Wisconsin Statewide Urban Forest Assessment: Development and Implementation

By

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Abstract

The urban forest is an integral part and significant contributor to urban landscapes. Approximately 80% of the US population interacts with urban forests on a daily basis. The ecologic, sociologic, and economic benefits provided by urban trees have been shown to be worth billions of dollars. Urban forestry has been recognized within the scientific literature for over 30 years. As public education pertaining to the urban forest continues, it has become clear that a lack of a standardized definition complicates transmission of the message. This study used a content analysis of 77 scientific and reference articles to determine the primary constituents comprising definitions of the urban forest and urban forestry. We discovered that urban forestry definitions created since the first by Jorgensen are either similar or partial representations of his. Likewise, definitions of the urban forest created since Moeller have neither added to his or were partial representations. This study also developed spatial definitions of the urban forest. A programmatic spatial definition to delineate the areas considered urban by the Wisconsin DNR Urban and Community forestry program was developed and compared to areas spatially represented by urban areas in the 2000 census using ESRI Arc 9.1 software. It was determined that the most representative spatial extent at this time comprised both the 2000 census urban areas and all cities and all villages within Wisconsin. With the standard urban forest definition and programmatic spatial representation, this study makes contributions to both the theoretical and application components of urban forest research.

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CHAPTER 1

LITERATURE REVIEW

Introduction

Urban forests are an important and integral, yet often overlooked, portion of urban environments (Dwyer and Childs 2004, McPherson 2004). Understanding what we have for an urban forest resource facilitates achieving what we want to achieve from management of the urban forest (Miller 1997). Assessment of the urban forest at local, state, and national levels is an important and needed mechanism to measure if the urban forest at each level is moving in a direction that is consistent with desired management objectives. Urban forests can make a considerable difference in the quality of life by directly influencing the daily lives of approximately 80% of the United States population (Nowak *et al.* 2001, Dwyer *et al.* 2003). Nearly 25% of the United States land area is either located in or functionally tied to urban areas and the greater metropolitan area (Nowak *et al.* 2001).

Historically urban forests and tree planting efforts were viewed as city beautification projects (Miller 1997). The majority of people believe their communities are better places to live because of public trees (Elmendorf *et al.* 2003, Schroeder *et al.* 2003, Lohr *et al.* 2004, Treiman and Gartner 2005). A sole focus on the amenity value of the urban forests, however, can lead to overlooked or under-appreciated ecological and economic roles of urban vegetation, especially during periods of fiscal constraint. Further, the concept of the urban forest and its benefits do not appear to be well understood or recognized by the public (Hull 1992).

Urban and metropolitan areas that include substantial forest resources have the potential to significantly improve the environmental quality of the urban environment and the well-being of its residents (Dwyer *et al.* 2003). The urban forest contributes to the removal of air pollution, sequestration of atmospheric carbon dioxide, hydrologic benefits, energy conservation, and improves aesthetics (McPherson *et al.* 1994, McPherson 2004).

Trees remove gaseous pollutants (e.g., ozone, nitrogen dioxide, sulfur dioxide, and carbon monoxide) by absorbing them with other normal air components (e.g., carbon dioxide and oxygen) through the stomates (McPherson *et al.* 1997, Harris *et al.* 1999). Beckett *et al.* (2000) found that roadside trees also capture 60% more large-size (>10 microns) particulate matter than trees away from the road. These findings have significant implications for air quality standards. It has been estimated that the Wisconsin urban forest removes approximately 6,750 metric tons of air pollution per year, which has an associated societal value of $38.3 million per year (Nowak *et al.* 2005).

Trees also sequester carbon dioxide from the atmosphere during photosynthesis to form carbohydrates that are used in plant structure/function and return oxygen back to the atmosphere as a byproduct. Approximately 800 million tons of carbon is stored in

United States urban forests with a $22 billion equivalent in control costs (Nowak *et al.* 2005). Wisconsin urban trees store an estimated 5.5 million metric tons of carbon (Nowak *et al.* 2005). Furthermore, urban trees reduce surface runoff of water from storms (Xiao and McPherson 2002, McPherson 2004). Resultant from the urban forest is reduced soil erosion, reduced sedimentation of streams, increased groundwater recharge, and lower amounts of chemicals transported to streams.

Vegetative canopies in urban areas provide a cooling effect on microclimates directly by shading the ground surface and indirectly through transpiration (Scott *et al.* 1999). Because they lower air temperatures, shade buildings in the summer, and block winter winds, trees also reduce energy use associated with heating/cooling (Miller 1997, McPherson 2004). The estimated annual energy use savings from well-positioned trees around a conventional house ranges between 20-25% (McPherson 2004, Nowak *et al.* 2005). In Wisconsin, it has been estimated that shading of buildings by trees save residents $9.6 million annually in heating and cooling costs.

Aesthetically, well positioned urban trees and landscaping can increase property values up to 25-30%, improving resale values and increasing the tax base (Miller 1997). This aesthetic value also translates into human health values. Urban trees benefit mental health by creating feelings of relaxation and well-being (Kuo 2003). They can also provide privacy in the form of a natural fence and a sense of solitude and security (Kuo 2003). Ulrich (1984) observed shortened post-operative hospital stays when patients were placed in rooms with a view of trees and open spaces. At a larger scale, urban greening projects can also help to build stronger neighborhoods and improve community involvement (Westphal 2003). Finally, urban forests and parks provide an opportunity to improve physical health as they have become increasingly popular places to walk, run, and bike (Kuo 2003, Hansen-Moller and Oustrup 2004, Konijnendijk *et al.* 2004).

Urban forests are necessary green infrastructure and a cost efficient way to effectively address urban ecosystem issues. Economic valuation methods have been developed to quantify these benefits (McPherson 2004). For example, McPherson *et al.* (1994) calculated a benefit-cost ratio of 2.83 for urban trees in Chicago planted within yard, street, park, highway, and public housing settings. This indicates that the value of projected benefits is nearly three times the value of projected costs over the 40 year planning horizon, using a 7% discount rate. The Urban Forest Effects (UFORE) model uses urban forest structure based on field sampling of tree parameters to generate an estimated value of selected urban forest functions (e.g. carbon sequestration, air pollution removal) (Dwyer *et al.* 2000, Nowak and Crane 2000). These estimated functional benefits can then be used as a means to quantify the economic contribution of urban forests within built environments and urban ecosystems.

Another urban tree valuation model is the compensatory geared Council of Tree and Landscape Appraisers (CTLA 1992). The CTLA approach uses a base value of the tree derived from size and species. Multipliers for condition and location are then used to arrive at a final value. The urban forest nationwide has a compensatory value of more than $2 trillion (Nowak *et al.* 2002). The significant benefits of the urban forest necessitate accurate methods to quantify the extent and composition of urban trees.

Urban and Community Forestry

Uncertainty exists with the use of terms community forest, urban forest, or urban and community forestry. Urban and community forestry was used as early as November 1967 in the report *A Proposed Program for Urban and Community Forestry* developed through a federal interdepartmental task force led by the U. S. Department of Agriculture – Forest Service (USDA-FS) (Unsoeld 1978). Jorgensen (1970) first used the term urban forestry in 1965 at the University of Toronto. Within Europe, recognition and application of the urban forestry concept came later than in North America (Konijnendijk 2003). However, a strong growing tradition of urban greening activities on private lands occurred in Europe over several millennia and neoclassical origins of trees incorporated into urban and town design and community forests occurred at least since the 16^{th} century (Zube 1973, Lawrence 1988, Lawrence 1993).

Community forestry, in contrast to urban forestry, has a much longer history. Prior to European influence, native North Americans practiced extensive natural resource management including forests near settlements that are consistent with the modern concept of community forestry (Baker and Kusel 2003). Originating in the Middle ages within Europe, the first record of community forestry in North America dates to 1710 in Newington, MA (Brown 1938, Holscher 1973, Barret and Baumann 1994, Konijnendijk

2003). Community forests are public forests near a town, community, or municipality and managed for similar benefits that urban forests are detailed to provide today. A distinct difference is a strong emphasis on managing for forest products (e.g., timber, fodder, and extractives) in community forests. Community forestry has also been used to describe the participatory process of rural people in the use of public owned forests to provide the basic needs (i.e. food, shelter, etc.) of people, especially in third-world rural development (Pardo 1995). Community forests occur on public lands, therefore, they are held in common and should be managed in the public's best interest, which mandates public participation in the planning process (Baker and Kusel 2003).

Urban and community forestry is often used interchangeably with urban forestry. The community component suggests two things: (1) a population basis with community being less populated than urban areas and/or (2) it is a reflection of people being involved with decision making through participatory processes. Even though many state and federal forestry agencies combine both terms, Moll (1995) suggested using urban forestry as it was short and to the point. In contrast, Elmendorf and Luloff (2001) used community forestry solely to place an emphasis on the inclusion of people in the decision making process.

The importance of the urban forest resource to people and the end use varies along a geographic continuum. Since many urban residents use greenspaces near their residence for recreation, relaxation, and conveying with nature, local forested areas are very important for people (Dwyer and Barro 2001, Vogt and Marans 2001). Public urban greenspaces also have a positive effect on property values (Crompton 2001). People can also find similar uses and benefits in rural forested areas, yet time and cost involved with travel lessens the immediate importance to residents of urban areas.

Defining the Urban Forest

The terms 'urban forest' or 'urban forestry' have become commonplace within scientific literature. The history of arboriculture and urban forestry has roots tracing back thousands of years (Campana 1999, Miller 1997). In the 1970's urban forestry evolved into a separately recognized entity of forestry, and many proposed definitions have followed (Hauer 2005). There has yet to be, however, a single definition accepted by professionals within their field (Konijnendijk *et al.* 2006). Many researchers have posed their own definitions by describing the important aspects of the urban forest (Hauer 2005). These definitions have borrowed from previous research and presumably developed over time as urban forests and urban forestry have gained acceptance. A review of these shows the most common aspects or categories mentioned in relation to urban forests and urban forestry are people (those influenced by the urban forest), geography (where the urban forest is located), benefits (qualitative and quantitative benefits provided by urban forests), resource (trees and other plants), activity (planning and management of the urban forest), and science (professional, specialized, skill, discipline).

Jorgensen (1970) provided the first robust definition of the urban forest and it included the six aforementioned integral components. The six categories can be further distilled into constituent parts. For example, benefits may be more fully described through attributes such as physiological, sociological, economic benefits associated with the urban forest. An agreed upon definition of the urban forest would be beneficial to the professionals for future research, professional directions, and contribute to a better public understanding of urban forestry (Rowntree 1988).

Previous Urban Forest Assessment

Urban forests are ecosystems characterized by the presence of trees and other vegetation in association with people and their developments (Miller 1997, Dwyer *et al*. 2000). Municipalities regularly conduct city tree inventories, but they traditionally only account for public street and park trees, and rarely assess the urban forest growing on private land (Nowak *et al.* 1996, Dwyer *et al*. 2000). As an example, approximately 90% of trees in the Chicago, IL area are located on private property, with approximately 75% of the urban forest canopy associated with these trees (McPherson *et al.* 1994). Trees in suburban, rural-residential, and rural-agricultural areas that occur outside city limits are routinely not captured in urban forest assessments (Reimann 2003).

Urban ecosystems represent a complex mosaic of vegetative land cover and multiple land uses (Foresman *et al.* 1997). Though related, there is a clear distinction between land cover and land use. While land cover refers to the biophysical earth surface, land use is shaped by human, socio-economic and political influences on the land (Geist and Lambin 2002). Land use links land cover to the human activities that transform the landscape (NRC 1999). The unique combination of buildings, impermeable cover (e.g. asphalt, concrete, etc.) and vegetation complicate classification methods and hinder assessment of the urban forest. Furthermore, the gradients in ecological, sociological, and land uses that exist along urban to rural transects and complicate attempts to define the extent of the urban forest (Pickett *et al.* 1997). Valid and replicable estimations of the urban forest resource therefore requires a robust sampling approach and a well defined spatial definition as to the extent of the urban forest.

Approaches for Assessing Urban Forests

Traditional forestry is management that is applied to rural forest settings (Helms 1998). These forests are managed to provide forest products, recreation, environmental services, tourism, and other societal desires that are reflected in management techniques. Urban forests also provide, or have the potential to provide, outputs similar to rural forests. Since trees serve a vital function regardless of location, understanding this recourse is vital to incorporating urban vegetation into land use planning. However, an ecological understanding of urban ecosystems must also include less densely populated areas because of reciprocal flows and influences between densely and sparsely populated areas (Pickett *et al.* 2001).

Urban forest structure is a three-dimensional spatial arrangement of vegetation in urban areas and includes parameters such as species composition, tree size and health, number and location of trees (McPherson 2004). Quantifying this structure provides the basis for understanding the urban forest functions that affect urban inhabitants and improving management practices aimed at maximizing the environmental and social benefits derived from urban forests (McPherson *et al.* 1994, Dwyer *et al.* 2000). Data such as tree species, diameter breast height (DBH), health, structural integrity, and site factors such as location, soil condition and competition describe the potential productivity, from which value of an urban tree population may be estimated.

Various approaches have been used to measure urban tree cover, structure, and species composition (Nowak *et al*. 1996). Complete tree inventories are one possibility, but they require considerable time and money to conduct. They are suitable for small tree populations (e.g., one to two thousand trees) or when information on individual trees is required (Rideout 2006). Another approach is to sample representative portions of the urban forest. Sampling estimates tree populations and may be appropriate for large tree populations, especially when individual tree attributes are not required. Sampling is also an efficient approach to assess the urban forest when the land base is too large or when financial resources are limited. One sampling approach uses plots of a fixed size to establish a representative estimate of urban forest attributes (McPherson *et al*. 1994, Nowak and Crane 2000). Another approach uses aerial photographs to provide highly detailed and cost-effective means of measuring urban tree and other surface cover (Nowak *et al.* 1996). Analysis of canopy cover coupled with an on-the-ground examination of the composition of tree species provides the basis to estimate the urban forest value to the urban ecosystem.

Remote Sensing Assessment

On a statewide or national scale, remote sensing technology can be used to coarsely survey the urban forest resource. Sensors such as the Landsat-5 Thematic Mapper (TM) can record reflectance from 30 meter ground cells in 7 wavebands of the spectrum (Bolstad 2005). Moderate resolution TM and *Systeme Pour l'Observation de la Terre* (SPOT) imagery have been widely used to understand the characteristics of urban surfaces (Harris and Ventura 1995, Gluch 2002, Zhang *et al.* 2002). Images such as Advanced Very High Resolution Radiometer (AVHRR) data, TM, or SPOT provide information of very limited use at the scale of an individual neighborhood or city because of pixel size (Myeong *et al.* 2001). The inherent limitations of remote sensing due to spatial resolution can be addressed primarily through field verification, but doing so requires additional time and effort.

FIA Assessment

The FIA system uses permanent plots systematically located across the United States and periodic inventories to assess changes in the Nation's forest resource in rural areas. Developed by the USDA Forest Service this sampling procedure also has potential application in urban areas. The urban forest is summarized from general data collected on all plots and detailed tree data collected on forested plots (Reimann 2003). Forested plots have been defined by the FIA as areas of at least 1 acre (.004046 km^2) in size, at least 120 feet (36.576 m) wide, at least 10 percent stocked with trees, and have an understory that is undisturbed by another land use. Under this system of classification a non-forest designation does not necessarily mean that a plot is devoid of trees. This results in a data gap as it relates to the urban forest. Plots that may be omitted include forested backyards, small woodlots in the middle of developments, road and highway medians and right-of-ways, or riparian buffer strips. These plots represent a portion of the tree resource for which information on species, health, and biomass is not currently collected (Reimann 2003).

Even though the FIA does not claim that its data capture more than forested areas, this information is sometimes used to describe all of the trees in a state because it is the only inventory that exists over large areas. This becomes a functional problem for urban forest managers because the data does not necessarily reflect the resource they manage. The introduction and spread of exotic pests such as Asian longhorned beetle (*Anoplophora glabripennis*) and emerald ash borer (*Agrilus planipennis*) necessitates accurate estimates of tree populations across the entire landscape because the potential impact may be seriously under-estimated. Reliable assessments of urban forest resources enable communities to project the potential impact of destructive pests. Current estimates of the maximum potential national urban impact of infestations by *A. glabripennis* are $669 billion (Nowak *et al.* 2002).

Several preliminary studies have been conducted to collect tree data on plots defined by FIA as non-forest in urban areas to address the void in data for the urban forest resource. In areas that were determined to be nonforest by FIA definition, a 0.10 acre nonforest plot (37.24-foot radius circle) was established (Reimann 2003). The decreased sample plot size was a compromise between being small enough to avoid multiple ownerships and large enough to capture sufficient tree data. A pilot study conducted within a five county study area in Maryland used the .10 acre nonforest sample plot design (Reimann 2003). The results were positive and added considerably to the knowledge of the forest resource in Maryland. Results have been mixed in other locations, including Wisconsin, due to an insufficient number of FIA sample plots (Nowak *et al*. 2005).

State and Local Assessment

On a local scale, tree inventories within cities or even counties typically have been conducted for public trees. The vegetation included within these surveys is found in public right-of-ways or in park land and likely underrepresents the total urban forest. As an example, street trees in Chicago were found to constitute 1 of every 10 trees overall and 1 of every 4 trees in single family to multi-family residential areas (McPherson *et al.* 1994). The remaining trees on private property are often overlooked because of accessibility and the difficulty of inventorying. An assessment methodology is needed to incorporate both public and private trees in an urban forest inventory. Some communities have used remote sensing to conduct a canopy analysis using CITYgreen software. While fully inclusive, remotely sensed canopy analyses do not provide data for identifying tree species or condition. Furthermore, the sampling needs to be representative of the statewide urban forest rather than just a city or county for statewide urban forest planning. The findings from the 2004 Governor's Council on Forestry in Wisconsin listed developing statewide urban forest assessment as the first of three priority areas out of 50 identified actions (Wisconsin Council on Forestry 2004).

Before a statewide inventory can be started, it must first be decided where to sample. Using the FIA definition of "non-forest" the unsampled areas from the national forest inventory can be mapped. This is a potentially large void as any area not classified as rural forest would be included within this classification. The fundamental problem with FIA at the statewide level is that using only a non-forest land designation is not appropriate because there are non-forest land uses (i.e. agriculture) that are still not urban in nature. For example, row crop agriculture would be classified as "non-forest" using the FIA forest definition, but that type of land use should not be considered an "urban" area. Another method of deciding where to sample from involves using the census definition based on population. The US Bureau of the Census defines urban areas as incorporated or unincorporated areas with at least 2,500 people or density of at least 384 people/km^2 (1,000 people/mi^2) (Dwyer *et al*. 2000). These areas are easily defined and follow identifiable political boundaries, but this strict interpretation may result in excluding viable urban forest areas outside the identified political boundaries. Similarly there may be forested lands within a political boundary that ought to not be classified as urban forest (i.e. school forests, county forests).

A programmatic definition of political entities or communities (i.e., cities, towns, villages) is another way to define the urban forest. The Wisconsin DNR Urban and Community Forestry program defines communities that fall within their programmatic guidelines for providing technical and financial assistance. Their definition generally expands upon census defined areas by including areas that generally do not fit within the population parameters of the census-based definition of urban and metropolitan areas, but still exhibit urban characteristics through built environments. Regional DNR Urban and Community Forestry coordinators work with communities to help develop and implement these forestry programs.

Project Objectives

This project is the first step in an ongoing state-wide urban forest assessment being conducted by the Wisconsin DNR and the University of Wisconsin – Stevens Point. Prior to conducting an urban forest assessment, we must first define the urban forest and identify the sampling area within Wisconsin. The objectives of this study were to: 1) Develop a working 'urban forest' definition from the published literature, 2) define the spatial extent of the urban forest in Wisconsin using 4 approaches (2000 Census, DNR_{cvt}, DNR_{cv}, FIA), and 3) incorporate each definition into an ArcGIS 9.1 data layer to conduct spatial comparisons and facilitate future urban forest assessment work. Further, comparison of different sampling approaches will facilitate cross comparisons and applications of the Wisconsin urban forest for local, state, and federal needs while improving upon sampling procedure.

CHAPTER 2

PROJECT SCOPE AND METHODS

Expanding urban centers have increased the public visibility and role of urban vegetation. As with any resource, effective management begins with developing an understanding of the breadth of the resource and the development of management goals based on this understanding. Proposal of a universal working definition for the urban forest and a preliminary method for delimiting its bounds initiated urban forest assessment within Wisconsin.

Comparison of Urban Forest and Urban Forestry Definitions

Urban forestry is a relatively new addition to the field of forestry. There was no definition for urban forestry until 1970 or the urban forest until 1977 (Weck 1966, Jorgensen 1970, Moeller 1977). Since 1970 many definitions of the urban forest and urban forestry have been developed. An understanding of how these definitions relate is unknown.

A content analysis of urban forestry definitions over the last 40 years was used to describe the definitions. We identified commonalities and differences/omissions to formulate the basis for unified urban forest and urban forestry definitions. The definitions were found through searching professional journals where urban forestry related literature is published, review of urban forestry conference proceedings, and use of the University of Minnesota Urban Forestry Database (http://forestry.lib.umn.edu/bib/urban.phtml). There were six primary descriptive parameters associated with the definition urban forest or urban forestry; people, geography, benefits, resource, activity, and science (Table 2.1). The six categories were selected based on the initial definition by Jorgensen (1970). Attributes that correspond to the six categories were used to represent the presence or absence within a parameter. The initial selection of attributes was iteratively added to as additional definitions were analyzed. Thus, the definition by Jorgensen was used as a standard to compare all later definitions against. Later definitions were evaluated for additional categories that occurred as a result of the evolution of the urban forestry discipline or changes reflecting regional concerns/attitudes.

If any attribute described a parameter in a given definition, a tally was recorded within a matrix containing all definitions, category, and attribute combinations. A percentage of definitions containing references to the categories and attributes was then generated. Some terms or attributes were understood to represent multiple categories within the definitions. For example, the attribute 'urban' was used in both the people and geography categories because describing an area as 'urban' implies people inhabiting a geographic place. Three subcategories (ecological, sociological, and economic) were also created within the benefits category. In order to receive a tally in the ecological, sociological, or economic subcategories; those benefits had to be explicitly stated. The analysis was used to identify the terms most commonly associated with defining the urban forest.

Table 2.1. Six categories and attributes within a category used to describe urban forest and urban forestry definitions.

A) People Based	**C) Benefit Producing**	**D) Resource Containing**
Urban		Forest
Community	***1) Ecologic/environment***	Tree
City	Wildlife	Shrub
Village	CO_2 Sequestration	Lawn/Turf
Town	Shade	Water
Suburb	Windbreak	Soil
Local Government	Air Filter	Wildlife
Population Concentration/Density	Noise Reduction	Urban Plants/Woody Veg
Civilization	Soil	
People	Glare	**E) Activity Occurring**
Man	Municipal Watershed	Planning
B) Geographically Located		Management
Urban	***2) Sociological***	Cultivation
Urbanizing	Recreation	Protection/Conservation
Peri-urban	Cultural	Maintenance/Care
Suburban/Fringe	Community	Design
Adjacent Land	Health	Improvement
Rural	Physiological	Establishment
All	Sensory	Anything
City	Landscape	Utilization
Town	Ornament	Wise Use
Village	Engineering	
Public	Architectural	**F) Science Surrounding**
Private	Psychological	Professional
Community		Specialized
Greenspace	***3) Economic***	Art
Park/Street	Recycling	Discipline/Practice
County	Ameliorating	Systematic
Municipality	Aesthetic	Science
Metropolitan	Amenity	Technology
Man's Environment	Windbreak	
Social/Urban Interface	Energy	
Reclaimed	Real estate	
All Lands	Food	
Area We Live	Wood Products	
Urban Woodland		
Watershed		
Populated Place		
Population Concentration/Density		

GIS Integration, Layer Creation, and Comparison

To conduct an urban forest assessment in Wisconsin requires a spatial definition that delimits the potential geographical extent of the resource. Since no accepted standard exists nationally or within Wisconsin, analysis of the Wisconsin urban areas began with the 2000 census, FIA, and two separate DNR definitions. GIS layers representing the spatial extent of each category were established and served as the basis for comparison. All area measurements were rounded to the nearest hectare (2.47 acres).Land areas within and near populated areas in Wisconsin were defined using four classifications; 2000 US Census, Wisconsin DNR_{cvt} (including cities, villages, and towns), Wisconsin DNR_{cv} (including just cities and villages), and FIA definitions.

The 2000 US Census data and classification served as the starting point for area analysis. Discrete political boundaries were spatially defined and this presumably incorporated the majority of large urban areas across the state. Census population centers are represented as 'urban areas' or 'urban clusters.' Census data was downloaded from (http://www.esri.com/data/download/census2000_tigerline/index.html), and the data from each county was merged to create a statewide urban area. The 2000 US Census Bureau (2000) urban definition designated all territory, population and housing units located within an urbanized area (UA) or an urban cluster (UC). It delineated UA and UC boundaries to include territories consisting of core census block groups or blocks that have a population density of at least 390 people/km^2 (1,000 people/mi^2) and surrounding census blocks that have an overall density of at least 195 people/km^2 (500 people/mi^2).

The problem with strictly using census data is that since it is population based, there are cities, villages, and towns left out because they do not meet population requirements, but do contain community tree populations with associated benefits. The Wisconsin DNR provides financial and technical assistance to some of these communities that do not meet the population requirement as defined by the census parameters. From a funding prospective, consideration is also given to communities having the potential to support an urban forestry program. Financial eligibility is contingent upon communities having a standing local government to cooperate with the state and having expressed an interest in advancing current urban forestry programs or developing a new urban forest program.

A separate area was created incorporating all the communities the WIDNR believes contain tree populations within a defined area that they consider to be reflective of an urban forest. The expertise of the state urban forestry coordinator and regional urban forestry coordinators were applied to develop the "Wisconsin urban forest" programmatic definition. All cities (190 total) and villages (395 total) were designated as urban areas by the Wisconsin DNR because they represent most densely populated areas. For one of the WIDNR (DNR_{cvt}) definitions, selected towns (42 of 1265 total) across the state were also added as "urban" on the recommendation of the regional urban forestry coordinators. Towns were included on the basis of existing population centers, urban forestry programs, or the potential to support either in the near future. These towns were included as urban communities within the federal Community Accountability Reporting System (CARS). Town inclusion was a qualitative assessment rather than an implementation of quantitative guidelines using the aforementioned criteria as defined by the State of Wisconsin in their awarding of grant dollars. While portions of the 42 towns exhibit urban characteristics, it was felt that including the entire town may overestimate the area containing urban forest significantly enough that including the towns could be counter productive. Another WIDNR definition incorporating just the cities and villages (DNR_{cv}) was also developed for comparison. It was understood that some of the viable urban areas would be missed using just the cities and villages, but the error associated with missing a few small developments might be far less than the over estimation error introduced by including entire towns. Area analysis was performed on both approaches and comparisons were made to evaluate the influence of the selected towns.

The spatial extent of each area outlined by the three sampling definitions (2000 Census, DNR_{cvt}, DNR_{cv}) was incorporated into separate ArcMap 9.1 data layers. The Wisconsin Transverse Mercator 1983 projection was used. Using this "cookie cutter" approach, discrete boundaries were drawn identifying potential sampling areas and gaps in sampling areas. Layers were 'intersected' to determine the areas in common between definitions. Differences between the area of a given layer and the area of the 'intersect' layer were used to determine areas exclusive to each definition. For example, the total area encompassed by the intersected DNR_{cv}/census layer was subtracted from the DNR_{cv} layer to yield a spatial representation of area exclusive to the DNR_{cv} definition. The results were compiled into data tables and presented. This assessment was first and foremost designed to work at the statewide level, but ideally it will be able to integrate with the national and statewide FIA data to create a total statewide forest assessment, combining data from the rural and urban forest.

The census urban areas/urban clusters were not completely encompassed by the DNR definitions so a 'union' layer was created to include all areas of both definitions. This broad spatial representation of Wisconsin urban centers was used as a baseline for establishing areas eligible for future sample plots. The spatial analysis determined the total possible sample area of the Wisconsin urban forest.

FIA points were plotted to identify what urban areas could be currently sampled using the standard FIA methodology. The total spatial area containing at least one FIA plot and an average area per FIA plot was also calculated. FIA plot locations were downloaded in latitude/longitude coordinates and converted for projection in the WTM system (http://www.ncrs2.fs.fed.us/4801/FIADB/index.htm). The plot points used by our study were likely not the exact points defined by the FIA. There is inherent plotting error because the FIA program does not release the precise location of its sample points. The actual point is within a 1.61 km (1 mile) radius of the projected point. We assumed this error was negligible based on the fact that the number of missed points falling inside the urban areas was equal to the number of points falling outside urban areas that were wrongly included.

CHAPTER 3

TOWARDS A UNIFIED URBAN FOREST AND URBAN FORESTRY DEFINITION

Abstract: Jorgensen coined in 1965 and published in 1970 the first formal definition of urban forestry. Moeller proposed the first definition of the urban forest in 1977. Since then many competing urban forest and urban forestry definitions have been proposed. This paper summarizes key attributes of these definitions. We examined through content analysis 77 definitions found within peer-reviewed papers, secondary literature, and other urban forestry publications. We asked three questions. First, what attributes were used within these definitions and how frequently were they used. The attributes were partitioned within six categories; people based, geographically located, benefit producing, resource containing, activity involved, and science supported. Second, have definitions evolved to broaden the scope of the urban forest and urban forestry envisioned by Jorgensen and Moeller. Third, have categories found within Jorgensen and Moeller lost favor in more recent definitions through contemporary thought of what constitutes the urban forest and urban forestry. Our study found that while numerous definitions have been drafted since Jorgensen's and Moeller's first definitions, subsequent definitions have neither added to nor lessened the significance of their work. Most were simplifications or partial representations. The commonality of attributes found within each category grouping is also presented.

Key Words: Urban Forest, Urban Forestry, Definition, Urban and Community Forestry, Urban Forestry Model

Introduction

In 1970, Jorgensen proposed that urban forestry is "*a specialized branch of forestry and has as its objective the cultivation and management of trees for their present and potential contributions to the physiological, sociological, and economic well-being of urban society*." Jorgensen also believed urban forestry went beyond "…c*ity trees or with single tree management, but rather with the tree management in the entire area influenced by and utilized by the urban population*." Moeller (1977) proposed the first definition of the urban forest: "*The urban forest is a flexible concept that encompasses rows of street trees and clusters of trees in city parks, green belts between cities and eventually forests that are more remote from the inner city. The urban forest occupies that part of the urban ecosystem made up of vegetation and related natural resources found in urban, suburban, and adjacent lands, regardless of ownership. As we move across the urban-rural gradient, the mix of benefits provided by the urban forest changes. The limits of the urban forest cannot be defined by a line on a map. More importantly, the urban forest provides a conceptual framework within which to organize a research program to maximize the benefits that forests can contribute to improving urban environments."* Definitions of the urban forest and urban and/or community forestry provide the basis for defining the extent, management, and function of urban forest resources and the influence from and for human populations (Konijnendijk *et al.* 2006).

The concept and definition of urban forestry (what you do) and urban forests (what you have) has been steeped in controversy over time with competing definitions and scholarly attempts to explain and refine the terminology (Rowntree 1988, Grey 1996, Dobbertin and Prüller 2002, Dobbertin *et al.* 2002, Konijnendijk 2003, Konijnendijk *et al.* 2006). An extensive search by Hauer (2005) of the literature found nearly 80 definitions for urban forestry and urban forests since 1970 (Appendix A). Konijnendijk *et al.* (2006) suggest the need to harmonize urban forestry terminology to improve comparability, compatibility, and provide consistency with definitions.

Many concepts, terms, and definitions pertaining to trees and other woody and herbaceous vegetation and/or their management in and near urban areas have been developed. These include urban green, urban greening, urban greenery, urban green spaces, community forestry, urban and peri-urban forestry, metro forestry, city forestry, town forestry, municipal forestry, amenity forestry, environmental forestry, Stadwald, stadsbos, stadtforst, and urban and community forestry (Miller 1997, Forest *et al.* 1999, Konijnendijk 2000, Konijnendijk 2003). Even though these terms and associated definitions delimit an expressed meaning for the management of the urban forest, similarities among these do exist. Commonalities among definitions include statements that the urban forest is a geographically defined resource which people are a part of and realize the benefits (also liabilities) produced. Differences in the spatial extent, disciplinary interest and social acceptance of the urban forest have complicated attempts to develop a unified definition of the urban forest (Payne and Gallaher 1979, Shafer and Moeller 1979, Rowntree 1988, Konijnendijk 2003, Randrup *et al.* 2005).

Urban forestry involves activity based on building of science to support perpetuation of the resource. Additionally, urban forest management has traditionally relied upon many disciplines (e.g., foresters, arborists, horticulturalists, landscape architects, entomologists, pathologists, soil scientists, etc.) to care for the resource and their interpretations may differ (Miller 1997). As an early example, Abbott (1970) suggested the USDA Forest Service should title their newly developing urban and community forestry (U&CF) efforts as urban arboriculture to better reflect the activities performed on a routine basis. The importance of defining terms adequately and correctly was also stressed early on in a ruling that stated shade tree work is not horticulture and therefore allowed shade tree workers to become certified in a labor union (Anonymous 1970). The Ontario Labor Relations Act did not apply to horticultural workers who were defined as involved with cultivating and tilling a piece of ground for the cultivation of plants because shade tree workers did not prepare soil. Finally, definitions can change over time based on new knowledge and societal changes (Konijnendijk *et al.* 2006). Incorporation of these changes reflects a changing society and evolution of urban forestry.

Regardless of the definition used, concepts and definitions that make up a discipline's professional vocabulary are important for the assessment, planning, and management of urban forests. Measurement, enumeration, and analysis of urban forests is dependent upon what is studied as much as the extent to which conclusions regarding the forest resource are made (Rowntree 1988, Konijnendijk *et al.* 2006). Urban forest planning and management requires defining the spatial extent to which management is going to be applied and the recipients of the net societal contributions from the forest resource

(Rowntree 1986, Dwyer *et al.* 2000). Additionally, such spatial clarifications advance attempts to quantify the urban forest into clearly defined management zones. For example, Sanders and Rowntree (1984) define the urban forest as "… all outdoor vegetation within the legal boundary of a city, including herbaceous, shrub and tree canopy layers." In this case, the definition clearly articulated what resource comprised the urban forest, delineated the management area, and established management objectives.

The evidence suggests that a common/succinct definition of the urban forest and urban forestry would provide a foundation for the discipline. Three questions were asked to identify commonality among the 77 definitions and to determine if the definitions of the urban forest and urban forestry have evolved over the past 40 years. First, what attributes were used within definitions and how frequently were they used. These attributes were partitioned within six category concepts. The basis for these categories were the definitions of the urban forest as defined by Moeller in 1977 and urban forestry as described by Jorgensen (1970). Second, have definitions evolved to broaden the scope first envisioned by Jorgensen and Moeller. Third, have attributes and categories lost favor in more recent definitions through contemporary thought of the urban forest and urban forestry.

Methods

Definitions of urban forestry and the urban forest used in this study were obtained from sources published since 1970. Sources included journals where urban forestry related literature is published (e.g., Arboricultural Journal, Arboriculture & Urban Forestry, Journal of Arboriculture, Hortscience, Journal of Forestry, Landscape and Urban Planning, Urban Forestry & Urban Greening), reviews of urban forestry conference proceedings, urban forestry and arboriculture texts, and use of the University of Minnesota Urban Forestry Database (http://forestry.lib.umn.edu/bib/urban.phtml).

The definitions by Jorgensen (1970, 1974) and Moeller (1977) were used as standard definitions to compare later definitions against. This served two purposes; 1) to quantify changes in the definitions for urban forestry and the urban forest since 1970, and 2) to quantify the extent of similarity between later definitions and those proposed by Jorgensen and Moeller. In other words, did Jorgensen and Moeller use concepts that were later rarely used in proposed subsequent definitions.

Content analysis was used to delimit attributes within each definition for both the urban forest and urban forestry. Attribute frequency counts were derived from the number of definitions that included a particular attribute (Table 3.1). Each attribute was represented for its presence or absence within a definition. Attributes were classified into six categories: (1) people based, (2) geographically located, (3) benefit producing, (4) resource containing, (5) activity involved, and (6) science supported. Most attributes were included within one category; however the attributes urban, city, village, towns, and suburb, however, were included in both the people and geography categories. By definition, these attributes may be interpreted to reflect a focus on people and a geographical area. Within the benefit producing category, subcategories were added to classify attributes within either ecologic/environment, sociological, or economic benefits provided by urban trees. A percentage of definitions containing reference to each category, subcategory, and attribute was then generated.

Results

There were 19 unique urban forest and 58 unique urban forestry definitions found within the literature and used in this study (Appendix A). No published definitions of urban forestry were found prior to 1970. The first urban forestry definition presented by Jorgensen (1970) contained all 6 definition categories (people, geography, benefit, resource, activity, science). The first definition of the urban forest was provided by Moeller (1977) and referenced four specific categories (people, geography, benefit, and resource). Definitions proposed since Jorgensen and Moeller varied in length and the number of categories and attributes represented within a category (Tables 3.2 through 3.8). In no case did a more recent definition contain a new category.

Table 3.1. Six categories and attributes within a category used to describe urban forest and urban forestry definitions.

A) People Based	**C) Benefit Producing**	**D) Resource Containing**
Urban		Forest
Community	***1) Ecologic/environment***	Tree
City	Wildlife	Shrub
Village	CO_2 Sequestration	Lawn/Turf
Town	Shade	Water
Suburb	Windbreak	Soil
Local Government	Air Filter	Wildlife
Population	Noise Reduction	Urban Plants/Woody
Concentration/Density	Soil	Veg
Civilization	Glare	
People	Municipal Watershed	**E) Activity Occurring**
Man		Planning
B) Geographically	***2) Sociological***	Management
Located	Recreation	Cultivation
Urban	Cultural	Protection/Conservation
Urbanizing	Community	Maintenance/Care
Peri-urban	Health	Design
Suburban/Fringe	Physiological	Improvement
Adjacent Land	Sensory	Establishment
Rural	Landscape	Anything
All	Ornament	Utilization
City	Engineering	Wise Use
Town	Architectural	
Village	Psychological	**F) Science Surrounding**
Public		Professional
Private	***3) Economic***	Specialized
Community	Recycling	Art
Greenspace	Ameliorating	Discipline/Practice
Park/Street	Aesthetic	Systematic
County	Amenity	Science
Municipality	Windbreak	Technology
Metropolitan	Energy	
Man's Environment	Real estate	
Social/Urban Interface	Food	
Reclaimed	Wood Products	
All Lands		
Area We Live		
Urban Woodland		
Watershed		
Populated Place		
Population		
Concentration/Density		

Each urban forest definition contained, on average, 3 categories (median 3, mode 3), and ranged between 2 and 4 categories (Table 3.2). Each urban forestry definition contained, on average, 4 categories (median 4, mode 4) and ranged between 2 and 6 categories. Geography (100%), resource (100%), and people (89.5%) were the most common categories within urban forest definitions (Table 3.2). The least mentioned category was benefits (26.3%). Within the urban forestry definitions, geography (96.6%), activity (93.1%), and resource (89.7%) were the most commonly cited categories within definitions and fewer of these referenced benefits (55.2%) or science (32.8%).

Table 3.2. Commonality of category groupings within 77 proposed urban forest and urban forestry definitions.

	Urban Forest (n=19)		Urban Forestry (n=58)		Both (n=77)	
Category	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Geography	19	100.0	56	96.6	75	97.4
Resource	19	100.0	52	89.7	71	92.2
People	17	89.5	50	86.2	67	87.0
Activity	0	0.0	54	93.1	54	70.1
Benefits	5	26.3	32	55.2	37	48.1
Science	0	0.0	19	32.8	19	24.7

People Attributes: Ten different people attributes were identified in the definitions. The most commonly cited people attributes for the urban forest were urban (36.8%), population density (21.1%), and community (15.8%) (Table 3.3). The dominant people attributes of urban forestry definitions were urban (70.7%) and community (22.4%). Other attributes including city, town, suburb, people, man, village, and civilization were included but overall found in less than 10% in both urban forest and urban forestry definitions (Table 3.3).

Table 3.3. Frequency of attributes within the category people from urban forest (n=19), urban forestry (urban forestry n=58), and both (n=77) definitions combined.

	Urban Forest		Urban Forestry		Both	
Category Attributes	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Urban	7	36.8	41	70.7	48	62.3
Community	3	15.8	13	22.4	16	20.8
Population Density	4	21.1	5	8.6	9	11.7
City	2	10.5	5	8.6	7	9.1
Town	1	5.3	5	8.6	6	7.8
Suburb	0	0.0	4	6.9	4	5.2
People	2	10.5	0	0.0	2	2.6
Man	1	5.3	1	1.7	2	2.6
Village	1	5.3	0	0.0	1	1.3
Civilization	0	0.0	1	1.7	1	1.3
Any People Attribute	**17**	**89.5**	**50**	**86.2**	**67**	**87.0**

Geography Attributes: Twenty-five different geography attributes were identified in urban forest and urban forestry definitions. The most common geography attributes within the urban forest definitions included urban (36.8%), adjacent land (36.8%), city (26.3%), greenspace (26.3%), and population concentration (21.1%) (Table 3.4). The dominant geography attribute within the urban forestry definitions was urban (70.7%). The remaining descriptive attributes were found in less than 13% of both definitions.

Benefit Attributes: Attributes within the benefit category were mentioned infrequently (<10.5%) (Table 3.5). Benefit attributes associated with urban forestry definitions were much more prevalent, however, still identified in a minority of definitions. The most common references were within the subcategories economic (36.2%) and sociologic (34.5%), followed by the ecologic (22.4%) subcategory (Table 3.5).

Table 3.4. Frequency of attributes within the category geography from urban forest (n=19), urban forestry (urban forestry n=58), and both (n=77) definitions combined.

	Urban Forest		Urban Forestry		Both	
Category Attributes	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Urban	7	36.8	41	70.7	48	62.3
City	5	26.3	8	13.8	13	16.9
Adjacent Land	7	36.8	5	8.6	12	15.6
Greenspace	5	26.3	6	10.3	11	14.3
Suburban/Fringe	2	10.5	8	13.8	10	13.0
Park/Street	3	15.8	6	10.3	9	11.7
Population Concentration	4	21.1	4	6.9	8	10.4
Private Land	1	5.3	7	12.1	8	10.4
Public Land	1	5.3	7	12.1	8	10.4
Community	2	10.5	3	5.2	5	6.5
Social or Urban Interface	1	5.3	4	6.9	5	6.5
Urban Land	2	10.5	3	5.2	5	6.5
Suburb	0	0.0	4	6.9	4	5.2
Town	2	10.5	2	3.4	4	5.2
Man's Environment	1	5.3	2	3.4	3	3.9
Urban Woodland	0	0.0	3	5.2	3	3.9
Watershed	0	0.0	3	5.2	3	3.9
Metropolitan	1	5.3	1	1.7	2	2.6
Municipality	0	0.0	2	3.4	2	2.6
Peri-urban	0	0.0	2	3.4	2	2.6
All	0	0.0	1	1.7	1	1.3
All Land	0	0.0	1	1.7	1	1.3
Area We Live	1	5.3	0	0.0	1	1.3
County	0	0.0	1	1.7	1	1.3
Populated Place	1	5.3	0	0.0	1	1.3
Reclaimed	0	0.0	1	1.7	1	1.3
Rural	0	0.0	1	1.7	1	1.3
Urbanizing	0	0.0	1	1.7	1	1.3
Village	1	5.3	0	0.0	1	1.3
Any Geography Attribute	**19**	**100.0**	**56**	**96.6**	**75**	**97.4**

Within these subcategories the attribute description that was identical to the subcategory (i.e. generic environment, generic sociologic, generic economic) was most common, including generic sociologic (25.9%), generic economic (24.1%), and generic ecologic (13.8%). Some definitions also used the word benefit that was not linked to any subcategory within the urban forest (10.5%) and urban forestry (15.5%) definitions. All attributes within the subcategories with the exception of the generic benefit (e.g., ecologic, sociologic, and economic) and physiological (17.2%) within the sociologic subcategory were listed 10% or less of the time in all definitions.

Resource Attributes: Commonly identified urban forest resource attributes were urban plants/woody vegetation (57.9%), trees (47.4%), and forest (21.1%) (Table 3.6). Likewise, trees (69.0%), urban plants/woody vegetation (29.3%), and forest (26.7%) were frequently mentioned describing urban forestry. Other attributes including, wildlife, shrub, water, lawn/turf, and soil were listed in fewer than 10% of all definitions.

Activity Attributes: Within the activity category management (86.2%) and planning (29.3%) were most commonly listed (Table 3.7). Protection/conservation (12.1%) and cultivation (10.3%) were also mentioned in more than 10% of the urban forestry definitions. The remaining attributes included establishment, planting, maintenance/care, design, anything, improvement, utilization, and wise use, but occurred in less that 10% of the definitions.

Table 3.5. Frequency of attributes within the category benefits from urban forest (n=19), urban forestry (urban forestry n=58), and both (n=77) definitions combined.

Category and	Urban Forest		Urban Forestry		Both	
Subcategory Attributes	Number	Percent	Number	Percent	Number	Percent
Ecologic/Environmental	**2**	**10.5**	**13**	**22.4**	**15**	**19.5**
Generic Ecologic	2	10.5	8	13.8	10	13.0
Wildlife	0	0.0	5	8.6	5	6.5
Air Filter	1	5.3	2	3.4	3	3.9
Municipal Watershed	0	0.0	2	3.4	2	2.6
CO_2 Sequestration	0	0.0	1	1.7	1	1.3
Glare	0	0.0	1	1.7	1	1.3
Noise Reduction	1	5.3	0	0.0	1	1.3
Shade	1	5.3	0	0.0	1	1.3
Soil	1	5.3	0	0.0	1	1.3
Windbreak	1	5.3	0	0.0	1	1.3
Sociologic	**1**	**5.3**	**20**	**34.5**	**21**	**27.3**
Generic Sociologic	1	5.3	15	25.9	16	20.8
Physiological	0	0.0	10	17.2	10	13.0
Recreation	0	0.0	6	10.3	6	7.8
Landscape	0	0.0	5	8.6	5	6.5
Psychological	0	0.0	3	5.2	3	3.9
Health	0	0.0	2	3.4	2	2.6
Community	0	0.0	1	1.7	1	1.3
Architectural	0	0.0	1	1.7	1	1.3
Cultural	1	5.3	0	0.0	1	1.3
Engineering	0	0.0	1	1.7	1	1.3
Ornament	0	0.0	1	1.7	1	1.3
Sensory	1	5.3	0	0.0	1	1.3
Economic	**2**	**10.5**	**21**	**36.2**	**23**	**29.9**
Generic Economic	1	5.3	14	24.1	15	19.5
Aesthetic	0	0.0	5	8.6	5	6.5
Wood Products	0	0.0	5	8.6	5	6.5
Amenity	1	5.3	3	5.2	4	5.2
Ameliorating	0	0.0	3	5.2	3	3.9
Energy	0	0.0	3	5.2	3	3.9
Recycling	0	0.0	2	3.4	2	2.6
Food	0	0.0	1	1.7	1	1.3
Real Estate	0	0.0	1	1.7	1	1.3
Windbreak	0	0.0	1	1.7	1	1.3
Unspecified Benefit	2	10.5	9	15.5	11	14.3
Any Benefit Attribute	**5**	**26.3**	**32**	**55.2**	**37**	**48.1**

Table 3.6. Frequency of attributes within the category resource from urban forest (n=19), urban forestry (urban forestry n=58), and both (n=77) definitions combined.

	Urban Forest		Urban Forestry		Both	
Category Attributes	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Trees	9	47.4	40	69.0	49	63.6
Urban Plants/Woody Veg.	11	57.9	17	29.3	28	36.4
Forest	4	21.1	16	27.6	20	26.0
Wildlife	1	5.3	4	6.9	5	6.5
Shrub	2	10.5	2	3.4	4	5.2
Water	1	5.3	3	5.2	4	5.2
Lawn/Turf	1	5.3	1	1.7	2	2.6
Soil	1	5.3	0	0.0	1	1.3
Any Resource Attribute	**19**	**100.0**	**52**	**89.7**	**71**	**92.2**

Table 3.7. Frequency of attributes within the category activity from urban forest (n=19), urban forestry (urban forestry n=58), and both (n=77) definitions combined.

	Urban Forest		Urban Forestry		Both	
Category Attributes	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Management	0	0.0	50	86.2	50	64.9
Planning	0	0.0	17	29.3	17	22.1
Protection/Conservation	0	0.0	7	12.1	7	9.1
Cultivation	0	0.0	6	10.3	6	7.8
Establishment	0	0.0	5	8.6	5	6.5
Planting	0	0.0	4	6.9	4	5.2
Maintenance/Care	0	0.0	3	5.2	3	3.9
Design	0	0.0	2	3.4	2	2.6
Anything by a Forester	0	0.0	1	1.7	1	1.3
Improvement	0	0.0	1	1.7	1	1.3
Utilization	0	0.0	1	1.7	1	1.3
Wise Use	0	0.0	1	1.7	1	1.3
Any Activity Attribute	**0**	**0.0**	**54**	**93.1**	**54**	**70.1**

Science Attributes: The least common category of the six primary categories was science, with the specialized attribute most commonly mentioned in only 13.8% of the articles (Table 3.8). A total of 7 science attributes were found. Those found in less than 10% of the definitions were art, science, technology, professional, systematic, and discipline/practice. The lack of science attributes for the urban forest is expected since the urban forest does not produce science or activities such as planting, maintenance, or removal.

Table 3.8. Frequency of attributes within the category science from urban forest (n=19), urban forestry (urban forestry n=58), and both (n=77) definitions combined.

Category and Attributes	**Urban Forest**		**Urban Forestry**		**Both**	
	Number	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Specialized	0	0.0	8	13.8	8	10.4
Art	0	0.0	5	8.6	5	6.5
Science	0	0.0	5	8.6	5	6.5
Technology	0	0.0	5	8.6	5	6.5
Professional	0	0.0	4	6.9	4	5.2
Systematic	0	0.0	2	3.4	2	2.6
Discipline/Practice	0	0.0	1	1.7	1	1.3
Any Science Attribute	**0**	**0.0**	**19**	**32.8**	**19**	**24.7**

Discussion

Urban forestry is a relatively new addition to the field of forestry. There was no definition for urban forestry within the widely available forestry literature until the 1970's (Weck 1966, Jorgensen 1970, Ford-Robertson 1971). However, urban forestry was used as a term in the late 1800's as part of a Park Commission Report to the City of Cambridge, MA (Ricard 2005). This was also a time in North America for activities and programs consistent with urban forestry that were initiated through Shade Tree Wardens, municipal forestry, and arboriculture programs in the late 1800's (Campana 1999, Ricard 2005).

This study found that the fundamental definitions offered by Jorgensen (1970) and Moeller (1977) are sound. Changes or additions tend to reflect regional/temporal concerns. All definition categories tended to be mentioned more frequently in the new definitions relative to the old definitions. In some cases, more recent definitions are simplifications but still cover the categories and attributes presented by Jorgensen and Moeller. As an example, the definition by Helms (1998) was a concise restatement of Jorgensen's definition, stating that the urban forest comprises the forest resources in and around urban community ecosystems for the physiological, sociological, economic and aesthetic benefits trees provide society. Several later definitions borrowed closely from the Jorgensen description (e.g., SAF UF Working Group 1972, Nobles 1980, Kuchelmeister and Braatz 1993, Helms 1998, SAF 2004, Burley *et al.* 2004). Some definitions (Arnold 1971, Rowntree 1986, Cramb 1993, Burban and Andresen 1994, Tyrvainen *et al.* 2003) described the urban forest simply as any vegetation around human settlement, while others went as far to say that all forestry is urban forestry (Carlozzi 1971).

This study collectively points to urban forestry as being the management of urban vegetation for human benefit in areas impacted by people (Hauer 2005). Interestingly, none of the definitions explicitly stated local citizenry as being involved in the decision or planning and management stages. However, consistent with community forestry in third-world rural settings, forestry in urban areas also benefits from a participatory process to move urban forest management towards sustainable urban forests based on societal desires, ecological integration, and economic inclusion (Clark *et al.* 1997, Dwyer *et al.* 2003, Thompson *et al.* 2005). The six categories from this study provide a basis to describe the urban forest and manage it through urban forestry.

People Centered Urban Forest Descriptions

The nearly 90% of definitions that included people attributes reflects an increasingly urbanizing society that is escalating the importance of urban forestry and urban greenspaces (Miller 1997, Dwyer *et al*. 2000, Kim 2000, Konijnendijk *et al.* 2004, Nowak and Walton 2005). This is noteworthy considering 50% of the worlds population lives in urban areas and this is expected to reach 75% by the year 2025 (Dwyer *et al*. 2000, Kim 2000). With the attributes urban and community being identified in over 85% of the urban forest and urban forestry definitions, attributes have not lost favor over time (Jorgensen 1970, Moeller 1977, Miller 1988, Konijnendijk 2003, Burley *et al.* 2004).

It can also be argued that regardless of location, all forests are important. Carlozzi (1971) suggested that "*all forestry is urban forestry*" basing his idea on a shift from an agrarian-based society to an urban-based environment. During this time period Rhodes (1971) suggested the urban population and elected officials will guide management of rural forests through their collective value system. Urban residents are increasingly imposing their ideas, values, perceptions, life styles, and vision upon rural forests (Konijnendijk

2003, Dwyer and Childs 2004). More commonly however, forest resources in or near concentrations of people are taken to delimit the extent of urban forests (Jorgensen 1970, Miller 1997, Forrest *et al.* 1999, Dwyer *et al.* 2000, Konijnendijk *et al.* 2004).

Dwyer and Childs (2004) recently described the movement of people across the landscape. Their formulated thesis is one of a blurring of people across the landscape distinguishes a less apparent separation between areas traditionally called urban and rural. Rural recreation/amenity areas where residential and recreational communities arise through seasonal and permanent homes reflect urban forests through this built environment.

Geographical Depictions of the Urban Forest

Geography attributes were most commonly represented, being identified in over 97% of all definitions. The variety of geographical attributes also illustrates the large extent of the urban forest. Areas of dense population (i.e. urban land) have been regularly referenced throughout history (Jorgensen 1970, Harris 1983, Nowak 1997, Konijnendijk and Randrup 2004). More recently, adjacent land has been added to the definition (Nilsson and Randrup 1997, NUCFAC 1998, Konijnendijk *et al.* 2000). Because of the proximity of adjacent lands, it is appropriate to include them within the extent of the urban forest because of the reciprocal effect they have on urban areas. Adjacent lands provide refuge and benefits similar to trees more centrally located within urban centers.

Urban areas within the United States typically consist of a densely populated core with great landscape modification. The degree of modification diminishes asymmetrically towards a rural landscape (McDonnell *et al*. 1997). Moll (1989) identifies four urban forests zones that traverse the land from the rural/urban interface (*suburban fringe*) to the inner city (*city center*). Zones may be characterized by canopy cover, lot size, vegetation type and origin, tree location, and human population density (Moll 1989). Hence, development of the urban center alters existing landscapes (e.g., forested, agricultural, or arid) and future urban forest structure is dependent upon changes to forested or treeless land. Further, in some environments (i.e. arid) the post-development forest canopy coverage exceeds pre-development levels (Nowak *et al.* 1996).

Urban Forest Benefit Models

Even though the urban forest produces benefits and a rich history of describing this exists, less than 50% of all definitions explicitly mentioned benefits. This is a significant oversight when seeking to validate the urban forest and field of urban forestry. Benefits were initially addressed by Jorgensen (1970), but fell out of favor during intermediate years (Nobels 1980, Wenger 1984, Stevens and Rowntree 1989). Their recognition within the literature has increased in recent definitions, indicating increased appreciation and awareness of the resource (Nowak 1997, Helms 1998, Gilliland 1999, SAF 2004). Benefits are realized a number of ways and are an important component within the proposed definitions. The development of additional urban forest benefit models (i.e. UFORE, CITYgreen, etc.) will continue to improve future visibility.

Within communities, healthy urban forests promote ecological functioning, provide economic returns and enhance social well-being (Westphal 2004, McPherson 2004). At the ecological level, urban forests mitigate air pollution, protect watersheds through reduced runoff and erosion, foster energy conservation through shading and the moderation of winds, improve soil holding capacities, and provide wildlife habitat (McPherson 2004, Dwyer *et al*. 2000). Urban forests also foster a healthier society by improving air quality through reducing air pollutants (Nowak *et al.* 2002). Urban forests contribute to the economic well being of communities through increased shopping in treed retail centers, enhanced property values, the professional livelihood of those that care for urban tree populations and landscapes (Nowak *et al*. 2002, Wolf 2005).

Sociologically, urban vegetation has been linked to reduced crime rates, enhanced psychological well-being, expanded outdoor recreation opportunities and the creation of conditions leading to enhanced human fitness (Coley *et al*. 1997, Kuo *et al*. 1998, Dwyer and Barro 2001). People also passively benefit from nature. Nature, when viewed from a window at work, led to greater job satisfaction and emotional well being (Kaplan 1993). Similarly, visits to a local park may help relieve or mitigate stress (Hull and Michael 1993). Ulrich (1984) demonstrated that when exposed to a view of the natural world through a window patients spent less time in a hospital than those without such a view. People were also found to have less stress with regular contact with nature (Ulrich *et al*. 1991).

Social interaction is increased in treed and vegetated areas and subsequently higher levels of social cohesiveness among neighbors (Kuo *et al.* 1998, Coley *et al*. 1997). Urban forestry programs can foster safer communities by providing the citizens with a sense of ownership within the public space (Kuo 2003). Areas that have natural world attributes help develop stronger neighborhood ties, have been correlated with reduced child abuse, foster greater physical and mental health, and are more commonly used as centers of outdoor recreation (Kuo 2001). Ironically, even though outdoor recreation can be promoted through urban forestry efforts, urban forestry texts have limited suggestions as to how urban forest management practices can be direction to provide recreational opportunities (Bradley 1995, Grey 1996, Miller 1997, Manning 1999, Anderson *et al.* 2000).

Resource Comprising the Urban Forest

Urban forests are ecosystems characterized by the presence of trees and other vegetation in association with people and their developments (Miller 1997, Dwyer *et al*. 2000). The urban forest as such a resource was captured in over 90% of definitions. The urban forest resource includes vegetation on public (parks, road right of ways, public green areas) and private lands. A national assessment of the urban forest resource within the contiguous 48 states found that 3.8 billion trees exist within urban areas and 74.4 billion trees in the greater metropolitan region (Dwyer *et al.* 2000). Street trees only constitute approximately 10% of the urban forest within Chicago, IL (McPherson *et al.* 1994), necessitating the inclusion of trees on residential and commercial property.

Within the physical bounds of the urban forest, management is associated with a specific resource base. Trees are an important component of the urban forest that has historically been the major focus of management (Andresen 1976, Jorgensen 1970, Harris 1983, Helms 1998). Trees are an important contributor through benefits such as shade and carbon sequestration (McPherson *et al.* 1994). Trees tend to be the longest lived urban vegetation and therefore grow to be significant contributors to the urban landscape. While significant, trees are not the sole providers of urban greening and its associated benefits.

The more generic term of all urban plants/woody vegetation was even more prevalent than definitions that only included trees. Several definitions explicitly stated all plants contribute to the benefits associated with urban vegetation (SAF UF Working Group 1972, Grey and Deneke 1986, Miller 1997). These definitions included woody and herbaceous plants within the urban forest.

Activity Associated with Urban Forestry

A collection of activities associated with the urban forest have been identified throughout the literature, typically falling under the generalized umbrella of urban forestry by adding an action related to the resource (Miller 1997). The common inclusion of management in definitions suggests the importance of human intervention with growing the urban forest. While not as commonly stated, planning was also included in several definitions and places emphasis on a desired approach and anticipated future urban forest. These activities include but are not limited to planning, management, cultivation, and conservation (Jorgensen 1970, Burns and Moeller 1979, Costello 1993, Deneke 1993). Incorporation of an activity component while defining urban forestry is important to illustrate that the urban forest is not a stagnate resource, nor is it self-perpetuating. Rather, it is the function of natural regeneration and planting of vegetation. Urban trees are an integral component of the urban environment that must be tended to maximize utility and benefits. Because they exist in dense human settlements, physical management must occur to mitigate and remove potential conflicts with man-made infrastructure and reduce hazardous situations. Such mitigation efforts include the proper choice of urban friendly trees and their correct placement within the landscape.

Science Validating Urban Forestry

Urban forestry is actively infusing new science and technology into the management practices of a historic resource. It continues to advance as a specialized branch of forestry. The use of terminology commonly associated with the 'hard' sciences provides an easily identifiable association other scientific professions, essentially creating a sound bite validating the field of urban forestry. The profession of urban forestry has gained recognition as a specialized component of forestry (Jorgensen 1970, Moeller 1981, Dunster and Dunster 1996). While being the least frequently mentioned of the six identified components, science supporting urban forestry has surfaced regularly in the more recent literature (Helms 1998, NUCFAC 2003, SAF 2004, Burley *et al.* 2004, Konijnendijk and Randrup 2004). In the past, most assessments were conducted only for public trees because that was the resource the municipality was concerned with maintaining. The development of new assessment technologies and methods have allowed for drawing more inclusive boundaries. Satellites are now capable of delivering cost effective fine (<1 meter) resolution imagery that could possibly deliver very accurate urban canopy assessments. The data acquired from a canopy study can then be used within benefit models such as UFORE to quantify the resource. The growing use of other technologies such as GPS and GIS improve the mapping and tracking capabilities of municipalities to monitor the urban forest. Landscape designs can then be modeled and implemented to use urban vegetation most effectively.

Conclusion

Developing a standard definition for urban forestry and the urban forest is important to advance this discipline forward using common language others can agree on. Textually defining the location and attributes the urban forest includes is vitally important for establishing a spatial definition for assessment. Without an outline of textual attributes comprising the urban forest and urban forestry, creating defensible sampling boundaries is considerably more difficult.

From this study, more recent urban forest definitions did not add to that proposed by Moeller. Thus, it is fitting to use the first proposed definitions of the urban forest unless justification can be found to do otherwise. We found no such evidence, and therefore propose it as the definition of the urban forest.

The definition of urban forestry proposed by Jorgensen laid the base for the modern definition we are proposing. The definition by Helms (1998) is a more concise and was also the first to directly include the 'art, science, and technology' aspect to defining urban forestry. Including art, science, and technology within the definition lends more credibility to the field of urban forestry as a scientific discipline. Such as, the definition by Helms (1998) is a concise statement of urban forestry.

CHAPTER 4

SPATIAL REPRESENTATION OF THE WISCONSIN URBAN FOREST

Abstract: The state of Wisconsin is developing and implementing a statewide urban forest assessment. Before sampling could begin, the extent of the urban forest needed to be delineated. This paper explains how a set of programmatic definitions was developed to spatially represent the extent of the urban forest. The definitions that were used include the 1) census 2000 definition of urban areas and urban clusters, 2) all cities and villages, and 3) all cities, villages and selected towns. Data layers were downloaded and created using ESRI Arc 9.1 software. The three primary definitions were analyzed to weigh the similarities and dissimilarities associated with each method. The goal was to create the most inclusive definition without grossly under or overestimating the extent of the urban forest resource. We determined that using a combination (union) of the 2000 census definition coupled with the cities and villages yielded the most representative statewide sample set.

Key Words: Urban Forest, Statewide Assessment, Spatial Definition

Introduction

Urban forests are an integral portion of the urban environment and they directly influence the daily lives of nearly 80% of the United States population (Dwyer *et al.* 2003). Urban forests are ecosystems characterized by the presence of trees and other vegetation in association with people and their developments (Miller 1997, Dwyer *et al*. 2000). Contemporary urban forests evolved from city beautification efforts and the architectural functionality associated with trees (Campana 1999, Miller 1997). Even with this, the concept of the urban forest as a fundamental, working component of the urban landscape and the associated benefits are not well understood or widely recognized by the public (Hull 1992). Interestingly, however, the majority of people believe their communities are better places to live because of trees and other plants in the urban environment (Elmendorf *et al.* 2003, Schroeder *et al.* 2003, Lohr *et al.* 2004, Treiman and Gartner 2005). There is great value with the amenity functions of urban vegetation (Miller 1997). However, urban forests have additional environmental and economic values that are especially useful to support integration of trees and associated vegetation into urban landscapes.

Urban and metropolitan areas that support substantial forest resources have the potential to significantly improve the ecologic and economic quality of the urban environment and the well-being of its residents (Dwyer *et al.* 2003). For example, the urban forest contributes to the removal of air pollution, sequestration of atmospheric carbon dioxide, hydrologic benefits, and energy conservation (McPherson *et al.* 1994, McPherson 2004).

These benefits result in saving billions of dollars a year in equivalent control costs (Nowak *et al.* 2002). Urban vegetation also has been linked to social benefits such as reduced criminal activity and improved human health (Kuo and Sullivan 2001a, Kuo and Sullivan 2001b, Taylor *et al.* 2001, Kuo 2003). In addition, a positive correlation exists between vegetation and commerce and this translates into a more vibrant business community (Wolf 2005).

The introduction of exotic pests such as Asian longhorned beetle (*Anoplophora glabripennis*) and emerald ash borer (*Agrilus planipennis*) demonstrates the need to accurately assess tree populations across the entire landscape. For example, the estimated maximum potential national urban impact of infestations by *A. glabripennis* is $669 billion (Nowak *et al.* 2002). As such, a complete understanding of urban forest structure at smaller scales is needed to accurately prepare for the impact of exotic pest infestations.

Knowing where vegetation exists, species distributions, size classification of trees, insect and disease issues, and locations where vegetation can be integrated into the urban landscape is important for managing the urban forest and fostering improved urban environments. Dwyer *et al*. (2000) compiled a national assessment of the urban forests as a basis of the resource within the contiguous 48 states. The assessment estimated there were 3.8 billion trees within urban areas and 74.4 billion trees in the greater metropolitan regions. The assessment scale, however, was not suitable for local urban forest profiles of species composition and delimiting sizes of trees (Nowak *et al*. 2002).

Different approaches have been used to measure urban tree cover and species composition (Nowak *et al*. 1996). Complete ground-based inventories are one possibility for small populations (e.g., tens, hundreds, or a few thousand trees), but they require considerable time and money to conduct (Rideout 2006). A more efficient approach for complete inventories with large populations is the application of remote sensing sampling methodologies. Remote sensing technology may be used to coarsely survey the urban forest resource. Sensors such as the Landsat-5 Thematic Mapper (TM) can record reflectance from 30 meter ground cells in 7 wavebands of the spectrum (Bolstad 2005). Wavebands are used to identify vegetation (tree canopy and grass) and impervious surfaces based on the reflectance values. Satellite imagery and aerial remote sensing can indicate the presence or absence of vegetation within an urban environment (Lillesand and Kiefer 2000), yet they are not reliable for identifying the species of an individual tree. The inherent limitations of remote sensing due to spatial resolution can be addressed through field verification, but doing so requires additional time and effort. This type of technology is useful for assessment of canopy area within an urban setting. Field verification is an important method to confirm remote sensing based field estimates.

Estimating the urban forest through fixed area sample plots on the ground is another method to determine urban tree population structure (McPherson *et al*. 1994, Nowak and Crane 2000). Another ground survey method uses the United States Forest Service (USFS) Forest Inventory and Analysis (FIA) nationwide sample plot grid initially developed to assess the rural forest resource. The FIA plots that fell within urban areas have been used to estimate the urban forest resource with mixed results (Riemann 2003, Nowak *et al.* 2005). Within these studies the sample plots were established within political boundaries, which can be too restrictive, but enable simplified geographical representation.

On a local, city or even county scale, many inventories have been conducted for public trees (Nowak 1997). The vegetation included within these surveys is located on the public right of way, in park settings, and other public green areas. This seriously under-represents the actual urban forest regardless of the scale. In Chicago, IL only about 10% of trees are street trees (McPherson *et al.* 1994). As a result, vast misrepresentation of urban forest structure is possible unless public and private trees are accounted for within an urban forest assessment. While the geographical sphere of influence stretches beyond the borders of urban areas, assessing the urban forest requires boundaries. A fully inclusive assessment methodology is, therefore, needed to quantify both public and private trees in a city or state urban forest inventory. The FIA assessment can be scaled to state and regional levels but it looses reliability because it is too coarse for those levels. A gap exists between the national assessment and local assessments. An assessment that bridges this gap to provide reliable data at the state, county or city level is needed (Rideout 2006). Furthermore, quantification of the urban forest resource representative of the statewide urban forest is needed to support statewide urban forestry planning.

Preliminary nonforest and urban sampling methodologies have been developed in at least three states (Maryland, Massachusetts, Wisconsin) to address the lack of reliable data about the urban forest at county and state levels. The State of Maryland used the USFS forest health monitoring protocol to sample street trees (Cumming *et al.* 2001). Another pilot study within a five county area in Maryland utilized a modified FIA approach with very positive results, including future recommendations for plot design and sampling methodology (Riemann 2003). Results in other locations using FIA based methods, including Wisconsin, have been mixed due to an insufficient number of FIA sample plots (Nowak *et al.* 2005). In the Wisconsin pilot study Eastern hophornbeam (*Ostrya virginiana*) was determined to be the most common urban tree (Nowak *et al.* 2005). Common and frequently planted urban species such as green ash (*Fraxinus pennsylvanica*), white ash (*Fraxinus americana*), and American elm (*Ulmus americana*) were not within the top five. The data would suggest either the wrong areas were sampled (not truly urban areas) or correct areas were under-sampled (Nowak *et al.* 2005, Miller and Miller 1991).

Wisconsin, like many states, does not currently have a statewide urban forest assessment. In the process of implementing a statewide assessment, the spatial extent of urban areas must be established before sampling can begin. Currently there is no recognized or generally accepted definition for the spatial extent of the urban forest. Dwyer *et al*. (2000) used an approach that delineated the national urban forest based on the 1990 census definition of what geographically defines an urban area. The 1990 census defined urban areas as having at least 2,500 people or a population density of at least 384 people/km^2 (1000 people/mi^2). In contrast, state urban & community forestry (U&CF) programs often define the urban forestry from a programmatic point. Amherst, WI is an example of a community excluded by the census definition, but still qualifies for urban forestry assistance dollars under the Wisconsin Department of Natural Resources (WIDNR) definition.

The primary objective of this project was to develop and compare the spatial extent of Wisconsin urban areas using 3 different definitions. The 2000 US Census Bureau definition of urban areas developed a primary area of interest, yet because it is based strictly on population density; it may omit areas of interest to the WIDNR. For that reason, two programmatic WIDNR definitions were developed to more accurately reflect areas of interest to the WIDNR for funding and assessment purposes. One incorporated a combination of cities, villages, and selected towns and a second included only cities and villages within Wisconsin. Additionally, FIA points were plotted over the areas represented by each definition to determine if FIA sample plots adequately reflected urban areas.

Methods

Three approaches were used to delineate the spatial extent of the urban forest in Wisconsin. These approaches included the 2000 US census definition of an urban area and two programmatic definitions of the urban forest based on cities, towns, and villages that were developed by the WIDNR Urban and Community Forestry (U&CF) program. The WIDNR definitions reflect urban and built environments that support or have the potential to U&CF programs without regard to population and would be, based on the US census definition, might be excluded from a statewide assessment of the urban forest.

The first programmatic definition incorporated all cities (incorporated community with at least 1,000 citizens if it is in a rural area or 5,000 citizens if it is in an urban area) and villages (incorporated community with at least 150 citizens if it is in a rural area or 2,500 citizens if it is in an urban area) of record in 2005. The second programmatic WIDNR U&CF definition included all cities, villages and a subset of selected towns that reflect characteristics (managed tree population, tree board, etc.) consistent with an urban forest. These were communities identified as urban by the federal Community Accountability Reporting System (CARS).

Census Approach: The 2000 US Census Bureau data and classification served as the starting point for assessment area analysis because it is easily replicable and is proposed as the new standard for national and state U&CF assessments in the United States. The 2000 census definition uses population density to establish urban areas. Census block groups with a population density of at least 384 people/km^2 (1,000 people/mi^2) and surrounding census blocks with an overall density of at least 192 people/km^2 (500 people/mi^2) define an urban area. Census data were downloaded from ESRI in October 2004 (http://www.esri.com/data/download/census2000_tigerline/index.html). Data from each county was merged in ArcMap 9.1 to create a statewide urban area.

Programmatic DNR Based Approach: The Wisconsin DNR has a programmatic definition of the urban forest that includes the political boundary of a city, village, or town. Many of these communities fall within 2000 census-based-population densities consistent with urban areas. The first definition includes all cities, villages, and selected towns (DNR_{cvt}) and the other includes only cities and villages (DNR_{cv}). All cities (190 total) and villages (395 total) were designated as urban areas in both programmatic definitions. Programmatically the communities either administer or have the potential to administer U&CF technical and/or financial assistance to these areas; they represent densely populated areas or built environments perceived by WIDNR U&CF staff to be consistent with CARS. The CARS system is a USFS standard for defining urban forest communities within a state. Using this system, a few towns (42 of 1,265 total) were also considered as urban forest areas based on their inclusion in CARS (DNR_{cvt}). Some of the viable urban areas would be missed by not incorporating the selected towns, but it is believed that the error associated with missing a few small developments would be far less than the over estimation error introduced by including entire towns.

The spatial extent of each area outlined by the three sampling definitions was incorporated into separate ArcMap 9.1 data layers using the Wisconsin Transverse Mercator 1983 projection (Appendix B). It was assumed that all of the area designated urban by the census was relevant to spatially delineate the urban forests in Wisconsin and that the WIDNR programmatic definitions represented additional areas with urban forests. A union layer was created using the 2000 census layer with each DNR definition separately. The union included all area from either definition. A census comparison was also done to investigate the changes between the 1990 census and 2000 census. The spatial extents of each layer were compared to identify areas unique to each definition and to determine the total and mean number of FIA plots found within each spatial definition and the percentage of polygons (communities or census block area) that contained at least one FIA. If a polygon included an FIA sample point, the area of the entire polygon was included. The total potential urban area included all definitions.

Results

Three spatial definitions differed in the total number of communities captured and spatial extent (Figure 4.1). The DNR_{cvt} had the greatest number of communities with 626 and largest area 1,225,010 ha (3,027,066 ac). The DNR_{cv} had fewer communities (584) and less area 629,654 ha (1,555,908 ac). The census 2000 approach identified 115 communities with an area of 427,949 ha (1,057,446 ac) (Table 4.1). The DNR_{cvt} contained approximately 2.9 times more area than the 2000 census, while the DNR_{cv} was approximately 1.5 times larger than the 2000 census area.

Comparisons were made to investigate the amount of overlap for each of the DNR definitions relative to the 2000 census (Figure 4.2). The area in common between the DNR_{cvt} and 2000 census totaled 342,290 ha (845,818 ac) and was greater than similar area covering 310,023 ha (766,084 ac) between the DNR_{cv} and 2000 census (Table 4.2). The DNR_{cv} delineated 789,824 ac (50.8%) unique area and the DNR_{cvt} 2,181,248 ac (72.1%) unique area relative to the 2000 census spatial area. Of the total area in the WIDNR programmatic definitions, only 49.2% of the DNR_{cv} and 27.9% DNR_{cvt} of the total area within these was in common with the census 2000 spatially delineated area. The additional area included within the DNR_{cvt} definition included population centers falling within towns which was 1,471,158 ac or 48.6% greater than the area within DNR_{cv}.

Table 4.1. Area encompassed by three spatial definitions of the urban forest in Wisconsin.

Spatial Definition	Area (acres)	Area (hectares)	Percent of 2000 Census	Percent of DNR_{cv}	Percent of DNR_{cvt}
2000 Census	1,057,446	427,949	100.0	68.0	34.9
DNR_{cv}	1,555,908	629,654	147.1	100.0	51.4
DNR_{cvt}	3,027,066	1,225,010	286.3	194.6	100.0

DNR_{cv} – Programmatic definition includes cities and villages only
DNR_{cvt} – Programmatic definition includes cities, villages, and towns

Table 4.2. Comparisons of two programmatic spatial definitions of the urban forest in Wisconsin to the 2000 US census definition.

Spatial Comparison	Total Area (acres)	Unique Area (acres)	Percent Unique	Common (acres)	Percent Common
DNR_{cv} to 2000 Census	1,555,908	789,824	50.8	766,084	49.2
DNR_{cvt} to 2000 Census	3,027,066	2,181,248	72.1	845,818	27.9

DNR_{cv} – Programmatic definition includes cities and villages only
DNR_{cvt} – Programmatic definition includes cities, villages, and towns

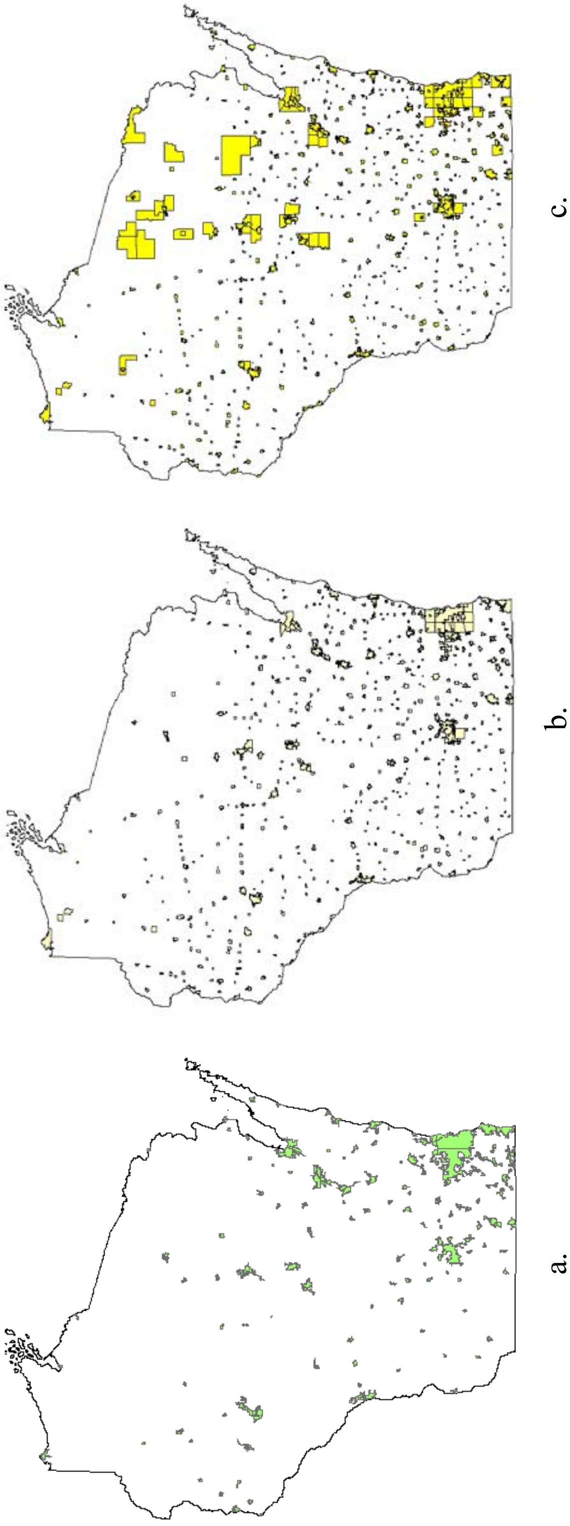


Figure 4.1. Spatial extent of the urban forest in Wisconsin using 3 spatial definitions 2000 US Census Bureau (a), DNR_{cv} (b), DNR_{cvt} (c).

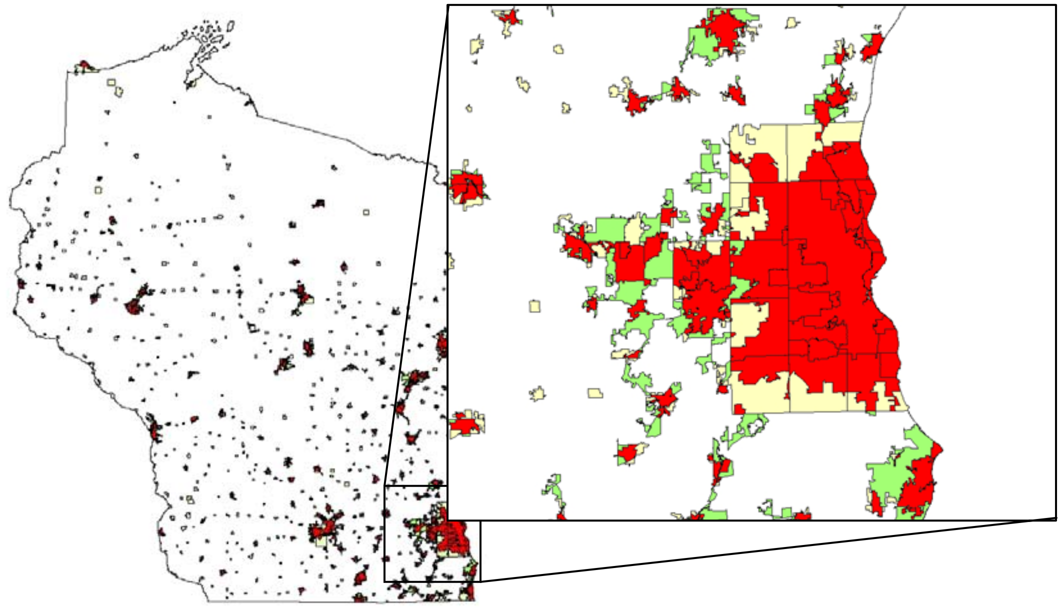


Figure 4.2. A comparison of the spatial extent of the Wisconsin urban forest around the Milwaukee metropolitan area using the 2000 census exclusive (green), DNR_{cv} exclusive (yellow), and areas in common (red).

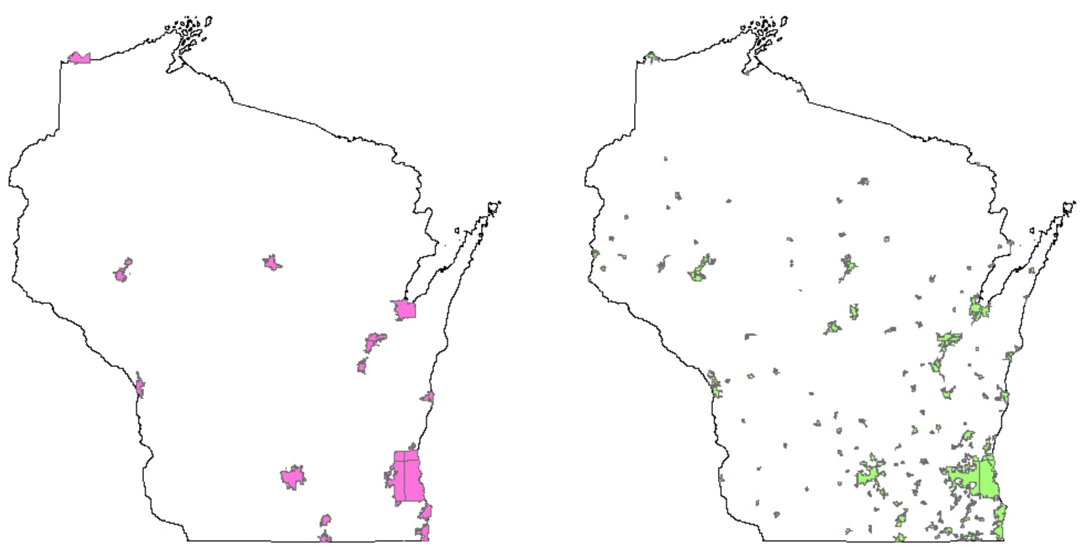
The area including all the DNR_{cvt} was 3,239,732 acres (1,310,668 hectares) while the area using the DNR_{cv} was 1,847,308 acres (747,579 hectares) (Table 4.3). This increased the total area spatially covered by census 2000 by 174.7% through addition of DNR_{cv} area or 306.3% through addition of DNR_{cvt} area.

The new 2000 census definition included 93 more communities and decreased the expanse of the boundaries around major urban areas (Figure 4.3). The area included within the 2000 census was 140% of the 1990 census total area (Table 4.4). There was a significant increase in the number of communities considered urban between the two census classifications, with 115 urban centers in 2000 compared to just 15 in 1990 (Table 4.4). The increase in urban areas does not necessarily reflect explosive population growth, but rather the change in census definition of an urban area between 1990 and 2000.

Table 4.3. Combined spatial area of two programmatic definitions of the urban forest in Wisconsin to the 2000 US census based definition.

Spatial Combination	Total Area (acres)	Percent Common Area / Total Area 2000 Census
DNR_{cv} and 2000 Census	1,847,308	174.7
DNR_{cvt} and 2000 Census	3,238,732	306.3

DNR_{cv} – Programmatic definition includes cities and villages only
DNR_{cvt} – Programmatic definition includes cities, villages, and towns



a. b.

Figure 4.3. The development and change of census urban areas over 10 years comparison between the 1990 census urban areas (a) in contrast to 2000 census urban areas (b).

Table 4.4. Comparison of the 1990 census and 2000 census used to spatially define the urban forest in Wisconsin.

Spatial Comparison	Area (acres)	Area (hectares)	Percent of 1990 Census	Percent of 2000 Census
1990 Census	756,157	306,017	100.0	71.5
2000 Census	1,057,446	427,949	139.8	100.0
1990 Census Exclusive of 2000 Census	222,235	89,946	29.4	21.0
2000 Census Exclusive of 1990 Census	523,524	211,878	69.2	49.5
Census 1990 and 2000 Area in Common	533,922	216,071	70.6	50.5
Combined 1990 Census and 2000 Area	1,279,726	517,887	169.2	121.0

Over 75% of areas that are considered urban within each definition contained at least 1 FIA sample point. The largest percentage of polygons containing FIA points were from the 2000 census definition because the census polygons were larger on average than the city and village polygons. The 2000 census polygons also contained the largest average number of FIA points. The larger polygons increased the probability that they contained a FIA point because the FIA protocol utilizes a systematic grid. This also indicated that the presence of a single FIA point within a polygon was not a sufficient predictor of urban areas.

Table 4.5. Comparison of the polygon size for the DNR_{cv}, DNR_{cvt}, and 2000 census areas and the FIA points contained within each definition.

FIA Comparison	Area (acres)	FIA Points	Polygons	Area per Polygon (acres)	FIA Points per Polygon
2000 Census	980,428	338	83	11,812	4.07
DNR_{cv}	1,194,670	492	259	4,612	1.90
DNR_{cvt}	2,665,828	947	301	8,857	3.15

DNR_{cv} – Programmatic definition includes cities and villages only
DNR_{cvt} – Programmatic definition includes cities, villages, and towns

Discussion

Three potential urban area definitions were used to spatially define the urban forests in Wisconsin. This step is a precursor to initiating a statewide Wisconsin urban forest assessment program (Figure 4.1). The 2000 census definition provided the smallest possible sample area, while the DNR_{cvt} definition represented the greatest area (Table 4.1). An important question is how three definitions compare. Political boundaries were used to delineate the boundaries around cities, villages and towns, but, not all of the area is likely urban or a built environment, resulting in a degree of overestimation of the urban forest. The confidence for projecting urban areas is, therefore, relative to the type of community being addressed. The highest level of confidence occurs for cities and the lowest within towns.

Because of their large size and relatively small population centers, towns in Wisconsin offer the greatest potential for inflating the urban spatial area. The majority of the area within most towns is managed as something other than urban forest. For example, there were two small communities within the Town of Menominee, yet most of the town is being actively managed as a rural forest. Interestingly enough, since the tribe manages the land for the benefit of the tribe, this forestry is analogous to community forestry. Elimination of the selected towns from the DNR definition decreased areas exclusive to the DNR definition were decreased 21% (Table 4.2). While the area exclusive to the DNR_{cv} definition is 75% (789,824 ac) greater than the total 2000 census definition area, that percentage increased to 206% (2,181,248 ac) greater when using the DNR_{cvt} definition. The percentages reflect a potential overestimation associated with each definition by using the 2000 census as a baseline. Omitting the towns using the DNR_{cv} definition underestimated the total urban forest area, but the degree of underestimation was less than the degree of overestimation via the DNR_{cvt} definition. Urban areas within towns can be delineated and added to the urban forest assessment of the state.

The combination of the census 2000 and both programmatic definitions represented the total possible spatial extent of the urban forest that the WIDNR U&CF program would be interested in sampling (Table 4.3). By not including the towns, the potential urban forest of Wisconsin was reduced by 43%. Because the towns have only small areas considered urban, this adds further support that including entire towns would be a significant overestimation of urban areas. In practice, towns in Wisconsin must be further delineated to select only those areas that reflect a built environment and therefore, where urban forests are likely to exist.

In this study some census defined urban areas fell outside of the political bounds of cities and villages and this is consistent with what Dwyer and Childs (2004) described. For the WIDNR U&CF program to consider an urban area from a funding perspective there needed to be a municipal government in place for the state to deal with (Rideout 2006). For example, neighborhood groups (i.e. garden clubs) do not have the political standing to receive funding from the state, regardless of initiative, so areas falling outside the political bounds of cities and villages were not included.

The most accurate spatial representation is likely some combination of the census and programmatic definitions. The census underestimated the total urban forest extent, but did have between 72% and 80% of the area in common with the programmatic definitions. The programmatic definitions likely overestimate the urban forest extent as they include the entire bounds of any city, village, or town as an urban area regardless of built environments and population density. Many smaller communities, especially in towns in Wisconsin, might not exhibit urban characteristics out to the political boundary delineating the city. We believe that the city classification most accurately represents the potential urban area and affords the highest level of confidence, while villages are less accurate, and finally towns reflect the lowest accuracy and confidence level for projecting the extent of urban areas. Using a hybrid spatial extent between the census and DNR_{cv} yields most of the urban areas and potential urban forests within Wisconsin that would meet programmatic needs.

Future Work

Establishing the spatial extent of the Wisconsin urban forest is the first step in an assessment program. The next step will be to develop a sampling methodology to reflect the assessment goals of the Wisconsin DNR. Relevant information would include the size of sampling plots and sampling intensity necessary to achieve a given level of precision. Sampling intensity information would be very useful in determining the feasibility of the assessment program, both in terms of time and money. The sample plot study will establish the best sampling methodology for implementation on the statewide level.

The final step in developing the Wisconsin urban forest assessment will be combining the spatial extent study with the conclusions drawn from a pilot sample plot study and beginning a rotational assessment across the state. Initially, it is anticipated that a 5 year rotational survey would be sufficient for gaining statewide coverage. As a result, no forest data would be older than 5 years, creating a continuously updated database.

By establishing the extent and constituents within the urban forest, more informed statewide decisions can be made regarding the resource. Tree diversity plans could be gradually applied to decrease homogenous urban forest populations and potentially diminish the damage caused by an exotic pest invasion. The value of the urban trees could also be quantified using models such as UFORE. The lack of appreciation/understanding of the benefits that urban forests provide contributes to the devaluation of urban trees and urban forestry programs by citizens and/or policy makers. Recognizing those values and benefits puts the urban forest and its management on a similar playing field with respect to the acquisition and use of public dollars relative to other municipal responsibilities such as public safety, education, and health care. Selling the significant potential ecological and financial returns on a well maintained urban forest could help the tax paying citizens understand that urban trees do far more than reside on boulevards and look nice.

Substantial population growth outside urban and metropolitan areas continues to extend urban influences to forest resources across the landscape, particularly in places with considerable scenic and recreational value (McGranahan 1999). This is particularly true for summer lake communities with relatively few permanent residents and significant population increases during the summer recreation months (Dwyer and Childs 2004). Using the current census 2000 and programmatic definitions, many of these communities would not be considered urban. However, the trees around and within these areas are likely managed as an urban forest. Changing from a population basis to a built vs. unbuilt environment would give a more accurate representation of all urban areas across the state. A further advantage would be the flexibility of incorporating only the developed (built) portions of a municipality or town, rather than following a strict political boundary. This would yield a more accurate assessment of total urban areas across Wisconsin, but could be potentially very labor intensive. Analysis of aerial photography or digital satellite imagery would likely be an easy way to delineate boundaries on the statewide level. Current technology likely makes this option cost prohibitive, but as remote sensing technology improves, this will become a more viable option and should be revisited in the future.

A surrogate for determining the built environment that could be tested is an analysis of road density. It is logical that environments with more development have a greater road density relative to less built environments. There are accessible road density layers within the Arc program and it would be interesting to compare urban areas to similar road densities in out-state areas to determine if it is an accurate predictor of built area.

Another need with urban forest assessment is stratification into different land uses (e.g., Residential, Commercial, Industrial, Parks, Roads, Water, Housing Density) and determining the practicality to stratify. Stratification benefits sampling as like land uses tend to have similar vegetation patterns. It further allows for comparison of areas based on similar land uses. Stratification tends to create more robust sample estimates by avoiding sampling errors between dissimilar areas.

CHAPTER 5

SUMMARY AND FUTURE IMPLICATIONS

Summary

The two primary goals of this project were to 1) identify a written definition of the urban forest and 2) develop a spatial definition for the Wisconsin urban forest. This thesis accomplished both, by identifying the first definition proposals of the urban forest and urban forestry to be adopted as a standard and successfully developing a readily usable spatial representation of Wisconsin's urban forest.

A review of the historical literature using content analysis found that Jorgensen (1970) provided the first and most complete definition of urban forestry. Helms (1998) simplified Jorgensen and we have slightly modified Helms to create the following definition; Urban forestry is defined as the art, science, and technology of managing trees and green infrastructure in and around urban community ecosystems for the ecological, sociological, and economic benefits trees provide society. The urban forest can be described by borrowing closely from Moeller (1977) and Miller (1988). The urban forest is the trees and any vegetation in and around dense human settlement that provide benefits vital to enriching the quality of life. It is hoped that the definition proposed will result in a clearly accepted standard definition for urban forestry and the urban forest. A standardized definition will ease future communication pertaining to the urban forest and field of urban forestry. Implementation of a standard urban forestry definition will also elevate the resource and profession to make it more recognizable. The urban forest will no longer be the forgotten sibling of rural forests.

The programmatic spatial definition of the Wisconsin urban forest is designed for use by the WIDNR statewide urban forest assessment. ESRI Arc 9.1 software was used to create a data layer incorporating the 2000 census area with all the cities and villages around the state. The definition is both highly inclusive of relevant areas and easily replicable. With the urban areas spatially defined, the urban forest assessment project is able to move forward to sampling and the ultimate goal of a 5 year rotational continuous urban assessment.

Future Implications

The next step in implementing a statewide urban forest assessment will be a sample plot study to determine the optimal size and spacing of sample plots within urban areas. This will be done to establish the optimal sampling intensity for a desired level of precision. The WIDNR will decide what level of precision is ideal and/or financially feasible. By using overlapping sampling windows, statistical precision can be compared between sampling intensities. This method will also help determine at what level of sampling the benefits of having more sample sites is outweighed by the additional cost of sampling those sites.

A potential problem with using population density as the predictor of urban areas is the omission of seasonal populations. Vast parts of Wisconsin are vacation destinations for people from urban areas within and outside the state. Because the summer homes are not permanent residences, these areas are not recognized as having large populations. In the summer months, these small city and village populations spike. It is expected that the vegetation around these areas is managed more like an urban area than a rural one. Thus a parameter is needed to look beyond simple population densities.

A comparison between built versus unbuilt environments would be the most accurate predictor of the urban forest. Remote sensing is one method to delineate the boundary between the built and unbuilt environment. While yielding very good results, a statewide analysis could take a considerable amount of time and money. If the resources are not available to do a complete remote sensing analysis, road density could potentially be used as a surrogate. Road density is another method to estimate building density and road data layers are already available online.

The findings from this research effort will further the study of the urban forest in theory and application. By providing a standard definition, a greater general understanding and appreciation of the urban forest should be gained. On a more local scale, with the establishment of a programmatic spatial definition of the Wisconsin urban forest, the statewide urban assessment sampling rotations may begin. The Wisconsin statewide assessment is the first of its kind and could serve as a model for other states seeking to develop their own statewide urban forest assessments.

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Appendix – A
Urban forest and urban forestry definition components

Proposed Definitions of Urban Forestry, and Related Terms	**Source**
No definition for urban forestry within the forestry dictionary.	Weck 1966
No definition for urban forestry within the forestry terminology reference. The reference does offer definitions for arboriculture (The cultivation, i.e. growing and tending, of trees and shrubs, individually or in small groups, generally for ornament and instruction rather than use or profit.) and community forestry (Forest owned and generally managed by a community, e.g. a village, town, tribal authority or local government, the members of which share in cash, kind, and/or other benefits.	Ford-Robertson 1971
Urban Forestry is a specialized branch of forestry and has as its objective the cultivation and management of trees (note: *and forests* added to the 1974 definition) for their present and potential contributions to the physiological, sociological, and economic well-being of urban society. These contributions include the over-all ameliorating effect of trees on their environment, as well as their recreational and general amenity value. (Note: Jorgensen also believed urban forestry went beyond "…city trees or with single tree management, but rather with the tree management in *the entire area* influenced by and utilized by urban populations.")	Jorgensen 1970, 1971, 1974, 1986
Urban forestry merely gives forestry a geographic setting, close to man's communities. Environmental forestry is the professional management and protection of forest communities in man's environment for his benefit.	Arnold 1971
Environmental forestry is the professional management and protection of forest and tree communities *in* man's environment *for his* benefit.	Barber 1971
…all forestry is urban forestry. (Note: context based on urbanization of a nation from an agrarian society)	Carlozzi 1971
Urban forestry is a specialized branch of forestry that has its objective the cultivation and management of trees for their present and potential contribution to the physiological, sociological and economic well-being of urban society. Inherent in this function is a comprehensive program designed to educate the urban populace on the role of trees and related plants in the urban environment. In its broadest sense, urban forestry embraces a multi-managerial system that includes municipal watersheds, wildlife habitats, outdoor recreation opportunities, landscape design, recycling of municipal wastes, tree care in general, and the future production of wood fiber as a raw material.	Society of American Foresters Urban Forestry Working Group 1972 (as found in Grey and Deneke 1986 and Miller 1997)
Environmental forestry involves those aspects of resource	Pinchot Institute

management dealing with man's needs for, and association with, the tangible and intangible values of forest vegetation in and around metropolitan areas. Such forested vegetation involves a wide range of forest conditions – ranging from city park environments to greenbelts and woodlands in rural areas that intersperse the huge, sprawling, urban complexes throughout Megalopolis.	1973
Anything a forester might reasonably do productively in an urban-oriented environment.	Richards 1973
The application of basic forest management principles in areas subject to concentrations of population.	Stewart 1975
Urban forestry encompasses the management of trees and forests affected by intensive social influence, use, and value.	Andresen 1976
Urban forestry is the management of the vegetation in urban and urbanizing areas.	Little 1978
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.	Cooperative Forestry Assistance Act of 1978, Nobles 1980, USDA-FS 2002
We view urban forestry as a concept through which the planning and management of woody vegetation and green space are coordinated and manipulated to provide multiple and sustained benefits to urban people.	Burns and Moeller 1979
Urban forestry is the wise use and management of urban vegetation. … The ultimate goal of urban forestry is to enhance the urban setting through the wise use and management of the urban forest resource.	Ehlers 1980
Urban forestry is a concept that encompasses the planning and management of all urban forest resources for their present and potential contribution to the physiological, sociological and economical health of urban society. Inherent in this concept is the development of an awareness by the urban population of the role of natural resources in the urban environment. In its broadest sense, urban forestry may relate to street and residential trees, urban woodlands, wildlife habitats, open spaces, windbreaks, green belts, roadside screens, curbs areas, parks and other areas within the urban development capable of supporting vegetation, as well as to landscape design, tree care and the utilization of urban wood. Urban forestry can and should complement arboriculture.'	Nobles 1980
Urban forestry is not a precisely defined profession but a conceptual framework through which many specialists can direct their talents toward a common goal: to plan, manage, and protect urban forest resources in order to produce the largest quantity and highest quality of desired benefits.	Moeller 1981

Urban forestry is a dynamic and evolving concept. This concept of urban and community forestry is expanding from its early natural focus on street trees to natural resource management throughout urban influence zones. This new concept also involves the recognition that an urban values system affects management practices on rural forest land. We find that city people still think like city folk even after they move into rural areas.	Deneke 1983
Urban forestry is the management of trees in urban areas on larger than an individual basis. (Note: also referred to it as a specialized form of forestry)	Harris 1983, 1992
Urban forestry is the management of publicly and privately owned lands in and adjacent to urban areas.	Wenger 1984
Urban forestry embraces trees grown in and close to urban areas for their value in the landscape, for recreation, and including trees in streets, avenues, urban parks, and on land reclaimed from previous industrial use, as well as those in urban woodlands and gardens.	Hibberd 1989
Urban forestry is about planning and managing existing and / or new treed vegetation of all types and associated wildlife, to establish attractive urban habitats, using systematic forestry-like approaches and environmental principles, in combination with arboricultural and modified silvicultural techniques.	Morsink *et al.* 1989
Urban forestry encompasses all the typical activities involving trees which occur principally, but not exclusively in urban areas. At its most comprehensive it involves the management of an entire urban tree population. Within this broad context, the main aims of urban forestry are likely to be centered around four basic principles: (i) as all trees within the urban area and the urban fringe make some contribution to the urban environment, they should, as far as is possible, be managed as one unified resource. This includes trees in both public and private ownership, (ii) urban trees should be treated as a multi-purpose resource with a range of potentials including enhancement of the urban landscape and environment, wildlife conservation, improvement of recreation experience and the production of timber. Trees should be managed to optimize these resources thereby improving the quality of life within the urban environment, (iii) a community based approach to tree management is fundamental. The owners of trees, both public and private, should be encouraged to contribute to the management of their local environments, taking part in both management discussions and implementation. (iv) the urban forest must be perpetuated in a healthy state by ensuring sufficient planting to counteract tree losses and to enhance the total tree resource.	Lewis 1991

The management of trees in urban areas. "management" includes planning, planting, and care of trees; "trees" include individual, small groups, larger stands, (e.g., green belts) and remnant forests; "urban areas" are those areas where people live and work (defined by Schoeneman, 1992, as population centers of 100 or more people) which can be categorized into four zones (based on Miller's model): downtown, city residential, suburban, and urban-rural interface.	Costello 1993
Urban forestry is the sustained planning, planting, protection, maintenance, and care of trees, forests, greenspace and resources in and around cities and communities for economic, environmental, social, and public health benefits for people.	Deneke 1993
Urban forestry is a specialized branch of forestry that has as its objective the cultivation and management of trees for their present and potential contribution to the physiological, sociological and economic well-being of urban society.... In its broadest sense, urban forestry embraces a multi-managerial system that includes municipal watersheds, wildlife habitats, outdoor recreation opportunities, landscape design, recycling of municipal wastes, tree care in general and the... production of wood fibre as a raw material. Urban forestry is a merging of arboriculture, ornamental horticulture and forest management. It is closely related to landscape architecture and park management and must be done in concert with professionals in these fields as well as with city planners. Urban forestry includes activities carried out in the city centre, suburban areas and the "urban fringe" or interface area with rural lands. Forestry activities can differ significantly according to the zone. In central areas, the potential for significant new urban forestry efforts are relatively limited in most cities. Here, it is mainly an issue of maintaining or replacing trees planted long ago.	Kuchelmeister and Braatz 1993
Community and Urban Forestry: is the planning, establishment, protection, care and management of trees and associated plants individually, in small groups, or under forest conditions within municipalities and counties. It is an opportunity to introduce specialized expertise and sensitivity for understanding the interrelatedness (ecology) of people, land, water, forests, and wildlife.	McFarland 1994
Urban and community forestry can be defined as the planning for and management of urban and community forests to enhance the quality of life for all residents. The process integrates the economic, environmental, political, historical and social values of the community into a comprehensive management plan for the forest.	NASF 1994

Urban forestry deals with the management of all wooded vegetation within urban areas.	Phillips 1993
Urban forest management is a specialized branch of forestry. It includes the planning, designing, establishing, improving, maintaining, regulating, treating, conserving, and protecting of woody vegetation in urbanized areas.	DOD 1996
A specialized form of forest management concerned with the civilization and management of trees in the entire area influenced and/or utilized by the urban population. It includes trees on streets, in parks, on private property, as well as watersheds. Urban forests provide many benefits, including climate amelioration, engineering, architectural, and aesthetic uses.	Dunster and Dunster 1996
That which must be done to make trees compatible and functional in the urban environment.	Grey 1996
A comprehensive definition of urban forestry may be that urban forestry is the planned, integrated and systematic approach to the management of trees, shrubs, and other vegetation in urban and peri-urban areas for their contribution to the environmental, psychological, sociological, and economic well-being of urban society. For practical reasons and to keep the definition short, flexible and understandable by the general public the definition does not need to describe all aspects of urban forestry. Therefore urban forestry can be simply defined as "*the management of urban vegetation to meet local need.*"	Kuchelmeister 1996
As a practice, urban and community forestry is broadly defined as the comprehensive management of forests and related natural resources in populated areas, from the inner city to the developing urban fringe to small communities. This includes an integration of natural, social, and economic systems as they affect and are affected by human activity.	USDA-FS 1996
Urban forestry is here defined as planning, design, and management of trees and forest stands with amenity value, situated in or near urban areas.	Nilsson and Randrup 1997, Konijnendijk *et al.* 2000
Urban forestry is the multiple-use management of vegetation, particularly trees, in urban areas. This vegetation is part of a complex urban fabric that includes people and many artificial and natural surfaces. Proper urban forest management can enhance various social and environmental benefits derived from trees (e.g., increased real estate values, improved sense of community, reduced energy use and air pollution) while minimizing the costs associated with maintaining an urban forest.	Nowak 1997
The management of trees and related natural resources in populated areas, from the inner city to the developing urban fringe and within small communities	NUCFAC 1998

The art, science and technology of managing trees and forest resources in and around urban community ecosystems for the physiological, sociological, economic, and aesthetic benefits trees provide society.	Helms 1998
Urban forestry is considered as the planning and managing of trees, forests and related vegetation to create or add values to the local community in an urban area.	Kuchelmeister 1998a
Urban forestry is considered as the planning, management, and conservation of trees, forests and related vegetation to create or add value to the local community in an urban area.	Kuchelmeister 1998b
Urban forestry is defined as the planning and managing of trees, forests and related vegetation to create or add values to the local community in an urban area	Kuchelmeister 1998c
The establishment, management and utilisation of woody and other vegetation which integrates the qualities and experiences of the hedgerow and woodland countryside into the urban setting, which ameliorates pollution, extreme weather and glare and which contributes to the production of timber, food and opportunities for public recreation.	Salter 1998
Urban forestry is a specialization within forestry that encompasses the management of naturally occurring and planted trees in urban areas.	Harris *et al.* 1999, 2004
Urban forestry can be defined as an integrated approach to the planting, care and management of trees in urban and peri-urban areas, to secure economic, environmental, and social benefits for urban dwellers.	Gilliland 1999
Urban forestry can best be described as the planting and management of all trees and woodlands in towns and cities. It includes all trees and how they interact to form a unified resource – the urban forest. The urban forest can be broken down into various categories, including: streets trees; trees in woodlands in public parks and open spaces; woodlands in private estates; trees in hedgerows; motorway plantings; and trees in private grounds, gardens, schools, golf courses, cemeteries, etc.	Gormley 1999
Urban forestry is the integrated biophysical management of urban forest ecosystems for improving the quality of life. This includes the art, science and technology of managing trees and forest resources as an integral part of urban community ecosystems for physiological, sociological, economic and aesthetic benefits	SAF 2004
Urban forestry involves the management of trees and associated resources in urban and urbanizing areas. This management may be planned and undertaken at several scales, ranging from individual tree to the metropolitan landscape and beyond.	Dwyer *et al.* 2002
Management of publicly and privately owned trees in and adjacent to urban areas.	Schuck *et al.* 2002
The art, science, and technology of managing trees, forests, and	NUCFAC 2003

natural systems in and around urban areas for the health and well being of communities	
The art, science, and technology of managing trees and forest resources in and around urban community ecosystems for the physiological, sociological, economic, and aesthetic benefits trees provide society.	Burley *et al.* 2004
Urban forestry, which is the management of publicly and privately owned trees in and adjacent to urban areas, has emerged as an important branch of forestry. Urban forests include many different environments such as city greenbelts; street and utility rights-of-way; forested watersheds of municipal reservoirs; and residential, commercial, and industrial property.	Encyclopedia Britannica Online 2004
Urban forestry is an integrated concept, defined as the art, science, and technology of managing trees and forest resources in and around community ecosystems for the psychological, sociological, aesthetic, economic, and environmental benefits trees provide society. An urban forests defined as comprising all tree-dominated green areas in and around urban areas.	Konijnendijk and Randrup 2004
Broadly defined, UCF is the comprehensive management of trees, forests, and related natural resources in populated areas, such as inner cities, suburbs, the outer areas of cities and towns, and communities of various sizes.	U.S. House of Representatives 2004
The cultivation and management of trees and forests for their present and potential contributions to the physiological, sociological and economic well-being of urban society.	Government of British Columbia (undated) borealforest.org (undated)
In the context of carbon offsets, tree planting undertaken in urban areas to provide shade and insulation to buildings and residences, reducing the energy required for heating and cooling. CO_2 emissions reductions are accomplished through sequestration in the trees and reduced energy demand.	Canadian Agricultural Energy End-Use Data and Analysis Centre (undated)
(1) The practice of forestry in an urbanized environment; (2) A specialized branch of forestry that has as its objective cultivating and managing trees in urban areas and the evaluating their contribution to the physiological, sociological, psychological (and sometimes economic) well-being of urban society.	Lasting Forests (undated)
Urban / Community Forestry is management of natural resources in urban and rural community environments. This includes the wildlife, aquatic resources, turf, flowers and shrubs and, of course, the trees.	Western Illinois University (undated)

Proposed Definitions of the Urban Forest and Related Terms	**Source**
The urban forest is a flexible concept that encompasses rows of street trees and clusters of trees in city parks, green belts between cities and eventually forests that are more remote from the inner city. The urban forest occupies that part of the urban ecosystem made up of vegetation and related natural resources found in urban, suburban, and adjacent lands, regardless of ownership. As we move across the urban-rural gradient, the mix of benefits provided by the urban forest changes. The limits of the urban forest cannot be defined by a line on a map. More importantly, the urban forest provides a conceptual framework within which to organize a research program to maximize the benefits that forests can contribute to improving urban environments.	Moeller 1977
An urban forest, therefore, is that portion of the urban ecosystem that consists of forest vegetation, water, soil, and wildlife in densely populated areas and adjacent lands.	Shafer and Moller 1979
We use the words "urban forests" to include all urban trees and related green spaces, whether those trees are growing singly or in groups.	Driver and Rosenthal 1980
The urban forest is defined here to include all outdoor vegetation within the legal boundary of a city, including herbaceous, shrub and tree canopy layers.	Sanders and Rowntree 1984
The urban forest can be most simply defined as the planted environment within the fabric of a variety of man-made uses. Collectively, it includes trees, shrubs, and lawns in city parks, public areas, private yards, and shopping centers – the overall green environment. It is a people-oriented forest designed to provide a quality living environment and enhance the social, cultural, sensory, and economic dimensions of urban life. The urban forest also has ecological value. It modifies the environment in a positive way by providing shade, wind protection, air filtering, noise reduction, and soil protection. It can modify the environment negatively when it requires more energy and water resources to maintain than are reasonably available in the long term. The measure of urban forests value and viability would be in how well positive benefits are balanced with consumptive requirements.	Hudson 1985
Urban forest, broadly defined, constitute all vegetation in urban areas.	Rowntree 1986
The urban forest may be defined as the sum of all woody and associated vegetation in and around dense human settlements, ranging from small communities in rural settings to metropolitan regions.	Miller 1988, 1997
We use a broad definition of the urban forest that includes all vegetation within, or adjacent to, an urbanized area. This includes suburbs and rural communities where vegetative	Stevens and Rowntree 1989

management is influenced by the neighboring urban center. Trees, shrubs, and herbaceous cover are all considered components of the urban forest.	
Urban forests are not restricted to urban areas, they can be found wherever trees are subject to stress imposed by the proximity of large numbers of people.	Cramb 1993
An urban forest is the area in and around the places we live that has or can have trees. Street trees, park trees, green spaces, residential land, public and private spaces with vegetation collectively make up the urban forest. This includes the urban fringe where subdivisions are under construction as well as the rural land that is being considered for development.	Moll 1995
Urban forests are ecosystems characterized by the presence of trees and other vegetation in association with people and their developments. Although people and developments influence forests across the country, urban forests are located where human influences are concentrated (cities, towns, and villages).	Dwyer *et al.* 2000
urban forest *n.* A dense, widespread growth of trees and other plants covering an area of a city.	The American Heritage® Dictionary of the English Language, Fourth Edition 2000
The urban forest includes all woody vegetation within the environs of all populated places. In this sense, it includes not only trees within city limits, but also those on associated lands that contribute to the environment of populated places.	Sudha and Ravindranath 2000
For the purpose of this study, 'urban forests' and 'urban trees' were defined as forest stands and trees with amenity values situated in or near urban areas.	Andersen *et al.* 2002
We define the urban forest as the aggregate of all vegetation and green spaces within communities that provide benefits vital to enriching the quality of life.	Pee Dee Resource Conservation and Development Council 2002
Urban forests refer to all forest and tree resources in (and close to) urban areas.	Konijnendijk 2003
Urban forest is defined as a forest situated within the area of a town, where social functions are stressed more than others. (Abstract translated into English by the authors. English language editing by Jana Oštir.)	Osanič and Pirnat 2003
Urban forest is defined as woodland located in or near an urban area.	Tyrväinen *et al.* 2003
The aggregate of all vegetation and green spaces within communities that provide benefits vital to enriching the quality of life	Center for Urban Forest Research (undated)

Appendix – B
Common tasks working with GIS

All instructions given for working in ArcMap

Adding Layers:

Pull down "File">Add Data
Specify where to import the data from (i.e. \\oasis\gis>Wisconsin>tiger>wi_urban_areas_2000.shp)
Ensure that the new layer is in the correct projection
    If not, **Pull down "View">Data Frame Properties**
    Click on the "**Coordinate System"** tab
    Click Predefined>Projected Coordinate Systems>State Systems>NAD 1983 HARN Transverse Mercator

Creating a Union:

Open the '**Arc Toolbox**'
Select 'Analysis Tools'>Overlay>Union
Within the **Union** window, **select** the '**Input Features**' (the layers to combine) from the folder button on the right and **click Add**.
Label the **Output Feature Class**
Click OK

Creating an Intersect:

Open the '**Arc Toolbox**'
Select 'Analysis Tools'>Overlay>Intersect
Within the **Intersect** window, **select** the '**Input Features'** (the layers to find similar areas between) from the folder button on the right and **click Add.**
Label the **Output Feature Class**
Click OK

Exporting Data Tables for Use Within Excel:

Right click on the layer to export
Select 'Open Attribute Table'
Click on **Options>Export**
Label the **Output Table** noting the title and location so it can be found later. Keep the file in .dbf format.
Open the exported data table in Excel. **Save** as an Excel file to save manipulations and/or calculations.

<u>Converting Downloaded Lat/Long Data into Representative Dots:</u>

Open the downloaded Excel data table
Export as "**Tab Delimited"** out of Excel into a new data table

In ArcMap **select "Tools">Add XY Data**
- **Choose** the data table that was just created and **specify** the **X Field** and **Y Field**
- This will bring the data in as an **Event**
- **Export** the data as a **Shape file**

Next the new file needs to be projected
From the "**Arc Toolbox**" **select Data Management Tools>Projections and Transformations>Feature>Project**
- **Select** the input data table
- **Label** the output file
- **Click** the box to the right of "**Output Coordinate System**"
    - **Click "Select">Projected Coordinate Systems>State Systems>NAD 1983 HARN Transverse Mercator**

<u>Adding an Area Field to a Table and Calculating your Area Value:</u>

Step #1:
Make sure that editing is turned off: **Click** on **Editor>Stop Editing** (If not already off)
Right click on the theme of interest and select "**Open Attribute Table**"
When the table opens select **Options>Add Field**

In the Add Field dialog box:
- Enter the Name of the new field: i.e. Area
- Change the type to: Double
- Field Properties:
    - Precision: # of significant digits (16 were used)
    - Scale: # of decimal places you want (2 were used)
    - Click on OK

Click on the new Area field header in the table
Right click and **Select "Calculate Values"** (Click on YES if a message appears)

Step #2:
In the Field Calculator window:
- Put a **check mark** in the "**Advanced Box**"
- **Click** on **Help**
- In the Help window, **scroll down** to where it says "**To Calculate Area**"
- **Highlight the four lines of code** (see below) and copy to the clipboard

```
Dim Output as double
Dim pArea as Iarea
Set pArea = [shape]
Output = pArea.area
```

Close the Help window

Click the cursor in the "**Pre-Logic VBA Script Code**" box
Paste the four lines of code into the box
In the bottom box (where it says Area =) **type** the text **Output**
Click on **OK,** this will give a calculated area in square meters because the layer was in WTM.
To convert into acres or hectares, the output is divided by 4,046.856 (acres) or 10,000 **(**hectares).