientific discipline is generally recognized as occurring in the 1960s in the United States. The 1962 President's Outdoor Recreation Resources Review Commission report included urban forestry information (Johnson 1997). A 1965 White House Conference on National Beauty promoted tree planting as part of a national beautification effort (Johnson 1997). In 1967, the Citizens Committee on Recreation and Natural Beauty recommended to the

President, in its landmark report *A Proposed Program for Urban and Community Forestry,* that an urban and community forestry program be created within the U.S. Forest Service (USFS) to provide technical assistance, training, and research. A 1968 Bureau of Outdoor Recreation proposal also supported the concept of federal assistance for urban forestry education and training to communities. This growing professional and public interest in urban tree resources culminated in the passage of federal legislation in 1972. The Urban Cooperative Forest Management Act of 1972 amended the Cooperative Forestry Assistance Act of 1950 to authorize the USFS to cooperate with the states in providing technical assistance for the "...establishment of trees and shrubs in urban areas, communities, and open spaces" (Johnson 1997).

In 1978, the initial interest in urban and community forestry was expanded by an appropriation of $3.5 million to fund a national urban and community forest program. Unfortunately, the federal commitment lagged in the 1980s, as funding appropriated for urban forestry programs declined to a low of $1.5 million in 1984 (Maco 2002).

The 1990 Farm Bill reestablished the federal commitment to urban forestry (Alvarez 2001). It expanded the authority of the USFS to work with states on urban forestry and created a 15-member National Urban and Community Forestry Advisory Council. In 1993, funding for state programs increased to $25 million. The America the Beautiful Act passed in 1990 was directed toward planting and improving trees in cities and towns (NASF 1990). Funding was provided for each state to create an urban forestry coordinator and establish state urban forestry advisory councils (Johnson 1997).

Currently, city inhabitants and elected officials in the United States, for the most part, appreciate the urban forest, not just because of aesthetics, but because of the environmental, economic, and social benefits it provides. City inhabitants and elected officials can see the merit of funding tree plantings and maintaining these resources because of their inherent benefits (Maco 2002). The stagnation of tree programs in the United States underscored the need to quantify the function urban trees provide to their communities (Tschantz and Sacamano 1994, Bernhardt and Swiecki 1999). In recent years, researchers have shown how the benefits of urban forestry can be qualified and quantified for use by communities, urban planners, and developers (Anderson and Cordell 1985, McPherson 1991, Dwyer 1995, Xiao et al. 1998, Nowak et al. 2001, Maco 2002).

The Cooperative Forestry Act of 1978 offered a statutory definition of urban and community forestry. "Urban Forestry means the planning, establishment, protection, and management of trees and associated plants, individually, in small groups, or under forest conditions within cities, their suburbs, and towns" (Miller 1997). USFS guidance amplified this, defining the management of the urban forest as the "planning for and management of a community's forest resources to enhance the quality of life. The process integrates the economic, environmental, political, and social values of the community to develop a comprehensive management plan for the urban forest" (Miller 1997).

Similarly, urban and community forestry can be distinguished as a discipline from conventional forestry, or silviculture, by its focus on areas where trees are typically a subordinate, as opposed to predominant landcover. The practice of traditional forest management often emphasizes the economic values of marketed outputs of forest resources (e.g., lumber, pulpwood), while urban and community forestry is more interested in the environmental, social, aesthetic, and nonmarket values of trees. However, this distinction has lessened as urban forestry practitioners are documenting the economic values of the urban forest as further justification for investment and protection measures (Jones and Grado 2005).

Urban Street Trees

On average, an urban street tree will have a life expectancy of approximately 10 years in an urban core and 30 years citywide (Godfrey 2005). During this period, the tree and its attributes (i.e., diameter, height, canopy spread) will grow, require maintenance (e.g., pruning, pest control, watering), and eventually removal as the tree will either die from natural causes, disease, pests, or other causes (e.g., vandalism, automobile incidents) related to its location. Making the appropriate selection of street tree species, joined with timely inspections and maintenance, can increase a street tree population's average life expectancy, canopy coverage, and environmental benefits. However, these benefits are not realized without internal and external costs requiring full support from a municipality's decisionmakers thereby allowing the community to achieve maximum return on investment.

Internally, decisionmakers oversee and fund agencies (e.g., public works, street departments, urban forestry departments (UFDs), parks and recreation departments) that tend to street tree needs. There are also external conditions that need to be considered when selecting a tree species to reduce maintenance costs (Godfrey 2005). These would include over-head wires (impacting expected tree height), distance to adjacent structures (impacting expected tree canopy radius as well as potential pruning cycle), and underground infrastructure (impacting root growth or tree pit design due to surface vents, manholes). Street trees will also be impacted by activities such as cyclical road reconstruction and capital improvements such as infrastructure/utility work. Most urban infrastructure assets (e.g., water pipes, sewer pipes, gas lines, stormwater drainage structures) are located underneath the street and any excavation and work done to these facilities can potentially impact the health of a street tree.

Trees and forests within municipalities, regardless of community size or whether they are within a rural, urban, or suburban setting, all have the potential to provide residents with environmental benefits and other amenities associated with urban and community forestry (Groninger 1998). Most studies have been conducted in the midwestern (i.e., Chicago, Illinois) and the western United States (i.e., Modesto and Davis, California) (McPherson et al. 1994, Peper et al. 2001); however, these studies have the potential to be applied in large measure to the South where fewer studies have been undertaken (Jones and Grado 2005). A primary component of these studies is the inventory of street trees. Whether this inventory is an estimate or a complete count, benefits and costs for urban and community forestry programs cannot accurately be represented without it.

Existing Inventory Tools

The USFS has adopted and funded a strategic initiative to coordinate the integration and dissemination of the inventory software tools such as Mobile Community Tree Inventory (MCTI), Urban Forest Effects Model (UFORE), and Street Tree Resource Analysis Tool (STRATUM). STRATUM can be used to generate a benefit/cost (B/C) analysis for a community's urban street trees and their management. Estimates of tree benefits produced by the integrated software suite STRATUM depend, in part, on accurate estimates of tree age, dimensions, shape, leaf area, foliar biomass, and growth (i.e., regional growth curves). These parameters vary by species and location due to differences in growing conditions, management practices, climate, and soils. Once all regional growth curves are completed, this software suite will give every community that has an inventory (estimated or completely counted) of their street trees a capability of assessing the structure, function, and value of its urban forest and provide a stronger identity for the USFS and its stewards involved in urban and community forestry programs nationwide (McPherson 2003).

Critical to nationwide implementation of assessment tools like STRATUM, is biometric information on tree growth rates, dimensions, and leaf area for predominant species in each of the Nation’s 17 regional tree growth zones (McPherson 2003) (Figure 1). Accurate biometric data are essential to modeling annual benefits such as energy savings, rainfall interception, air pollutant uptake, and carbon dioxide sequestration. Currently, the Center for Urban Forest Research (CUFR) in Davis, California, has generated biometric data for five regions in the western U.S., and funds exist to do another regional pilot city, Charlotte, North Carolina in 2005. Additional funding is needed to conduct analyses for the remaining 11 regions. The cost for data collection and analysis is approximately $50,000 per city, excluding overhead, and the goal is to complete all 11 regions in three years (McPherson 2003).

Until southern regional growth curves can be established, techniques and guidelines suggested here can be used to estimate benefit/cost ratios for many southern cities. Techniques and technological advances are being developed to facilitate data collection

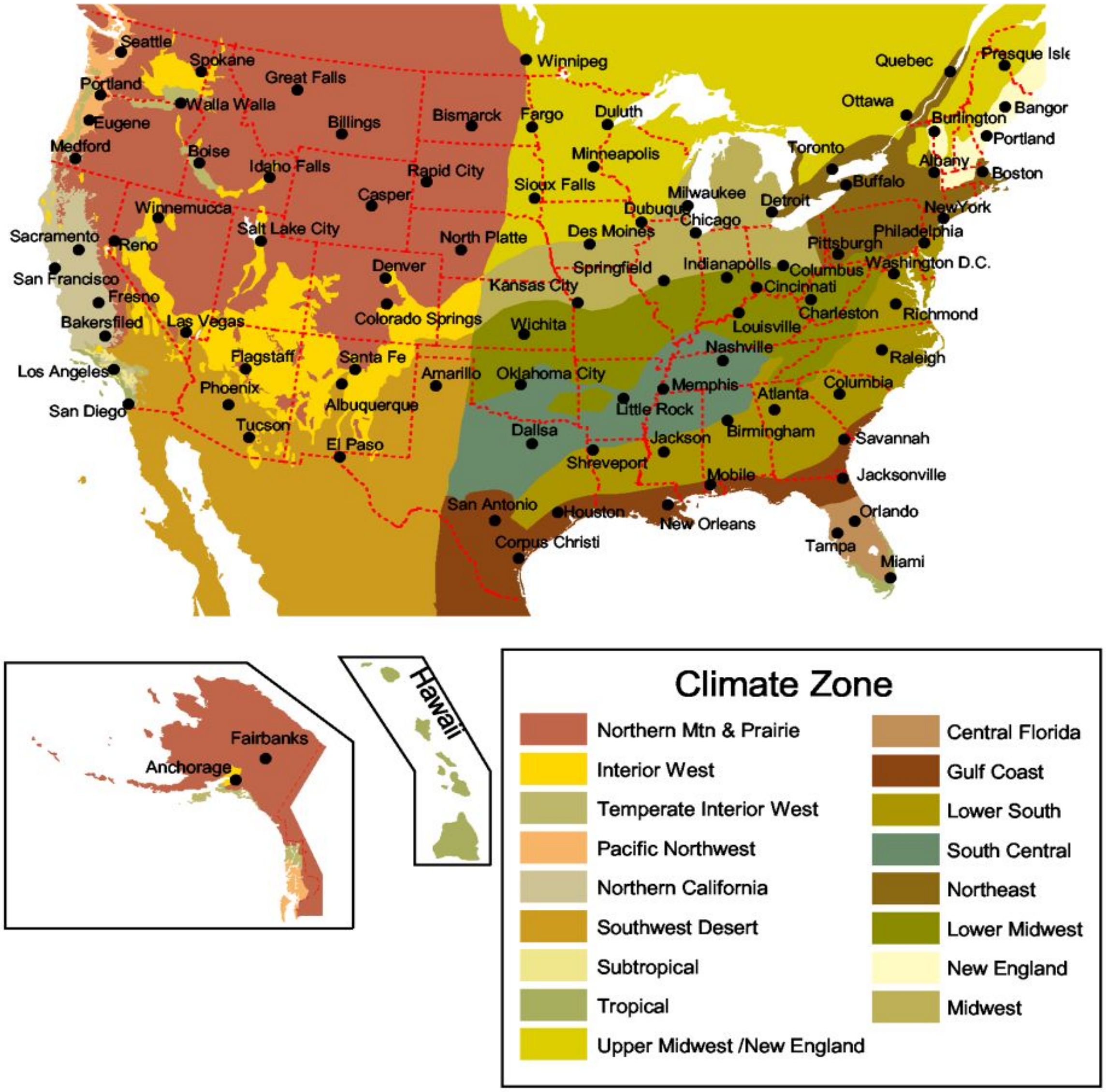

Figure 1: The 17 regional tree growth zones in the United States (McPherson 2003).

and storage more efficiently. Handheld global positioning system (GPS) units as well as palm pilots are being used for collecting data, while Geographic Information Systems (GIS) are providing new ways to store and manage collected data. These new advances all point toward more innovative ways to manage resources which, in this case, is a viable street tree inventory.

[Editor's Note: The current map of climate zones can be viewed at www.UrbanForestrySouth.org]]

Resource inventory is often undertaken as part of the planning phase in a tree care program. It is a comprehensive assessment of a community's tree resources and a fundamental starting place for most urban and community forestry programs. Inventories can be created using highly elaborate methods, involving computers and aerial photography or satellite imagery, or they can be accomplished using simpler techniques, such as a windshield survey of street trees. Technological advances, along with their learning curves and costs, need to be compared to simpler methods and associated costs (Maco 2002). Accuracy of the data (i.e., paper maps, CAD files, GIS coordinate systems, georefrenced imagery) acquired is critical to the accuracy of newly generated data for an inventory process.

All inventories should provide basic data on tree locations, numbers, species types, and to the extent possible, the condition or health of a community's trees. Inventories often focus initially on trees on the public estate (i.e., park and street trees); but increasingly, the availability of computer/remote sensing technologies are allowing communities to conduct comprehensive tree inventories on both public and private lands.

With recent technological advances in GIS, tree inventories can be produced with a database containing appropriate attributes (i.e., species, diameter, height, canopy spread, location, pruning needs), which can be used with STRATUM to calculate the benefits and costs of a community’s street tree inventory. These databases can be created and stored in a retrievable format that can increase effectiveness and efficiency in an UFD.

Technology in GIS has now advanced to a point where street tree inventory database files created with a licensed computer program (i.e., ArcGIS) can be supported in a GIS Internet Map Server (IMS) (Goodwin 1996). An IMS can provide users access to other digital data (i.e., parcel maps, utility lines, topographic maps, watersheds, wetlands), which can be used by interested individuals or groups and not require a program license. Interested individuals or groups using an IMS could be in a city's workforce looking to improve management or in the public domain looking for developable land.

JUSTIFICATION

One global problem faced by society is the phenomenon of urbanization. The United States population roughly doubled between the late 1950s and 2000, and the population of the South has grown at an even faster rate (USSRS 2005). An ever increasing urban population, especially in the Sunbelt, has led to unchecked growth, with living and environmental conditions deteriorating at an alarming pace in many urban areas. The share of the U.S. population living in the South grew from 30.7% in 1990 to 32.5% in 2000. People tend to move to, and expand, urban/suburban areas. Urbanization has had, and will have, a substantial impact on the extent, condition, and health of a municipality's surrounding forests and other natural resources.

Urbanization places a heavy burden on city planners and managers who struggle to balance competing demands for residential, commercial, and industrial development with directives to minimize environmental degradation. City planners, managers, and government agencies are increasingly relying on the use of information technologies and spatial modeling techniques to effectively manage this development process on a sustainable basis (Sugumaran 2005). Web-based decision support models are being developed using IMS for modeling urban growth. These web-based models are being used to identify watershed sensitivity, as well as other environmental issues, with a variety of user-defined conditions for a rapidly growing urban area. By using multi-criteria evaluation tools, users are able to specify which criteria, and what weights, the model can use to generate a future scenario (e.g., urban sprawl affecting street tree canopy cover (CC) or watershed quality). Being web-based, these models can be used by any interested group or individuals (with basic computer navigational skills), in contrast to other similar tools (e.g., programs with software licensing) which are accessible only to those with the data, expertise, and computing power to use them (Sugumaran 2005).

Many urban planners in metropolitan areas have computer-aided programs which allow them to develop a comprehensive inventory of public and private trees as well as document benefits provided by an urban forest. This research project will illustrate, for a community (or group of communities) a methodology on how to undertake a sample street tree inventory using the computer program ArcGIS. Most cities and towns do not have tree inventory data on numbers of street trees, health of their forest, or number of trees they gain or lose each year. The key point is that sampling methodologies for street trees have been developed using paper maps (e.g., Maco 2002, Jaenson et al. 1992); however, to date a methodology using a GIS has not been developed.

The net impact of this lack of data can lead to a misunderstanding of the status, condition, and trends affecting urban and community forests. Not only will communities be unable to document monetary benefits and costs of their trees but, without good inventory data, communities are limited in undertaking systematic planning for tree resources and adequately documenting benefits that trees provide to the community as a rational legal basis for protecting trees threatened by development.

This lack of knowledge about urban forests extends into the realm of the public utilization of technical information. Although there is a growing body of literature and educational materials available; there remains a need to deliver this information in a way that develops a broad public appreciation of the value and importance of urban forest resources and institutionalizes the proper technical expertise in urban forestry, community development, and public infrastructure in regard to the health requirements of urban trees.

Maintaining an inventory of urban street trees is a dynamic process involving citywide and individual needs of trees. While most trees are included in an inventory as a result of validation through censuses, inspections, and construction/economic development, there will also be trees that have been added to the inventory without notice due to unmonitored neighborhood or individual planting. There are also street trees located within a city's public space which are not the responsibility of an UFD (Godfrey 2005). These are trees located in areas maintained by federal and state highway administrations. Trees located in these areas are sometimes mistakenly referred as a service request (e.g., pruning, removal) to the UFD. However, once the request is inspected by an UFD representative, it is forwarded to the appropriate agency (e.g., state or federal highway departments). Also, while the inventory may consist of street trees as defined by an UFD (i.e., public space), there will also be trees that may be planted contiguous to the public space on private property, whose growth habits (i.e., above and below ground) can impact public spaces. Above-ground tree growth can impact public spaces when limbs break, hang, or fall onto a sidewalk or street. Hardscaping features such as, sidewalks, streets, or buildings can experience damage due to improperly located trees or by root growth in the wrong location. Conversely, a tree's roots may experience damage or death by hardscape features improperly located. In most cases, if a tree fails, it will become the responsibility of an UFD (Godfrey 2005). All UFD internal and external operations involving any of the previously mentioned situations (i.e., service requests, work orders, jurisdiction, location by species), can be managed through a GIS.

Methods laid out in this research project can provide guidelines directly tied to urban forest land coverage to reflect a new, GIS performance-based approach (i.e., sampling using ArcGIS) to goal setting. Having quantitative guidelines will allow the state, individual communities, and citizens to assess progress toward an urban forest vision supported by a budgetary guideline, and to adjust strategies and programs accordingly. Little research has been done in this area particularly in the South; however, a study by Jones and Grado (2005) looked at these issues and estimated a benefit/cost ratio (BCR) of 4:1 for the lower south city, Hattiesburg, Mississippi.

Measured progress towards meeting the goals of an urban forest vision will require states and communities to devise a new way of thinking about their tree resources. Using dollar values as guidelines, tree resources may be seen less as a limitless, expendable commodity that can be ignored, and more as a renewable resource that must be properly managed to benefit the whole community. The use of a GIS to record these resources and their attributes can provide any city or town with a process to understand benefits and management costs derived from street trees (Goodwin 2005).

Objectives

The primary objective of this project will be to develop a unique, yet effective methodology that employs ArcGIS tools to estimate (i.e., thru sampling) a street tree population in a GIS format. The city of Hattiesburg will serve as the basis for a model; however, other cities with completed inventories (e.g., Horn Lake and Meridian, Mississippi; Brookline, Massachusetts) will be used for validating the methodology. By using a city with a complete tree inventory to test this sampling methodology with the appropriate statistical methods, a level of reliability and confidence for estimating street trees and their parameters can be validated. Also, it will provide confidence limits and a standard error as to this technique's precision when estimating a street tree population which will present a reliable message to decisionmakers. Another objective will be to provide Hattiesburg, Mississippi, and other small- to medium-sized southern communities, a baseline to assess their street tree populations and develop cost effective tree planting and care programs. Project results will also provide urban areas, with a process to establish BCRs, which can help management, justify costs associated with their urban forestry activities and programs. The last objective will be to provide municipalities with insights into the benefits GIS can provide through increased efficiency, time and cost savings, revenue generation, decision support, improved accuracy, and the capability of automating tasks.

LITERATURE REVIEW

Costs of Urban Forestry

Large cities in the United States possess the resources to conduct urban forestry research; however, many small cities or communities do not (Maco 2002). Small communities, with small fiscal budgets, usually do not have the resources, whether monetary or technical, to conduct a comprehensive municipal tree assessment. By evaluating methods which are affordable and reliable, small communities will be able to manage their city trees for long-term sustainability of their urban forests. A new understanding of street tree populations in small communities will help managers mitigate urban heat islands, conserve water and reduce flooding, reduce air and water pollution, identify hazardous tree species, reduce sidewalk repair costs, preserve landmark trees, and protect critical wildlife habitat (Maco 2002). City leaders should be made to realize that benefits provided by investing in their trees can help make their cities more enjoyable places to live, as well as help attract new businesses and residents. As an example, if promoting tourism is a community objective; an attractive urban forest can help achieve this goal. However, success in achieving these goals can only be accomplished by providing urban and community leaders with appropriate assessment tools and information on the coinciding costs for use in evaluating urban and community forest programs.

Benefits of Urban and Community Forestry

The dollar value urban forests provide are tied to increased real-estate values; climate control and energy savings; air, soil, and water quality improvements; mitigation of stormwater runoff; reduction of the greenhouse gases such as carbon dioxide (CO_2); wildlife habitat and corridor improvements; as well as aesthetics and community vitality and well-being (Dwyer and Miller 1999). Identifying and describing these benefits is considered an essential step to increasing public awareness and support for urban and community forestry programs.

Benefit Assessments

One of the many benefits provided by street tree planting is appreciation of real estate value. Anderson and Cordell (1988) found that a single large front-yard tree was associated with a $336 increase in the sales price of single-family homes in Athens, Georgia. Not all trees are as effective as front-yard residential trees in increasing property values. For example, trees adjacent to multi-family housing units will not increase property values at the same rate as trees in front of a single-family home.

Changes in building energy use from tree shading can be assessed based on computer simulations outlined by McPherson and Simpson (1999). These models incorporated differences in building structure, climate, and effects of shading. Building characteristics were differentiated by age of construction (pre-1950, 1950-1980, and post-1980) and took into account number of stories, floor area, window area, and insulation (McPherson and Simpson 1999).

Guidelines developed by McPherson and Simpson (1999) can also be used for calculating CO_2 reductions attributed to urban forests. Net CO_2 reductions were calculated on the basis of avoided emissions as the product of energy use and what can be directly sequestered and released through tree growth, removal, and maintenance. These guidelines illustrated how to sum stored sequestered CO_2 in above- and below-ground biomass over the course of a year for representative species of nine tree classes.

Xiao et al. (1998) described how numerical simulation can be used to estimate annual rainfall interception and storage by urban trees. The model incorporated tree species, leaf area, crown density, and height, and used hourly meteorological and rainfall data specific to a municipality. The implied value of the intercepted rainfall ($/m^3) was based on an annual expenditure for a municipality stormwater quality program. This simulation can produce a total annual benefit of intercepted rainfall over 40 years, or whatever time is estimated to recoup complete reinvestment for a stormwater quality program (Xiao et al. 1998).

Environmental benefits of trees are associated with the amount of CC they will provide (Maco 2002). Ideal CC is difficult to assess for a given community because of influencing factors (e.g., climate, land use, location). Though it is generally considered that more CC is better, a most favorable degree of CC can be assessed for a given city (Clark et al. 1997). In general, varying levels of CC depend on location and the municipality’s objectives on that area for development and tree cover. Municipalities can perform a periodic CC analysis to determine whether their ordinances and management methods are adequate and effective in increasing CC (Bernhardt and Swiecki 1999).

McPherson et al. (1999) derived benefits associated with extending pavement longevity, and assumed a standard estimation by which 50% of street tree canopy provided direct shade over street pavement. However, a more accurate estimation can be made using simple trigonometry with data collected in a sample inventory incorporating planting location and average setback distance (Maco 2002). This method measures not only actual total CC, but the amount of CC over pavement and sidewalks, yielding results applicable to quantifying benefits as well as providing a measure of management success and comparison with other communities. An alternative proposed by Bernhardt and Swiecki (1999) used an index based on CC at the edge of pavement (CCEP). While useful for comparison over time, CCEP is not a true measurement of CC and cannot be used to estimate benefits directly related to the area of CC (Maco 2002).

Remote sensing is a technology of collecting data by way of imaging while not in direct contact with the area, object, or phenomena under investigation (Lillesand and Kiefer 2000). This art and science is enabling cities to analyze their urban forest CC. For example, American Forest's computer program, 'City Green' uses satellite imagery (Landsat) taken at different intervals in time (e.g., 1972, 1982, 2000) to show change in CC. Remotely sensed imagery from aircraft and satellites represents one of the fastest growing sources of data available (Maco 2002). Imagery obtained with this technology is collected using either passive or active sensors to collect data. Data collected with a passive sensor relies on naturally reflected or emitted energy of the surface's appearance (similar to a photograph taken under sunlit conditions). Most remote sensing instruments fall into this category, which obtains pictures of visible, near-infrared, and thermal infrared energy. Data collected with an active sensor provides its own illumination and measures what illumination returns to the sensor in ranging stages. Remote sensing technologies using active sensors include LiDAR (laser) and radar (Lillesand and Kiefer 2000). This technology is expanding methods used previously, as well as providing new ways to look a city's natural and built resources either separately or together.

Recent studies in California facilitated by the USFS's Urban Forestry Research Center have developed procedures for qualifying B/C analysis for urban forests (McPherson et al. 1999). This research described methods used to estimate environmental benefits provided by urban trees in Modesto, California. Twenty-two of Modesto's most abundant species were inventoried in a two-stratum random sample of young and old trees. Data collected on tree age, size, leaf area, and biomass were used to estimate growth rates for each species. The Modesto study included many tree species found in Hattiesburg, Mississippi which will be used as a baseline in this study.

Maco (2002) used a practical approach to assess structure, function, and value of street tree populations in small communities. This methodology provided Davis, California (population 55,000) with a BCR of 3.78:1. In other words, for every $1 invested in street tree management $3.78 was returned to the community (Maco 2002). Maco's methodology, while not based on a GIS format, provided an affordable approach for small- to medium-sized cities seeking to perform BCR analyses.

A 2005 study using Hattiesburg, Mississippi, as the study area, examined the benefits and costs of their street tree program (Jones and Grado 2005). This study demonstrated an approach for small- to mid-sized communities with limited funds to estimate their street tree population with a sample inventory. This was demonstrated with examples and illustrations to simplify the process for those with limited knowledge of a tree inventory. This study used methods, adaptations, and inferences similar to a study performed in Davis, California. A BCR of 4:1 was estimated for Hattiesburg, Mississippi.

Hattiesburg's five wards were divided into 11 zones for the sample inventory. Conditions of street trees varied with each zone. Good trees ranged from 41 to 83% over the 11 zones. Fair trees ranged from 12 to 34%, while dead and dying trees ranged from 2 to 25% over all zones. Results indicated that Hattiesburg maintains nearly 12,000 public street trees in their five wards that provide over a half million dollars in net annual environmental and property value benefits, with a benefit-cost ratio of 4:1 (Jones and Grado 2005). The study demonstrated how the city can acquire information to assist in improving the long-term stability of this valuable resource (i.e., street trees) by managing diversity, CC, and maintenance on a zone by zone basis.

Street Tree Structure

Explaining street tree structure is a first step in providing an understanding of tree program costs. This will enhance the effectiveness of long-term management and increase the ability of street trees to maintain community benefits. Species composition, age complexity, CC, condition, and plantable spaces are the structure's telltale indices of urban forest health, stature, management needs, and conflicts (Maco 2002). Only by explaining tree structure can dollar values be assigned to the environmental functions street trees provide to enable tree caretakers to use this information to maximize those benefits while reducing costs.

Several trees that occur in Modesto, California also occur in Hattiesburg, Mississippi (e.g., crape myrtle (*Lagerstroemia indica*), Chinese tallow (*Sapium sebiferum*), Southern magnolia (*Magnolia grandiflora*), sycamore (*Plantanus spp.*) and oaks (*Quercus spp.*). Comparisons can apply, yet further research will be required to compare possible differences in growth rates due to climatic differences. Using methods of digital image processing, described by Peper and McPherson (1998), crown volume and leaf-surface area (LSA) was estimated for each species group (Peper et al. 2001). Non-linear regression was also used to fit a predictive model for diameter at breast height (dbh) as a function of age for each species. Predictions of LSA, crown diameter, and tree height were modeled as a function of dbh using the same model as dbh versus age (Peper and McPherson 1998).

Clark et al. (1997) stated that the vegetative resource is the engine that drives urban forests. Moreover, its structure, arrangement, scope, distribution, and physical condition all define the effective benefits provided and costs accrued (Dwyer et al. 1992, Clark et al. 1997). Like any resource, caretaking and management of urban forest resources should begin with an inventory (Miller 1997).

Benefit/Cost Analysis

During the early 1980s BCRs were an unfamiliar concept in urban forestry, yet Bartenstein (1981) promoted BCRs as a planned precedence for assessing urban tree program cost-effectiveness. Hudson (1983) demonstrated that B/C analyses quantified benefits gained through city street trees, but demonstrated the need for caretakers and managers of urban forests to identify all program costs. This need was viewed as an important step in developing an economically feasible urban and community forestry program. As the process moved into the early 1990s, McPherson (1992) found that B/C analysis could be used as a planned method to acquire funding for urban forestry programs. This was accomplished by showing the rate of return through investment in an urban forestry program. With an understanding that B/C analyses were guides to be used, and were not constant, this provided caretakers and management with insights on how to direct their program needs. Freeman (1993) acknowledged the true utility of B/C analysis:

> "If the objective of management is to maximize the net economic values associated with the use of environmental and natural resources, then benefit-cost analysis becomes, in effect, a set of rules for optimum management and a set of definitions and procedures for measuring benefits and costs."

There has been extensive research and recommendations on what could be quantified in monetary terms in the caretaking and management of urban forestry (Dwyer 1991, Gobster 1991, Hull and Ulrich 1991, McPherson 1991, Schroeder and Lewis 1991, Dwyer et al. 1992, Macie 1994), but actual quantification has been slow in coming. Fewer still are efforts aimed at putting quantified components into a full-scale B/C analysis (Maco 2002). This has been particularly true in the southern United States.

B/C analyses have been performed in large U.S. cities such as Chicago, Illinois and Sacramento and Modesto, California (McPherson et al. 1994). By quantifying and qualifying the structure of their city trees, these communities were able to show the dollar values of their urban forestry programs. This type of analysis has shown that benefits of street trees can outweigh program costs (i.e., Davis, California returns $3.78 in benefits for every $1 of costs). They have also demonstrated how street tree assessments lead to better tree programs with fewer costs and more public and environmental benefits (Maco 2002).

Geographic Information System

The true advantage of a GIS over separate conventional maps or analytical spreadsheets is the ability to utilize the map and related data together. In a GIS environment, the base map remains constant in the ever-changing kaleidoscope of interactive data analysis and comparison functions that is only possible with GIS technology (Godfrey 2005). Case studies (e.g., Brookline, Massachusetts; Grand Terrace, California; Washington, D.C.) involving municipal street tree management using GIS to its full potential, have shown how management becomes more thorough and cost effective.

Funding through a grant from the USFS's Northeastern Area Urban Forestry Research Center and private sources precipitated a partial street tree inventory in Springfield (complete in the Metro center, but not the whole city) and a complete street tree inventory in Brookline, two Massachusetts municipalities. These cities employed the use of a GIS to record their street tree locations and attributes (Goodwin 1996). This 1995 study demonstrated how GIS software provided for more efficient street tree management. By using tree locations, attributes, and maintenance needs, which have been carefully inventoried and stored geographically, managers will have a functional ability to process their data more cost effectively.

Many GIS initiatives are precipitated at the local municipal level as a desire to promote the community to others and to residents (Berado 2005). The impetus could all begin with a municipality's need to update a hand drawn street map. Upon completion, this street map can be made available to residents, visitors, and a municipality's many departments (i.e., public safety, public works, code administration, police) where other resources (e.g., street signs, fire plugs, 911 addresses, water mains, shut off valves) can be inventoried to assess conditions and needs. When a street tree inventory database (either as a sample or complete) is completed as part of a planned GIS implementation, it can become an integral part of the overall development of an urban forestry program (Berado 2005).

A case study in Grand Terrace, California, demonstrated how, in spite of having a small staff with many diverging demands on their available time, the benefit of a GIS program aided in a small city’s development and increased management’s efficiency (Godfrey 2005). The study outlined some ambitious goals within the city’s GIS program. Through grants available to many municipalities, software was acquired, and through cooperation with adjacent jurisdictions and regional agencies, Grand Terrace was able to initiate this program. The evolving goals were in line with the City Council's overall goal of improved communications with the community. The city recognized that by providing widely available geographic and related information to its staff and citizens, it enabled its staff to do their job more efficiently and effectively, as well as providing requested information to citizens of Grand Terrace via the Internet (Godfrey 2005).

A case study in Washington, D.C. demonstrated how using a GIS computer program to store and query inventory data in conjunction with a central relational database management system platform, can provide a municipality’s UFD with a dynamic tool for integrating functional requirements (Godfrey 2005). The primary functional requirements of any new system can include customer call intake, generation of service requests, tracking of inspections, generation and tracking of work orders, flexible reporting capabilities, cost tracking (internal and external work), inventory, work history, maintenance, capability for field data collection and download (real time and/or end of day), and distributed access and maintenance.

Godfrey's study demonstrated how, when planning a GIS-supported tree information system, it should be flexible, have an open architecture, and maintain an intuitive manner of data entry for maintenance and editing. This was demonstrated, when determining data needs for a tree inventory system to determine process refinement of business and data flow modeling in a GIS environment. By defining a business process model (i.e., the flow of business process activities) and a data flow model (i.e., the timing and responsibilities for data input and output) a municipality can better understand input and output data requirements for their information system.   This study demonstrated, by distinguishing static data (i.e., addresses) from dynamic data (i.e., dates), that insights can be provided into daily, weekly, monthly, and yearly reporting cycles and performance benchmarks (Godfrey 2005). This study's importance is in illustrating the process for determining functional requirements for a GIS and how it will become important in defining the database model necessary for a tree inventory model.

Street Tree Sampling Methods

Methods described for this study on estimating street tree populations were based on accepted and validated methods to conduct random stratified samples of street tree populations. Jaenson et al. (1992) established a methodology to estimate a city's street tree population and its structural characteristics. Maco (2002) further developed this methodology by establishing an order of equations to estimate street tree structural characteristics in a manner which can be applied to estimating resource units to benefits.

Jaenson et al. demonstrated, and Maco confirmed, that using 2,300 street trees as a sample will provide an accurate estimation of species diversity, population, and other variables. Increasing sample size will increase precision; however, the improvement will not be substantial enough to warrant the extra time, personnel, and data analysis (Jaenson et al. 1992).

Sampling Methods in Geographical Information Systems

Duzgun and Usul (2005) demonstrated how a GIS-based sampling methodology can be used to estimate mean elevation in a river basin without research bias. This study showed that, by using ArcGIS, sample size can be determined in a probabilistic sampling method. The method estimated mean elevation based on simple and stratified random sampling techniques. By drawing various sized samples and comparing their summary statistics (i.e., mean, mode, variance, standard deviation) and their calculated confidence intervals, the size of the sample was determined. An optimum sample size for a sampling scheme was determined using a confidence interval length and its mean standard error. This study demonstrated a technique and algorithm development for both simple and stratified random sampling using visual basic applications (VBA) within ArcGIS. VBA provided ArcGIS users with the ability to write codes and describe unique objects as well as create customized commands, menus, and tools.

Determination of required sample size is an important task in many spatial problems, since the accuracy of estimations about the population is basically dependent on sample size (Duzgun and Usul 2005). Although there are some rules of thumb on the required sample size in conventional data analysis (Walford 1995), when a sampling frame is spatial, the optimum sample size is dependent on the area of concern.

Sampling methods are basically divided into two categories (i.e., probability and non-probability sampling). Non-probability sampling is based on subjective judgment (i.e., researcher bias), while probability sampling uses random chance as a determining factor for an observation in the sample (Walford 1995). In this respect, probabilistic sampling has advantages over non-probabilistic sampling since it ensures that all population members have an equal chance of being included in the sample. It also minimizes bias introduced into the sample by subjective judgment of the researcher.

The five most commonly used sampling types in probabilistic sampling are simple, stratified, nested, cluster, and systematic (Duzgun and Usul 2005). Two of the most commonly used types of probabilistic sampling employ simple and stratified sampling techniques. These can be successfully used in determining street tree populations (Jaenson et al. 1992). Simple sampling is usually reserved for situations where population size is known. Duzgun and Usul's methodology assigned each member of the population (e.g., known points of elevation) a unique reference number. Using a random number generator with these unique reference numbers (i.e., possible samples), a sample of these reference numbers were drawn from the population. Duzgun and Usul (2005) demonstrated how simple random sampling forms the basis for other probabilistic sampling methods (e.g., stratified random sampling). By using stratified random sampling, which involved grouping population members into strata (e.g., zones) according to similarities (e.g., density of elevation points), their study demonstrated how samples can be drawn from each stratum by using the simple random sampling technique. The study concluded that by using tools in ArcGIS to perform a probabilistic sampling method, samples can be drawn from stratum in a study area without researcher bias.

STUDY AREA

The economy of Hattiesburg, Mississippi evolved from the timber industry in the late 1800s and the city was incorporated in 1884 (City of Hattiesburg 2003). Located at the fork of the Leaf and Bouie Rivers, Hattiesburg provided a unique blend of affordability and a high standard of living for its nearly 50,000 residents.

Hattiesburg's growing micropolitan area, which includes Forrest and Lamar Counties, was designated a Metropolitan Statistical Area in 1994. In 1994, it ranked 68th among 313 metropolitan areas in the United States for "economic strength," with a combined population of more than 100,000 residents (Fruth 1997).

Hattiesburg is known as the "Hub City" because U.S. Highways 49, 11, and 98 and Interstate 59, radiate from the community like spokes from the hub of a wheel. Hattiesburg's location, within 100 miles of Jackson and Natchez, Mississippi; Mobile, Alabama; and New Orleans, Louisiana provides easy access via modern highways.

The primary street trees occurring in Hattiesburg to be targeted for inventory will include but not be limited to the following categories: deciduous oak, crape myrtle, hackberry, maple, pecan, sweet gum, sycamore, and live oak, magnolia, and pine.

METHODOLOGY

Sampling Using a Geographic Information System

The methodology will be based on a GIS procedure which conducts random stratified sampling in known populations of points (i.e., points created in ArcGIS and referenced with VBA) (Duzgun and Usul 2005). Methods described present a unique

GIS-based methodology based on sampling to estimate a city’s street tree population and its structure. These methods will add to the urban forestry body of knowledge through the creation of a street tree sampling approach using a GIS platform as a model. This approach can work with the USFS’s benefit/cost analysis program STRATUM to provide guidelines for decisionmakers tied to urban and community forest management. To date, a street tree sampling approach using a GIS has not been publicly established. This will benefit many urban areas and interested groups who may be convinced of the advantages in using a GIS supported street tree sampling method to estimate benefits and costs street trees provide. With these inventories properly stored in a GIS format, communities will possess the ability to query a single tree or all trees sampled with a certain attribute (e.g., species, dbh, height, age, condition, pruning requirements) or for any attribute pertaining to benefits and costs.

For a building to stand firm and endure through the years, a strong foundation is required so integrity is not in question. This principal holds true when building a municipal GIS program (i.e., street tree inventory, fire hydrant inventory, parcel maps, zoning districts). The foundation for a street tree inventory is an accurate base map. Just as a foundation determines how well a building will stand, the base map determines how functional the municipality’s GIS will be. There are many base maps readily available; however, choosing the appropriate base map depends on functionality and intended use. Base maps that can function in combination with utility infrastructure, emergency address locations, law enforcement, municipal land use, and urban planning applications provide strong foundations. As an example, customized layers of geographic and attribute data regarding land uses, are generally defined with color arrays. However, without an accurate base map to overlay or compare them to, these splashes of color will look more like an abstract painting on your computer screen than designations of residential, commercial, or agricultural properties.

The methodology uses tools in ArcGIS (e.g., spatial analyst, visual basic scripts, geoprocessing wizard) to sample and assess street tree populations in any city or community. This process is aimed at planting locations (i.e., with trees or without) in public spaces. This approach provides spatial locations (i.e., geographically located points) of street trees and four types of inventory information:

- tree structure (species composition, diversity, age distribution, condition),
- tree care needs (sustainability, canopy cover, pruning, young tree care),
- tree function (magnitude of environmental and aesthetic benefits), and
- tree value (dollar value of benefits realized versus costs).

Using a GIS supported computer program (i.e., ArcGIS) developed by the Environmental Systems Research Institute (ESRI) with an appropriate base map, a stratified sampling technique of planting spaces (PSPs) will be applied to municipal street trees and any additional private street trees located in the public right-of-way (ROW). PSPs are points spaced 30 feet apart placed on top of street lines and represents the area to be inventoried (i.e., trees within 15 feet of a street). PSPs will be targeted for inventory in Hattiesburg, Mississippi during 2005. Street trees found in PSPs are used to estimate the population and its structural characteristics. Statistical sampling shows that a suitably selected random sample consisting of only a small fraction of the population can often be used to estimate characteristics of an entire population with an acceptable high level of accuracy which implies an acceptable low degree of error (Cochran 1977). The purpose of the sample inventory will be to estimate tree populations based on planting space occupancy. Inferences from frequency of occurrence of growth categories will estimate Hattiesburg's citywide totals of municipal and private street trees and their structural characteristics with enough accuracy to confidently describe the forest's attributes as provided by tree cover.

In this study, a GIS-based methodology is proposed for implementing a stratified random sampling technique that uses PSPs (i.e., with trees or without) as the determinant variable. The optimum sample size is determined by using the geostatistical analyst tool in ArcGIS. The sampling method will be implemented on Hattiesburg, Mississippi, a city without a complete tree inventory, and Meridian, Mississippi a city with a complete tree inventory recorded in a GIS format. To draw planting space samples in a GIS environment, summary statistics such as mean, mode, variance, and standard deviation are used as well as confidence intervals. The optimum sample size for the sampling scheme is based on the length of the confidence interval and standard error of the mean. The methodology should improve accuracy when estimating street tree populations as well as reduce costly and time consuming fieldwork.

Sampling Method of Planting Spaces

City Zonation

Using street data, provided by Hattiesburg, Mississippi's GIS department, in the form of digital line and polygon shape files, stratified random sampling of planting spaces will be performed. To apply the sampling method, Hattiesburg, Mississippi's streets within the city limits require that sampling points be placed on all streets. These points, located 30 feet apart, are created as a map layer using the ArcGIS Toolbox. Street density is analyzed using the spatial analyst tool in ArcGIS. Using spatial analyst's density classifying extension, unique zones of street densities are created as polygons. These polygons are color coded in ArcMAP to distinguish each density zone as a specific colored polygon (Figure 2).

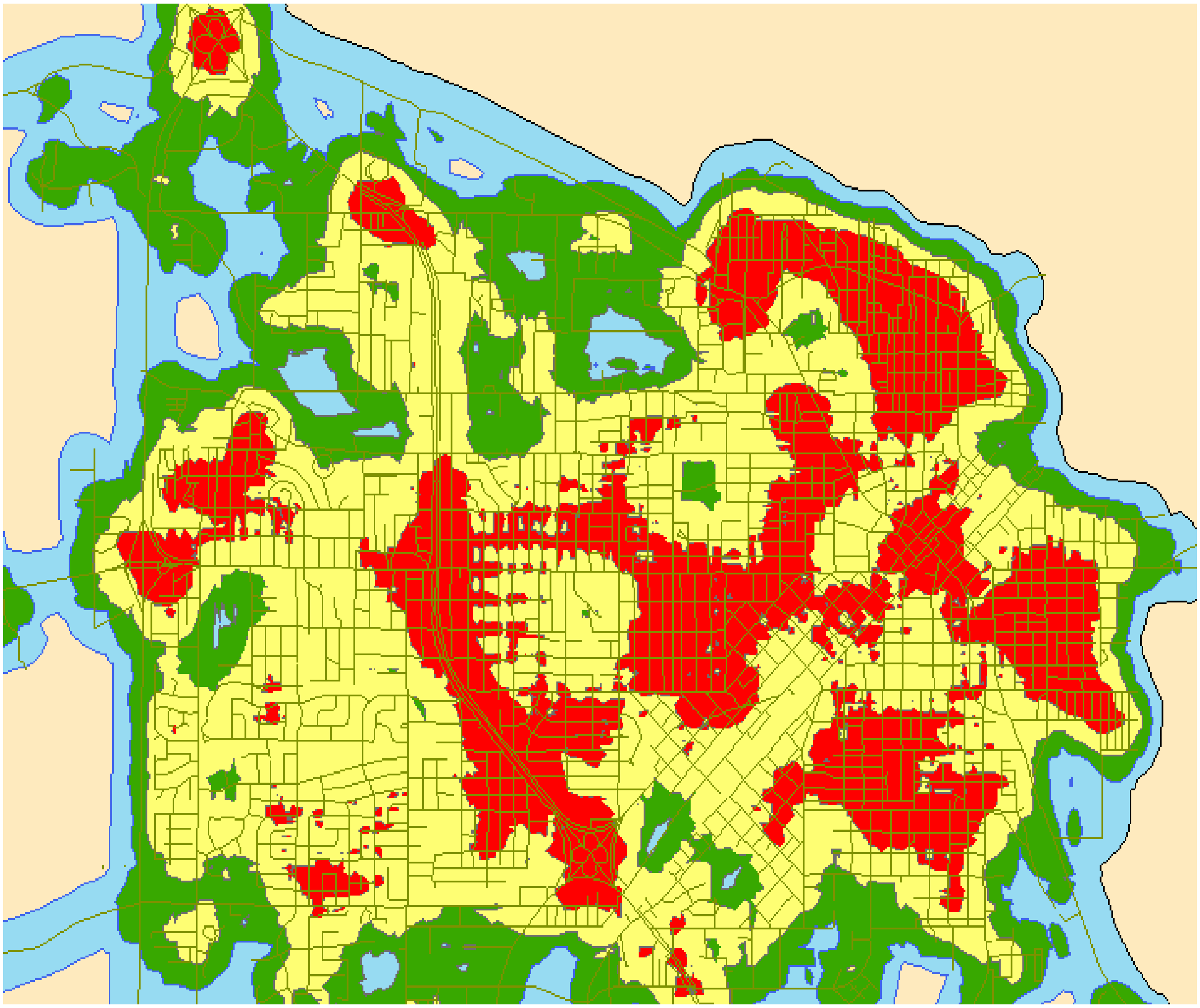

Figure 2: Hattiesburg, Mississippi street map illustrating 5 zones based on street density. Zone 1 high density is red, zone 2 medium-high density is yellow, zone 3 medium density is green, zone 4 low-medium density is light blue, and zone 5 low density is beige.

These density zone polygons are used to create new map layers specific to each zone's unique street density (e.g., high, medium-high, medium, low-medium, low).

Using the geoprocessing wizard tool in ArcGIS, streets with points in each density zone polygon are clipped to form new density zone layers (Figures 3-4).

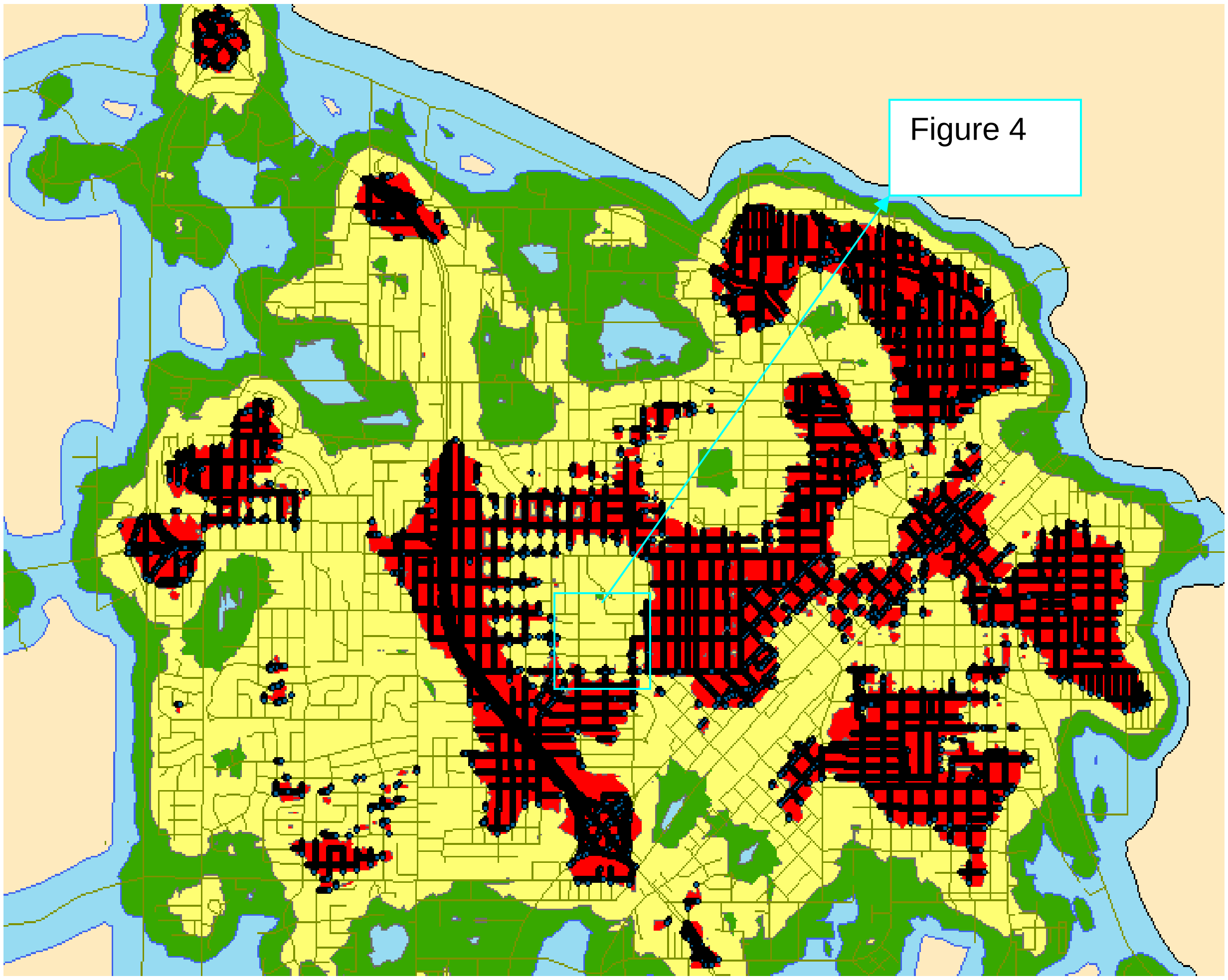

Figure 3: Hattiesburg, Mississippi street map illustrating uniquely referenced sampling points in the high density polygons as a new layer. Figure 3 illustrates how high density polygons are used to clip uniquely referenced sampling points from a base map layer to form a new layer based on street density. Zone 1 high density is red, zone 2 medium-high density is yellow, zone 3 medium density is green, zone 4 low-medium density is light blue, and zone 5 low density is beige.

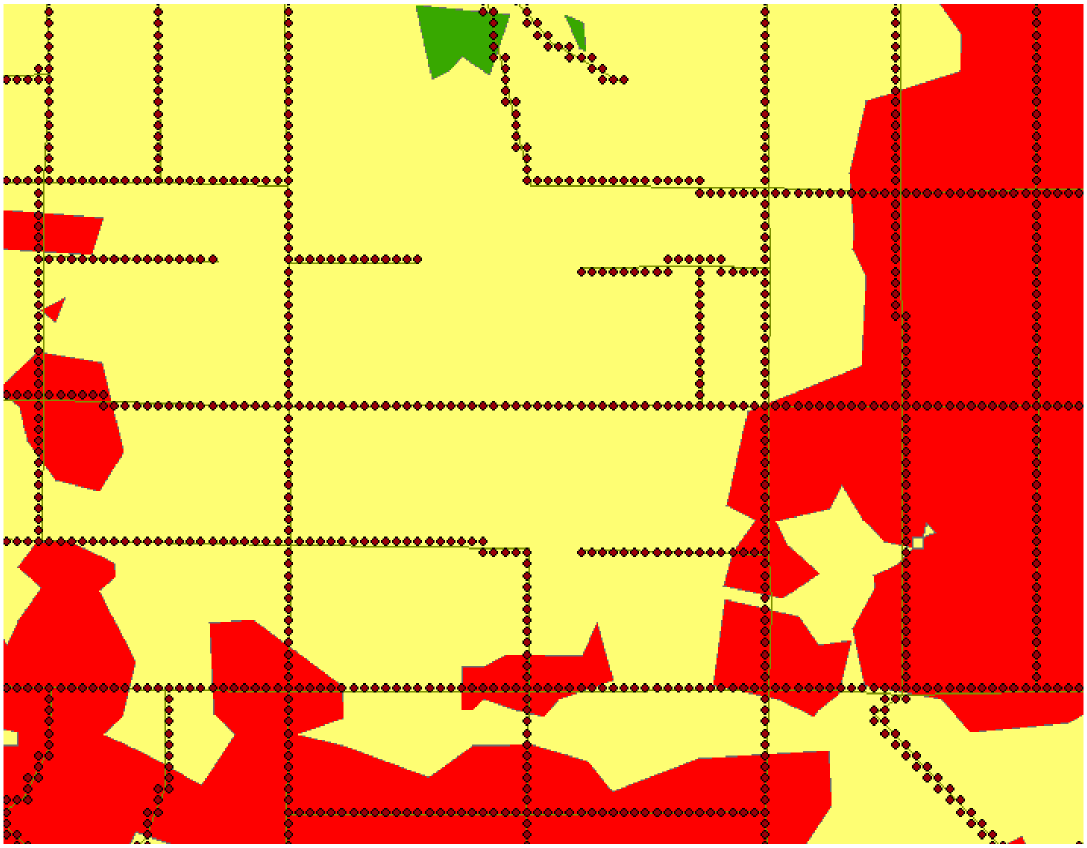

Figure 4: Hattiesburg, Mississippi street map illustrating how uniquely referenced sampling points are placed on street lines, illustrated as an enlarged view. Enlarged view is a cut out of Figure 3. Zone 1 high density is red, zone 2 medium-high density is yellow, and zone 3 medium density is green.

Each new zone layer unique to its street density contains polygons with URSPs. Street points are uniquely referenced using the visual basic script function in ArcMAP. This gives each density zone a known amount of uniquely referenced points (i.e., sampling points). After the clip function, there will be a certain number of points found in each density zone. Using each zone's unique amount of points divided by the total amount of points found citywide places a percentage on each zone. As an example, if 84,000 points were found citywide and 30,000 points were found in zone 1 of high density, it would comprise 36% of the points in all zones. Where 10,000 points are found in zone 5 of low density it will represent 12% of the points in all zones. Using this sampling scheme, 36% of the total sample size is selected from the 1st zone, and 12% is drawn from the 5th zone. To take a well distributed sample of PSPs, citywide density zones are weighted. Weighted zones estimate numbers of street trees found in each density zone with greater precision. Zones are weighted using equations that pre-samples and estimates the percentage of street trees to target in each zone.

Using each density zone, the next step is to implement the stratified random sampling method with Duzgun and Usul's algorithm. The algorithm developed by Duzgun and Usul (2005), for stratified random sampling is as follows:

1. Generate random numbers between the coordinate ranges of the sampling points.
2. Search the total population and find the corresponding point which has coordinates generated randomly in Step 1.
3. Read the unique reference number of the selected point.
4. Locate the point into one of the five zones by checking its unique reference number.
5. Repeat Steps 1-4 until each zone contains the required number of samples.
6. Determine the optimum sample size.

To determine optimum sample size, several samples are drawn based on Step 1. Statistics such as, mean, standard deviation, variance, mode, minimum (min), maximum (max) and standard error of the mean are computed and confidence intervals established. Statistical results of samples drawn indicate the sample size to draw by comparing each sample's confidence interval and standard error. Large samples indicate a decrease in confidence interval and standard error while small samples indicate the converse.

Street Tree Sampling Target

Using Jaenson's stratified sampling technique, municipal street trees and any additional private street trees located in the public ROW will be targeted for inventory (i.e., trees within 15 feet of street) in Hattiesburg, Mississippi during 2005.

Using a "windshield" survey method, each of the randomly chosen sampling units previously mentioned will count the total number of city trees present using inventory protocols and field inventory sheets (Appendix A). Trees on both sides of street segments will be counted. To estimate the average number of street trees in each zone, the total number of trees counted in the pre-sample will be summed for each zone using Equation 1 (Maco 2002). This number is then divided by the number of sampling units pre-sampled and multiplied by the total number of sampling units in each respective zone to estimate tree numbers per zone using Equation 2.

$$\text{Avg. \# of trees per sampling unit} = \frac{\sum \ \text{\# of trees counted per sample unit}}{\text{\# of street units pre - sampled}} \qquad (1)$$

$$\text{\# of trees per zone} = \begin{pmatrix}\text{Avg. \# of trees} \\ \text{per sampling unit}\end{pmatrix}\begin{pmatrix}\text{Actual \# of sampling} \\ \text{units per zone}\end{pmatrix} \qquad (2)$$

The total number of city street trees in Hattiesburg will then be estimated by summing the previous zone totals using Equation 3.

$$\text{Total \# of city streets citywide} = \sum_{i=1}^{N} \text{\# of trees per zone} \qquad (3)$$

where,

N = the number of zones.

Equation 4 will then be used to estimate the percentage of the total city street tree population located in each zone.

$$\text{Tree population \% in each zone} = \frac{\text{\# of trees per zone}}{\text{total \# street trees citywide}} \tag{4}$$

Last, the desired number of trees and sampling units to be inventoried per zone will be determined by Equations 5-6:

$$\text{Target \# of trees to sample per zone} = (2{,}300)\left(\frac{\sum \text{ Total tree population}}{\text{percent in each zone}}\right) \tag{5}$$

$$\text{\# of URSPs to be inventoried} = \frac{\text{Target \# of trees per zone}}{\text{avg. \# of trees per URSP}} \tag{6}$$

Discrete random numbers are generated for the number of sampling units inventoried per zone. Street segments and units identified are marked on the base street map in preparation for the sample tree inventory.

Inventory Protocols

Once the number of sampling units to be inventoried is determined per zone, all trees in the city ROW within each unit are sampled according to the following data collection protocols. If any additional comments are needed that do not fall into the following data collection protocol they are noted on the back of the field inventory sheet (Appendix A). Two-person teams (a measurer and a recorder) are recommended to record data using a field inventory sheet. Equipment used during the inventory will include a Brunton® compass for orientation measurements, a Suunto® clinometer for measuring tree height, a dbh-tape to measure tree diameter, and a Spencer Products Co. ‘ProTape-S’ for measuring distances.

The following will be recorded for each inventoried sampling unit:

- Beginning address (unique referenced point),
- Ending address,
- Zone segment number,
- Inventory date, and
- Names of persons who conducted survey.

Tree Data Recorded

Data is recorded for each tree during the inventory process. This data includes species code, tree ownership, location, and use. A species code will be the first two letters of the tree’s genus followed by the first two letters of the species epithet. For example, a Chinese hackberry (*Celtis sinensis*) will be coded as CESI. VOID is entered for a vacant planting area within the ROW, where a linear measurement of 80 feet or more is a plantable space and void of trees (Maco 2002). A species code reference list was assembled and attached (Appendix B).

Trees are considered city owned (Yes = 1) if they are within a 10 foot city ROW, or located in a median, or within the city ROW and not privately owned and cared for (Maco 2002). All other trees are considered private (No = 0). Determination of private trees is identified by evaluating the landscaped area for recurring species selection and groupings planted by the property owner. Likewise, out of place trees located within the ROW, and not deemed city trees, are considered private trees. For example, if a street unit’s city trees consist of a relatively uniform distribution of Chinese tallow, and a single

Windmill palm (*Trachycarpus fortunei*) is in the distribution, it is considered a private tree (e.g., a Windmill palm that matches other Windmill palms found in landscaping on property beyond the city ROW). If a street tree was planted by the community, a date will be recorded; otherwise N/A is entered where information is not available. A number (1-4) is entered to correspond with the type of neighborhood or environment adjacent to the inventoried tree. These trees will be coded as:

1 = Single home residential,
2 = Multi-home residential,
3 = Commercial/industrial, and
4 = Other (e.g., vacant, institutional, agricultural, park).

Using standard methods of forest mensuration, a dbh-tape will be used to measure bole diameter (Avery and Burkhart 2002). The diameter is then recorded to the nearest inch. Total tree height will be determined using a clinometer and height is recorded in feet. Crown diameter is measured by averaging the widest crown radius and narrowest crown radius measurement and multiplying by two. The measurement of crown diameter is recorded to the nearest foot.

The condition of each inventoried tree will be recorded as a number (1-3) that corresponds with the following condition classes (Maco 2002):

- 1 = Good = Healthy vigorous tree. No signs of insect, disease, or mechanical injury. Little or no corrective work required. Form representative of species.
- 2 = Fair = Average condition and vigor for area. May need corrective pruning or repair. Lacks desirable form characteristic of species. Shows minor insect injury, disease, or physiological problem.
- 3 = Poor = General state of decline when it shows severe mechanical, insect, or disease damage; if death is imminent, remove (RMV) will be recorded in pruning needs column.

The adequacy of pruning will be determined visually. Y = yes (i.e., pruning recommended) and the following codes are recorded for each type of pruning recommendation:

- YLL = 1 = Lower limbs need pruning.
- YA = 2 = Dead-wood present and needs crown cleaning.
- YC = 3 = Large limbs greater than 2 inches needing removal.
- YUG = 4 = Needs undergrowth removed.
- YT = 5 = Thin two or more stems or other undesirable tree stems.
- N = 0 = Entered if the tree does not exhibit or require any of the above conditions.

Yes = 1 is recorded where the following conflicts (e.g., damaged sidewalks, hazardous trees, improper spacing, poor visibility) are present or exacerbated by the inventoried tree. No = 0 is recorded where conflicts are not present. If a tree's root or roots are causing adjacent sidewalks to heave > 0.75 inches it is noted as either Yes = 1 or < 0.75 inches No = 0.

Harris (1992) considered a tree to possess hazardous characteristics if it was structurally unsound and there was a possible target (i.e., structures, vehicles, people), significant weak structural growth is present (e.g., lack of dominant stem, poor limb attachment), if there was decay of the trunk or if there are branches, cankers, rot, and signs of root loss or decay. If these conditions existed it is noted as a Yes = 1 or No = 0. However, if target structures, humans, or vehicles were not present then no hazard exists (Harris 1992). These hazards are considered conflicts when clear views of street signs or intersections are obstructed by a tree or trees. Additionally, public street lamps or lighting that is obstructed by a tree constitutes a conflict.

Conflicts are also considered as present if a tree or trees are spaced too closely to other public or private trees or structures or if the tree reaches its full potential size and it is determined that the form compromises or inhibit the tree's limited growing space (Maco 2002). If trees obstruct or interfere with overhead utility lines it will be noted as either a Yes = 1 or No = 0. If any portion of an automotive vehicle is present within the tree's dripline then it is considered shaded and a Yes = 1 is entered into the database. If, at the time of inventory, no vehicle is present within the dripline, then a No = 0 is entered.

Data Analysis

Citywide tree counts of public and private trees and their attributes are calculated based on proportions of trees counted in the actual sample inventory. Estimated total numbers of individual tree species (X) per zone are calculated using the model for stratified random sampling with proportional allocation (Equation 7) (Cochran 1977). From Equation 7, zone totals for each inventoried species is calculated using Equation 8, and citywide species totals are calculated using Equation 9; estimating the percentage of the citywide population represented by species X is determined by Equation 10:

$$\frac{\sum^{L} n_h \overline{y_h}}{h=1}$$

where, (7)

$$y_h = \frac{\sum_{i=1}^{n_h} y_{hi}}{n_h},$$

L = # of zones,
n_h = # of URSPs in zones, and (7 continued)
y_{hi} = value obtained from the ith unit

$$\text{Relative Dominance} = \frac{\text{Canopy cover of species X}}{\text{Total canopy cover of all species}} * 100 \qquad (8)$$

$$\text{Relative Density} = \frac{\text{\# of individuals of species X}}{\text{Total individuals of all species}} * 100 \qquad (9)$$

$$\text{Relative Frequency} = \frac{\text{Frequency of species X}}{\sum \text{Frequncy values for all species}} * 100 \qquad (10)$$

Standard Error

Jaenson et al. (1992) found their statistical methodology for street tree sampling to be accurate within 10% of actual population totals. This error was determined through comparison of the sampling method results coupled with known populations in four cities. Four cities or urban areas in New York were surveyed between fall of 1989 and summer of 1990. These sites were chosen because they represented areas ranging from 5.6 square miles (Ithaca) and 78.5 square miles (Brooklyn) and had complete or partial street tree inventories. Existing inventories allowed the sampling method to be validated for accuracy and was found to be within 10% of actual tree populations.

Lacking an accurate inventory for all public trees found in the city of Hattiesburg, a standard error will be calculated to validate the sampling procedure and consistency of street tree population totals found in Hattiesburg, Mississippi based on the standard error found in cities with a complete inventory. Results will be calculated citywide using Equation 11 and, zone totals, using Equation 12 (Cochran 1977):

$$se_{citywide} = \sqrt{\sum_{i=1}^{n} (se_{zone})_i^2} \qquad (11)$$

$$se_{zone} = \sqrt{V(\bar{y})} \qquad (12)$$

where,

$$\bar{y} = \frac{\sum_{i=1}^{n_h} y_{hi}}{n_h},$$

$$V\left(\bar{y}\right) = \frac{1-f}{n} \sum W_h S_h^2$$

and,

$$S_h^2 = \frac{\sum_{i=1}^{n_h} (y_{hi} - \bar{y}_h)^2}{N_h - 1},$$

$$Y_h = \frac{\sum_{i=1}^{N_h} y_{hi}}{N_h - 1},$$

$$W_h = \frac{N_h}{N},$$

$$f_h = \frac{n_h}{N_h}$$

$N_h =$ total number of URSPs in a zone,
$n_h =$ number of URSPs sampled in zone, and
$y_{hi} =$ number of individual trees counted for the ith unit.

Structural Analysis

Data collected during the sample inventory facilitates assessment of the structural components in Hattiesburg's municipal forest. This assessment provides for the type of management needed to improve forest health and sustainability, and demonstrates how investing in a management program provides benefits through maintaining the urban forest. Determining species makeup by zone segment and citywide is described in Equations 4-9, and by substituting species X for different recorded tree attributes (e.g., dbh, condition class, pruning needs), these six equations will be used to calculate structural characteristics, unless otherwise noted. Data summaries will be constructed using computer software programs such as Microsoft Excel (Maco 2002).

Importance Values (IV)

Importance Values (IV) refer to the relative contribution of a particular species to the entire community (Barbour et al. 1987). While this holds true in an urban forest setting, as well as natural communities, it may also be stated that an IV will provide meaningful interpretation with respect to the degree a city might depend on particular urban trees insofar as their environmental benefits are concerned (Maco 2002).

A traditional determination of ecological importance is defined as the sum of relative dominance (e.g., basal area), density, and frequency (Krebs 1978). This is widely used in forestry, and can be altered to better describe the importance of urban trees where CC is a better descriptor of dominance than basal area (Miller and Winer 1984). With this in mind, three elements are summed to obtain an IV for each public street tree species using Equations 13-16 (Maco 2002):

IV of species X = Relative Dominance + Relative Density + Relative Frequency (13)

where,

$$\text{Relative Dominance} = \frac{\text{Canopy cover of species X}}{\text{Total canopy cover of all species}} * 100 \qquad (14)$$

$$\text{Relative Density} = \frac{\text{\# of individuals of species X}}{\text{Total individuals of all species}} * 100 \qquad (15)$$

$$\text{Relative Frequency} = \frac{\text{Frequency of species X}}{\sum \text{Frequency values for all species}} * 100 \qquad (16)$$

Canopy Cover

Canopy cover of public and private trees will be estimated as total CC, CC over pavement, and CC over pavement and sidewalks. Total CC will be estimated from tree canopy spread. Total estimated CC for all species that fall within each of the three coverage areas is determined by multiplying total CC from Equations 13-16 by each unique zone's respective estimation factor determined by Equation 7, where only one individual of species *X* is sampled during the inventory. The result estimates the number of identical individuals that could be expected in that zone. Therefore, multiplying actual sample numbers by this unique zone estimation factor will yield accurate zonewide totals based on each tree's actual CC (Maco 2002).

Recent aerial imagery (i.e., within the past five years) provided by the Mississippi Forestry Commission, will be used to qualify and quantify CC determined in sample inventory. Imagery at present contains geometric and differential illumination distortions that will have to be corrected for use as a base map in qualifying and quantifying CC and tree types.

Imagery will be processed using the following steps with the computer software Imagine: normalization, georefrencing, mosaicing, and classification. Imagery is normalized by creating a polynomial illumination response model that will correct for sun angle and bidirectional illumination effects. Next, imagery will be georefrenced or geographically corrected with ground points (i.e., latitudes and longitudes) of known origin. After imagery is georefrenced it will be tiled into one large mosaic map from which trees can be classified (i.e., hardwoods, pines). Canopy cover extracted from imagery for street trees is measured in ArcGIS to validate sampling results.

Tree Species Selection

Tree species diversity within the population is determined using Simpson's Diversity Index (Simpson 1949, Barbour et al. 1987, Sun 1992). Simpson's Diversity Index (Simpson 1949) points out dominance that identifies where rare species are more likely to vary from place to place than common species of street tree populations. This reduces discrepancies between samples. The process of determining species' diversity will be calculated using Equation 17 (Maco 2002):

$$C = \sum_{i=1}^{s} (pi)^2 \tag{17}$$

where,

$C =$ index #,
$s =$ total # of species in the sample, and
$pi =$ proportion of all individuals in the sample that belongs to species i.

The index ranking created denotes the probability that two trees, chosen at random, are of the same species. Tree species found within the population are considered to have a greater diversity with a low index ranking.

Benefit/Cost Analysis

The methodology has dealt with quantifying populations and structure of street trees into data categories (i.e., species frequency of occurrence, dbh, height, CC, condition, pruning requirements). This population and structural data can be used to quantify benefits (i.e., resource units, dollar values) street trees produce in a community.

The Modesto Approach

Growth rates from 22 sampled tree species in the Modesto, California study will be used to infer growth rates for Hattiesburg's street trees. However, Charlotte, North Carolina, a lower South city, is in the process of determining growth curves for their trees. These are to be finished in 2006 and may be used for calculating Hattiesburg's BCR. Each street tree in Hattiesburg will be categorized based on tree type (i.e., deciduous or evergreen).

Tree species in Hattiesburg will be placed in one of nine categories listed below to make inferences from growth curves used in Modesto's study:

- Broadleaf deciduous
  large (>15 m [50 ft]) (DL)
  medium 8-15 m [25-50 ft] (DM)
  small (<8 m [25 ft]) (DS)
- Broadleaf evergreen
  large (EL)
  medium (EM)
  small (ES).

Property Values

Anderson and Cordell (1988) indicated a single large front yard tree, regardless of species, was associated with a $336 increase in the sales price of single-family homes in Athens, Georgia. This price category will be adjusted in this study using the Consumer Price Index (CPI) to determine a present day dollar value, on a similar large tree in Hattiesburg. For example, using the CPI in 1998 dollars, the Modesto study put a price of $508 on a hackberry at 15 m tall (49 ft), 57 cm (22 in) dbh, and 250 m^2 (2,691 ft^2) of LSA (Maco 2002). This price was used as an indicator of the additional value a Modesto resident would gain from sale of residential property with a large street tree in front of a home. The $508 was annualized over the life of the tree depending on the increased percentage of LSA incurred over a single year for street trees. The Modesto study assumed that 5% of all street trees had no increase in property value, due to planting locations with little resale value. Incorporating this reduction, the price per m^2 LSA was $1.93 ($0.18 ft^2) (Maco 2002). Using a price per ft^2 LSA, a guideline established for Hattiesburg shows different values for different tree sizes.

Energy and Natural Gas Savings

Changes in building energy use in Hattiesburg, from tree shading, will be inferred based on computer simulation models outlined by McPherson and Simpson (1999). These models incorporated differences in building structure, climate, and effects of shading. Building characteristics were differentiated by age of construction (pre-1950, 1950-1980, and post-1980) and take into account number of stories, floor area, window area, and insulation. Shading effects for deciduous and evergreen large, medium, and small trees were calculated at four ages (5, 15, 25, and 35 years after planting) for three different tree-to-building distances (3-6 m [10-20 ft], 6-12 m [20-40 ft], 12-18 m [40-60 ft]) using eight different positions with azimuths as follows (0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315°).

From the simulation result, an algorithm can be developed predicting energy savings for a tree at each possible location (i.e., distance and direction from building) with each leaf pattern and size. Using aerial photos and the distribution of street tree locations, of Modesto’s street trees with respect to buildings, the algorithm will determine average energy savings per tree at each location. Average annual savings need to be summed over species and age for all trees to derive citywide totals. In addition to shading effects, climatic effects of lowered air temperature and wind speeds from increased neighborhood CC can be calculated using the estimate of CC from street trees alone, where each percentage of CC coincides with an ambient air temperature reduction of 0.2 °F (0.1 °C). Cooling and heating effects will be adjusted based on the typical type and saturation of air-conditioning (e.g., central heat/air pump, evaporative cooler, wall/window unit or none) or heating (e.g., natural gas, electric resistance, heat pump, fuel oil, or other) equipment used in each typical housing vintage. Shading values will be increased by 15% to account for shading on adjacent structures (e.g., neighboring homes). Dollar values of electrical energy savings and natural gas savings will be based on market prices in Hattiesburg for \$/kWh and \$/therm, respectively. Until growth curves are established in the Lower South, computer simulations which establish an algorithm to calculate energy savings can only be inferred from other studies (e.g., Modesto, California).

Atmospheric CO_2 Reductions

Net CO_2 reductions will be calculated based on avoided emissions from energy use and that which is directly sequestered and released through tree growth, removal, and maintenance. As a byproduct of electricity generation, the benefit of CO_2 reductions for Hattiesburg is based on a local utility emission factor of \$/kg per kWh (lbs/kWh). Summing the storage of CO_2 in above- and below-ground biomass determines sequestration over the course of one season for a representative species of different tree type categories. Carbon dioxide release is based on the estimation that 80% of tree carbon is released to the atmosphere the same year as mortality occurs through the process of chipping and the resultant decomposition of tree biomass such as mulch. Tree mortality will be determined from the percentage of the age class removed due to tree mortality in Hattiesburg using a three-year average. Released CO_2, as a result of tree maintenance, is estimated to be \$/kg of CO_2/cm dbh based on an average annual consumption of gasoline and diesel fuels used by the city's UFD. A dollar value of CO_2 reductions will be expressed in (\$/metric tonne or \$/short ton) based on control costs recommended by the Southern Energy Commission.

Air Quality Improvement

When building energy use is reduced by shading, power plant emissions of air pollutants, as well as CO_2, are reduced. Changes in volatile organic compounds (VOCs), nitrogen dioxide (NO_2), as well as particulate matter of <10 micron diameter (PM_{10}) are calculated as emission offsets. Calculations for obvious offsets will be performed using the same method for CO_2, as described above with utility-specific emission factors (Maco 2002).

The direct removal of pollutants from the atmosphere is expressed as the product of dry deposition velocity: $v_d = 1/(R_a+R_b+R_c)$, a pollutant concentration C, a canopy projection area, and a time step (Maco 2002). Hourly deposition velocities for NO_2, ozone (O_3), and PM_{10} is calculated using methods described by Scott et al. (1998) to estimate resistances (R_a, R_b, and R_c) on an hourly basis throughout a “base year” (Maco 2002). This value is yet to be determined for Hattiesburg, Mississippi.

Dollar values for resource units will be applied using the market value of pollution emission credits traded on the open market. Weighted averages of all transactions ($/metric or shot ton) during 2005 will be used to determine the $/kg values of NO_2, PM_{10}, and VOCs in Hattiesburg.

Stormwater Runoff Reductions

As described by Xiao et al. (1998), a numerical simulation can be used to estimate annual rainfall interception and storage by urban trees. The model incorporates tree species, leaf area, crown density, and height, and uses hourly meteorological and rainfall data from Hattiesburg. The implied value of the intercepted rainfall ($/$m^3$) is based on annual expenditures for Hattiesburg's urban stormwater quality program and produces a total annual benefit of intercepted rainfall over 40 years, or the time estimated to recoup complete reinvestment in a stormwater quality program (Xiao et al. 1998).

An essential component in understanding stormwater runoff is the evaluation of each type of land area and its effectiveness in producing runoff as illustrated in Figure 5. If Hattiesburg lacks complete data for annual expenditures on stormwater management, total land area will be classified using estimations comparable to Olympia, Washington. At present this is the only study of its type. Based on Olympia's Impervious Surface Reduction Study, both percent land area and effective runoff is used to determine Hattiesburg's coefficient (City of Olympia 1995) (Figure 5).

Using Equation 18, total stormwater runoff is estimated as:

$$R_D = A * E_{is} * P$$

where,

R_D = total stormwater runoff units (m^3), (18)
A = total land area,
E_{is} = total effective impervious surface, and
P = average annual precipitation.

Dividing total annual expenditures by total stormwater runoff demonstrates what the city spends on managed stormwater ($\$/m^3$).

Effective interception is the proportion of precipitation intercepted by a tree that would otherwise result in direct surface runoff, a factor that must be accounted for in

Land use	Total Area (acres)	% of Total Area	Effective Runoff Coefficient	Weighted Average (% of Total Area) (Runoff Coefficient)
Low density resident[a]				
High density resident[b]				
Multi-family resident[c]				
Commercial/industrial				
Total				

[a] Estimate of all city areas that have less than one dwelling/unit per acre and includes parks, open spaces, green belts, agricultural lands, and golf courses.

[b] Estimate of typical single-family suburban residential area (3-7 units/acre).

[c] Estimate of land area occupied by multi-family residential housing (7-30 units/acre).

Figure 5: A sample table of a city's land areas divided into classifications (i.e., low density residential, high density residential, multi-family residential, commercial/industrial areas) to determine an effective citywide runoff coefficient.

valuing effectiveness in reducing stormwater management costs (Maco 2002). Precipitation occurs at greater rates in Hattiesburg than in the Modesto area; therefore an adjustment factor is needed. A price adjustment factor can be determined to calculate effective interception from total interception because the Modesto data relies on total interception to calculate stormwater benefits. This factor assumes an initial subtraction of two mm (0.078 in) for the average city ROW based on computations of runoff curves for land areas (NRCS 1986, Maco 2002). In other words, small rainfall events of less than two mm (0.078 in) are not likely to produce direct runoff and are, therefore, excluded in valuing stormwater reduction benefits.

Assessing Total Benefits

Annual benefits (B) will be summed for each street tree (i), in each ward's zone types (j), and is summed using prices in Equation 19:

$$B = \sum_{j}^{i} j \left(\sum_{j}^{i} i \left(e_{ij} + a_{ij} + c_{ij} + h_{ij} + p_{ij} \right) \right) \tag{19}$$

where,

$e =$ net energy savings $=$
annual natural gas savings $+$ annual electricity savings,
$a =$ net air quality improvement $=$
PM_{10} interception $+$ NO_2 absorption $+$ O_3 absorption,
$c =$ carbon dioxide reductions $=$
CO_2 sequestered less releases $+$ CO_2 avoided
from reduced energy use,
$h =$ stormwater runoff reductions $=$ effective H_2O
interception, and
$p =$ aesthetics $=$ increase in property value.

Assessing Total Costs

Assessing total costs associated with Hattiesburg's street tree management was facilitated with their urban forester, Mark Anderson. Mr. Anderson has provided records on their urban forestry program for the past five years, 2000-2004, from the UFDs cost file database. Many costs under examination can be found in this database. Costs that can not be provided by Mr. Anderson or the city comptroller will be determined based on McPherson's (2000) survey of 18 California cities and their expenditures on tree related damage. In addition, a survey developed by this project will be given to several southern cities (Appendix C). Dollar values for Fiscal Years (FYs) 2000-2004 will be adjusted for inflation using the CPI (Figure 6). If legal and litter removal/disposal cost information is not available it will be inferred from mean per capita cost of reporting cities in the California study and local cities surveyed. Total net expenditures are derived from all reported internal and external costs associated with annual management of Hattiesburg's street trees. Annual costs for public street trees summed using Equation 20.

Expenditure Category (per capita)	FY 2000 ($)	FY 2001 ($)	FY2002 ($)	FY 2003 ($)	FY 2004 ($)
Infrastructure repair					
Liability/claims[a]					
Litter clean-up[b]					
Total					

[a] Inferred from mean reported values for 18 California cities and southern cities surveyed by this project (McPherson 2000).

[b] Mean reported values from southern cities surveyed by this project.

Figure 6: A sample table for estimating per capita external street-related urban forestry costs for FYs 2000-2004 for southern cities surveyed.

The Benefit/Cost Ratio

Total street tree annual net benefits as well as the BCR Equation 21 will be calculated using Equations 19 and 20:

$$C = p + t + r + d + e + s + c + l + a + q \tag{20}$$

where,

p= planting,
t = pruning,
r = tree and stump removal and disposal,
d = pest and disease control,
e = establishment/irrigation,
s = repair/mitigation of infrastructure repair,
c = litter/storm clean-up,
l = litigation and settlements attributed to tree-related claims,
a = program administration, and
q = inspection/answering service request.

$$BCR = {}^{B}/_{C} \tag{21}$$

SUMMARY

Methods in this project will establish a new GIS sampling technique using ArcGIS to develop a street tree inventory. A sound inventory will provide the capability to report on the approximate dollars spent by the City of Hattiesburg on a per capita basis for direct costs and the approximate dollar value in benefits per capita from their street trees. Based on this information, a BCR will be determined for individual aspects of the Hattiesburg urban forestry program as well as an overall BCR to assess the entire program. This information will be used to demonstrate the magnitude of benefits versus costs of urban forestry initiatives when applied in a GIS format. This information can then be used to educate community leaders in other southern cities. It can also be used by any city or town interested in establishing a street tree inventory with a GIS or tying it to an already existing GIS program.

As important, this information can promote urban and community forestry projects and/or support funding requests to provide money for projects many of these communities could not otherwise afford. Using a GIS to manage street trees is an underutilized concept that is becoming a reality for many municipalities. As many municipalities realize street trees are assets they will also understand that they need to be managed much the same as streets and water lines. This has also opened up an opportunity for growth using this concept. In summary, the creation of a partial street tree inventory using a GIS database over conventional maps or analytical spreadsheets, can provide a municipality with the ability to utilize mapping and related data simultaneously. This ability will be made possible using GIS technology while in a dynamic environment of ever-changing arrays of interactive data and comparison functions.

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Appendix A

Inventory Protocols:

PSP Location				Zone #			Date		
Beginning Address							Recorder's name		
Ending Address									
Tree #	Species Code	Year Planted or N/A	Land Use (1-4)	Tree Location	Orientation of House or N/A	Setback From Street	DBH (inches)	Tree Height (1-6)	Crown Diameter (feet)

Land Use:

1 = Single home residential
2 = Multi-home residential
3 = Commercial/industrial
4 = Other (e.g., vacant, institutional, agricultural, park)

Tree Location:

1 = Front yard
2 = Planting strip
3 = Cutout
4 = Median
5 = Other (e.g., planter, island)

House Orientation:

N = North
NE = Northeast
E = East
SE = Southeast
S = South
SW = Southwest
W = West
NW = Northwest

Appendix A continued:

Inventory Protocols continued:

Condition (1-3)	Pruning needs	Conflicts Present ?: Yes = 1, 0 = No						
		Sidewalk Heave	Hazardous Tree	Intersection	Spacing	Overhead Lines	Car Shaded	Other Requirements

Conditions:

- 1 = Good = Healthy vigorous tree. No signs of insect, disease, or mechanical injury. Little or no corrective work required. Form representative of species.
- 2 = Fair = Average condition and vigor for area. May need corrective pruning or repair. Lacks desirable form characteristic of species. Shows minor insect injury, disease, or physiological problem.
- 3 = Poor = General state of decline when it shows severe mechanical, insect, or disease damage; if death is imminent remove (RMV) will be recorded in pruning needs column.

Pruning Codes: YLL = 1 = Lower limbs need pruning.
YA = 2 = Dead-wood present and needs crown cleaning.
YC = 3 = Large limbs greater than 2 inches needing removal.
YUG = 4 = Needs undergrowth removed.
YT = 5 = Two or more stems or other undesirable tree stems that need thinning.
N = 0 = Entered if the tree does not exhibit or require any of the above conditions.

Appendix B: Tree Codes, Common Names, Latin Names, and Growth Categories*

Codes	Common Name	Latin Name	DS	DM	DL	ES	EM	EL
ALJU	Mimosa	*Albizia julibrissin*		X				
ACPA	Japanese Maple	*Acer palmatum*	X					
ACRU	Red maple	*Acer rubra*		X				
ACSA	Silver Maple	*Acer saccharinum*		X				
BENI	River Birch	*Betula nigra*		X				
CABI	Southern Catalpa	*Catalpa bignonioides*		X				
CAIL	Pecan	*Carya illinoensis*			X			
CECA	Eastern Redbud	*Cercis candensis*	X					
CELA	Hackberry	*Celtis laevigata*			X			
CAMO	Chestnut	*Castanea mollissima*		X				
CICA	Camphor	*Cinnamomum camphora*		X				
COFL	Flowering Dogwood	*Cornus florida*	X					
DIVI	Common Persimmon	*Diospyros virginiana*		X				
FRPE	Green Ash	*Fraxinus pennsylvanica*		X				
GIBI	Ginkgo	*Ginkgo biloba*		X				
GLTR	Locust	*Gleditsia triancanthos*		X				
HAVI	Witch Hazel	*Hamamelis virginiana*		X				
ILOP	American Holly	*Ilex opaca*	X					
JUVI	Eastern Red Cedar	*Juniperus virginiana*		X			X	
LAIN	Crepe Myrtle	*Lagerstroemia indica*	X					
LIST	Sweetgum	*Liquidambar styraciflua*			X			
LITU	Tulip Poplar	*Liriodendron tulipifera*			X			
MAGR	Southern Magnolia	*Magnolia grandiflora*						X
MASP	Crabapple	*Malus spp.*	X					
MEAZ	Chinaberry	*Melia azedarach*		X				
MAVI	Sweet Bay Magnolia	*Magnolia virginiana*					X	
MYCE	Waxmyrtlye	*Myrica cerifera*				X		
NYSY	Tupelo Blackgum	*Nyssa sylvatica*		X				
PLOC	American Sycamore	*Plantanus occidentalis*			X			
PRCE	Purple Leaf Plum	*Prunus cerasifera*	X					
PRSE	Wild Black Cherry	*Prunus serotina*		X				
PIPA	Long Leaf Pine	*Pinus paulustris*						X
PITA	Short Leaf Pine	*Pinus taeda*						X
PYCA	Bradford Pear	*Pyrus calleryana*		X				
QUFA	Southern Red Oak	*Quercus falcata*			X			
QULA	Laurel Oak	*Quercus laurifolia*			X			
QUMI	Sawtooth Oak	*Quercus michauxii*			X			
QUNI	Water Oak	*Quercus nigra*						
QUPH	Willow Oak	*Quercus phellos*			X			
QUST	Post Oak	*Quercus stellata*						
QUVI	Live Oak	*Quercus virgininana*						X
SAAL	Sassafras	*Sassafras albidium*				X		
THOR	Arborvitae	*Thuja orientalis*	X			X		
TRWE	Windmill Palm	*Trachycarpus H. Wendl.*	X					
ULAM	American Elm	*Ulmus americana*			X			

* DS, DM, DL, ES, EM, and EL denotes Deciduous and Evergreen small, medium, and large.

Appendix C

April 11, 2003
Dear Participant **(this will be personalized)**:

The Mississippi Forestry Commission's Urban Forestry Program (Walter Passmore, Partnerships Coordinator, wpassmore@mfc.state.ms.us, (601) 359-1386) has provided funding to develop a predictive model for the costs and benefits of the urban forest for small to medium-sized cities in the South. The model's function will be to provide city administrators and planners with benefits, in dollars, relative to their current or proposed expenditures. This actual worth of the urban forest can help facilitate future development in these communities. We are enclosing a scope of the project as well as a cost survey form. We are asking you to provide annual costs for the past three years as they pertain to the trees (not flowers or shrubs) in your city. We would like to thank you in advance for taking time out of your busy schedule to help us with this project.

Please take your time completing the enclosed questionnaire. It is part of a study being conducted by Mississippi State University.

Your name was selected from a list of **(will be specific to each group)**. It is important that each questionnaire be completed and returned so results will accurately represent the benefits and costs of urban forests. If you choose to fill out the questionnaire, please know that your participation is voluntary, you may stop at any time and you do not have to answer any questions. The results will be used to develop a predictive benefit/cost model and other educational materials.

You may be assured of complete confidentiality. The return envelope has an identification number for processing purposes only. It will be used to remove your name from the mailing list when you return your questionnaire. Your name will never be placed on the questionnaire or associated with any responses.

I appreciate your willingness to take part in this study. If you should have any questions, please contact me at (662) 325-8358, email: jwj42@msstate.edu or write me at Department of Forestry, Box 9681, Mississippi State, MS 39762-9681. You may also contact Dr. Stephen C. Grado at (662) 325-2792, at Mississippi State University. Thank you for your assistance with this study.

I ask that you return your questionnaire in the enclosed, self-addressed stamped, envelope before **(date to be determined)**.

Sincerely,

Wes Jones

Graduate Research Assistant
Department of Forestry
Mississippi State University

ESTIMATED OR ACTUAL MUNICIPAL STREET TREE COSTS

ANNUAL COSTS PER YEAR	**Year 1**	**Year 2**	**Year 3**
Tree Removal			
Tree Pruning			
Newly Planted			
Existing			
Irrigation			
Newly Planted			
Existing			
Pest and Disease Control			
Newly Planted			
Existing			
Tree Planting			
Purchase Price			
Planting (stakes, wrap, mulch, etc.)			
City Funded			
Grant Funded			
Infrastructure Repair			
Sidewalks			
Curbs			
Paving			
Sewer Lines			
Other-Specify (e.g., storms, vehicular, roots, etc.):			
Root Pruning			
Leaf Litter Clean-up			
Urban Forester/Urban Landscaper Compensation			
Supervisor			
Foreman			
Technicians or laborers			
Clerical			
Other-Specify (e.g., specialist, consultant, director, etc.):			
Social Security (match)			
Insurance (health)			
Workers compensation			
Retirement			
Equipment			
Vehicles (Annual costs should be based on rental, lease, purchase, mileage as replacement or mileage non-replacement)			
Cars			
Trucks			
Bucket Truck			
Dump Truck			

ESTIMATED OR ACTUAL STREET TREE COSTS CONTINUED:

Other-Specify:

Related Tools
Specify (e.g., power, hand, hoses, phones, safety markers, etc.):

Uniforms
Repairs and Maintenance
Specify:

Litigation/Liability (e.g., trip and fall, etc.):
Specify:

Administration

For additional comments or other costs, please use space below or back of questionnaire.