Understanding Washington, DC's Urban Forest through GIS

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May, 2007

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With a mission to restore, enhance and protect the tree canopy of Washington, DC, Casey Trees has a set of ambitious goals, and to achieve them, we must use the most efficient tools available. One of those tools is Geographic Information Systems, or GIS.

Since 2001, Casey Trees has used GIS:

- For inventories and surveys including neighborhood analysis
- To share information with District and Federal Government partners, citizens, business improvement districts and other organizations
- For canopy analysis to set objectives for programs and strategic planning
- To measure success and track performance

Established programs that are supported by GIS, using the ESRI ArcGIS suite, include the Community Tree Planting and inventory programs, GreenTech education program, and the Casey Trees interactive Tree Map (See "ArcGIS: Helping Regreen Washington, DC, ESRI 2004). Recently we have begun looking at the use of GIS in our long-range strategic planning, in particular analyzing and setting tree canopy goals district-wide. Section one of this paper gives a brief overview of urban tree canopy goals methodology. The second section details a GIS analysis piece of an active case study on how the methodology has been easily transferred in urban planning specifically storm water management in the District.

SECTION ONE

Urban Tree Canopy Goals

Urban Tree Canopy (UTC) goals and Forest Opportunity Spectrum (FOS) models are used widely in the Mid Atlantic region – particularly in the Chesapeake Bay Watershed. These models enable jurisdictions of all sizes to set tree canopy goals and facilitate regreening strategies on a broad scale. Casey Trees has begun working with partner organizations to set similar tree canopy goals for Washington, DC, and we've begun this process by analyzing the existing canopy and what opportunities there might be to increase tree canopy. There are several different ways to facilitate the regreening effort, but the UTC method efficiently breaks the process into three steps: understand the existing canopy, locate the opportunity then strategize to establish what is realistic within that opportunity. These methods will serve as a starting point for discussions with key agencies, partners and others this spring for implementation.

To ensure the setting of a tree cover goal, we must answer the question – 'what will increased canopy cover provide?' – a significant part of that is stormwater runoff reductions. In April, Casey Trees released the results of the Green Build Out Model, a research project between Casey

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Trees and LimnoTech engineering firm, under an EPA Water Quality Cooperative Agreement. The Model is a planning tool that quantifies stormwater benefits of trees and green roofs and calculates potential reductions in stormwater runoff within the District's separate and combined sewer systems. The model integrates GIS land cover data in a similar way as the UTC model. However because DC has such extensive street tree and impervious surface data (provided by the District government's GIS department - DCGIS) a more detailed analysis was done to model the impacts of street trees over impervious streetscapes. The methods are based on models and data for the District of Columbia though easily transferable to other municipalities interested in quantifying the relationship between tree canopy and stormwater runoff. (See Section Two)

Setting and implementing the Urban Tree Canopy (UTC) goals for the District will be a priority for Casey Trees in the coming years. Along with this, Casey Trees will focus on long term organizational goal setting. How can we track our progress in fulfilling our mission and how can we work with partner agencies to ensure the city is able to move the greening initiative forward?

By using GIS technologies, Casey Trees has made a significant impact, not only in terms of collecting and sharing important data for our organization and our partners, but also in raising public awareness about the importance of trees in an urban area. Having information at our fingertips allows us to quickly answer questions about the city's canopy, species mix, individual tree locations and what trees provide in terms of environmental and other benefits.

In just 5 years, Casey Trees has led by example, implementing state of the art technology not only in its re-greening efforts but in devising its approach to achieving the re-greening goal. GIS has moved to the forefront of government, corporate and independent agency management as well as for non-profit operations. Casey Trees being no exception. The use of GIS has facilitated new opportunities for strategic and operational program management within the organization. These innovative ways to use GIS software is a progressive step that has put Casey Trees and our partners on the cutting edge of technology in environmental and urban forest management practice.

SECTION TWO

The following is documentation describing the tree cover inputs for the Green Build Out Model. The document can be found in its entirety at www.caseytrees.org.

1. INTRODUCTION

The Green Build-out Model adds the 'green component' to the rainfall storage amounts for trees and green roofs to the Mike Urban model according to the following relationship.

*Storage = Interception storage * Coverage area*

This article documents the analysis process for determining the tree canopy data inputs for the "Green Build Out Model" and considers two coverage scenarios. The methods are based on available data for the District of Columbia and transferable to other municipalities interested in understanding existing canopy conditions and opportunities to add tree cover.

2. BACKGROUND

Three related analyses needed to be performed to generate the inputs for the tree cover model assumptions: precise spatial representation of the existing canopy by land cover type and sewershed; and the two opportunity scenarios for the moderate and intensive greening assumptions. The data generated for the existing tree cover canopy of the District is the key base data. Joined with the land cover type and sewershed data, these data sets complete the baseline and the assumption scenarios.

For this type of large area land cover and vegetation analysis the most reliable and practical data source is satellite imagery. To generate the tree cover data set we were able to obtain high resolution IKONOS satellite imagery taken for the DC area in July 2006 through GeoEye. The scenes were then classified for land cover particularly tree canopy at a one-meter resolution.

The District of Columbia's Office of the Chief Technology Officer, DCGIS, has an extensive publicly available data set digitized 'leaf off' from aerial photos (April, 2005). This data is FGDC compliant and readily available on the District of Columbia's website. This data was used to establish the boundaries needed to divide the city into the specific areas of interest for the existing canopy analysis and the opportunity scenarios. The sewershed layer was compiled by the Water and Sewer Authority (WASA) of DC. The layers extracted for these methods are: impervious surface, buildings and sewershed boundaries.

The DCGIS layers provide a reliable data set for establishing the assumptions for a majority of the land cover (impervious surface) types. However, for the streetscape opportunity scenarios we were able to use the Casey Trees street tree space inventory data layer (2002). This data set spatially represents 130,000 street tree spaces in DC including the size and condition of the tree in the box. This layer created a more detailed measurement for the street scape (roads, sidewalk and intersection) assumptions.

3. METHODS

The methods use geographic information system analysis to generate the data sets needed as inputs to the Green Build out/Mike Urban model. The fundamental data set in this analysis is the *existing tree canopy* layer for the District. This layer is analyzed to generate existing tree cover by land cover type (impervious surface) and by sewershed. The assumptions (Table 1) for proposed increases in tree cover for both the moderate greening and intensive greening scenarios were also determined by each land cover type and sewershed.

A relationship is made between existing canopy and the outfall percentage from each sewershed demonstrating the impact of 'greening'. The assumptions are made for interception rates by drawing a comparison from *existing* canopy and *increasing* canopy. The methodology for calculating existing and increasing tree cover to build these assumptions is primarily described in this section. The methods for generating the road, sidewalk and intersections assumptions are described here where the assumptions for the other land cover types are described in the body of the paper.

Table 1: Percentage Tree Cover Assumptions by Land Cover Type

Land Cover Type	Existing Coverage	Moderate Greening Scenario	Intensive Greening Scenario
Impervious Tree Cover			
Roads, sidewalks, intersections	**22%**	25%	35%
Parking lots	**7%**	30%	50%
Paved drives	**23%**	50%	80%
Alleys	**26%**	35%	50%
Median islands, traffic islands, hidden medians, other	**23%**	30%	40%
Pervious Tree Cover			
Includes parks, open space, cemeteries, yards, etc.	**53%**	57%	80%
Total Tree Cover	***35%***	***40%***	***57%***

Data Sources and Data Preparation

Data sets needed for existing canopy and opportunity analysis:

- Existing tree canopy
- Boundaries for surface land cover type and sewersheds

Data sets needed for assumption analysis:

- Existing tree canopy
- Boundaries for surface land cover type and street tree spaces

3.1.1 Land Cover/Tree Canopy Base Data

IKONOS satellite imagery taken of the District of Columbia in July 2006 was used to classify the land cover in one meter resolution by the Spatial Analysis Lab at the University of Vermont/US Forest Service. Figure 1 illustrates the classification process: the satellite image on the top half and the bottom showing the color bands depicting the vegetation vs. the other land cover areas. As the classification is from a top-down perspective, features obscured by the tree canopy, such as some pervious and/or classified as 'canopy'. "Canopy" was extracted and used as the 'existing canopy' data set. 'No Data' was also extracted to identify where an alternative method was needed for determining existing canopy.

The land cover was classified into five (5) class types (Table 2):

Open Land: Scattered small vegetation, grass, bare earth
Canopy: Existing tree canopy
Impervious Surface: (i.e.) Buildings, Sidewalks, Roads, Artificial turf
Water
No Data: Cloud Cover

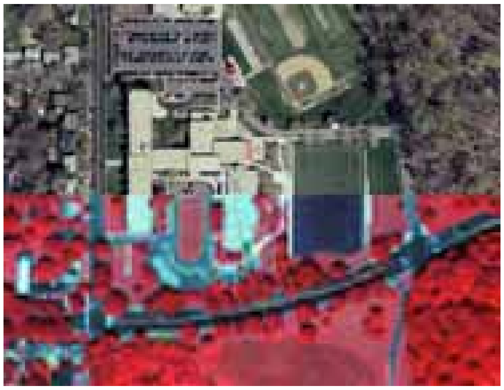

Figure 1: Image taken by IKONOS Satellite, Washington, DC

Table 2: IKONOS Land Cover Classes Citywide

CODE	Existing Land Cover 2006	Square Meters Total
1000	Open Land	27,807,457
2000	Canopy (~34%)	55,807,105
3000	Impervious	70,336,770
4000	Water	15,342,741
5000	No Data (Cloud) (~4.5%)	7,239,821
	TOTAL	**176,533,894**

3.1.2 Existing Canopy Cover where satellite imagery was unavailable

Clouds covered 4.5% of the District in the IKONOS images inhibiting the use this imagery for existing tree canopy. In this instance to show the existing canopy cover we used the Casey Trees 2002 street tree inventory. The street tree inventory is an inventory of street tree *spaces* with an attribute of existing trees or empty box as well as size of the tree crown. The crown radius field was used to determine the existing canopy of the street tree in these areas. The layer was converted to the same projection as the IKONOS and DCGIS base layers.

3.1.3 Land Surface Cover Type (i.e. Impervious Surface) and Sewershed Base Data

DCGIS impervious surface and boundary data sets (2005) were used to define the surface boundaries for the impervious or pervious base layer analysis. Using ESRI ArcGIS Spatial Analyst software, this vector data set was converted to raster in the same projection and one meter cell size as the IKONOS imagery to ensure a precise overlay. Each impervious field of interest was reclassified and given a unique CODE. Table 3 displays the results.

Table 3: DCGIS-OCTO Land Cover Surface Type Data Classes

CODE	Impervious Surface ReClassified (Grouped)	Square Meters Total
10000	Road and Hidden Road	17,455,450
20000	Sidewalk and Hidden Sidewalk	8,509,836
30000	Median and Traffic Island and Hidden Median	603,874
40000	Paved Drive	3,267,858
50000	Parking Lot	8,545,049
60000	Building and Parking Garage	24,221,620
70000	Alley	2,952,640
80000	Intersection	2,648,948
	TOTAL	**68,205,275**

3.2 Determine the District's Existing Tree Canopy for Land cover type and sewershed

Using the 'canopy' data set extracted for the district illustrated in Table 3, further analysis was performed to generate:

- the area (m^2) of existing canopy in each land cover type (i.e Roads, sidewalks Table 3.2)
- the area (m^2) of existing canopy in each land cover type by sewershed.

3.2.1 Determine Area of Existing Canopy in each Impervious Surface Class

The key analysis was performed using ESRI ArcGIS Spatial Analyst cell statistics and raster calculator functions. With each raster cell size equal to one square meter the sum of the *Canopy* CODE (Table 2) and the *Impervious Surface* CODE (Table 3) produced a formula for the area in square meters that canopy extended over that surface (Table 4).

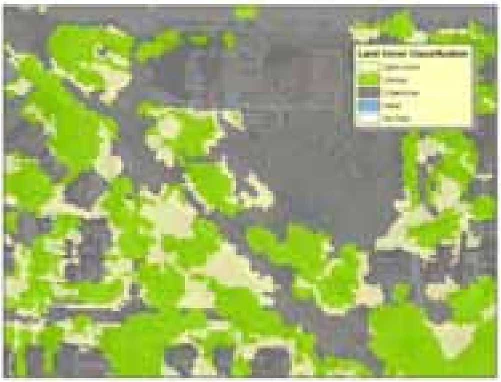

Figure 2: IKONOS Land Cover

Figure 3: Rasterized Street Scape

3.2.2 Determine Area of Existing Canopy over each Impervious Surface Category by sewershed (CSO and CSS)

The existing canopy was determined for each sewershed. A relationship between existing tree canopy can be made from the data available on outfall to each sewershed. Over 700 sewersheds are in the District stormwater system. Each CSS (456) and CSO (316) were also given a unique three digit CODE. Using the same methods of the 1^2m cell size, the SUM of each CODE results in tree canopy and surface (m^2) in each sewershed (Table 4). See example below:

Table 4: Example Canopy Calculations

CODE	Square Meters
12032	1673.0
12033	2495.0
12034	430.0
12326	1991.0
12327	561.0
52188	168.0
52189	7.0
52190	585.0
82190	270.0

<u>Example</u>

CODE 12032 inferred from chart at left: Roads (10000) with overhanging canopy (2000) in CSO 032 equals 1673 square meters

CODE 52186: Parking Lots (50000) with overhanging canopy (2000) in CSS 188 totaled 168 square meters

CODE 82190: Intersections (80000) with overhanging canopy (2000) in CSO 190 total 270 square meters

The final CODE(s) was the formula used as inputs to the Mike Urban Model for existing tree canopy over each land cover type in each CSO and CSS in the District.

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3.3 Determine Street Tree Canopy Opportunity for land cover types for the Two Assumption Scenarios: moderate and intensive

Assumptions for the ‘moderate’ and ‘intensive’ greening scenarios for tree canopy were generated for each impervious surface cover class (Table 1). The extensive street tree data available of 130,000 street trees spaces provided a more accurate representation of the street scape for opportunity over roads, sidewalks and intersections therefore these three land cover surface types were analyzed using a different methodology than the other land cover surface types. The methods for the assumptions scenarios for roads, sidewalks and intersections are described here. The other land cover types are described in the body of the report.

The assumptions scenarios are based on the percentage of available land cover area not currently occupied by existing tree canopy or the tree canopy ‘opportunity’. The easiest way to find the opportunity is to create a layer with maximum tree canopy coverage and then subtract the existing canopy. The existing tree canopy has already been determined for the first stage analysis described above.

__Determine maximum street tree canopy__

With the knowledge that the District plants street trees an average distance of 40 feet apart, the maximum ideal tree canopy would have a 20ft radius where the dripline’s are touching. To generate this layer of maximum street tree canopy, we used a 20 foot buffer on the Casey Trees street tree point file creating the polygon layer used for analysis (Figure 4). The polygon layer was converted to raster and given a CODE and calculated for square meter area (Figure 5).

__Methods for ‘moderate’ and ‘intensive’ scenario assumptions__

The maximum street tree canopy numbers were totaled individually for roads, sidewalks and intersections (Table 4) and then within each sewershed. Using the same ArcGIS Spatial Analysis tools the existing canopy generated in previous analysis (Section 3.2) was subtracted from the maximum canopy. The result was the ‘intensive’ opportunity assumption.

The ‘moderate’ case scenario used the same methodology using a 15ft crown radius. An ideal canopy would have a graduated age class of trees where not all of the trees were at a maximum (20ft radius) or minimum at the same time. An illustration of the overlay for the ‘moderate’ case scenario analysis in ArcGIS is in Figure 4.

Figure 4: ‘Moderate’ streetscape scenario

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Table 4: The Maximum street tree canopy opportunity by land cover type

CODE	Build Out Scenario	Square Meters Total
6000	Canopy over Pervious	5,715,465
7000	Canopy over Road	5,764,744
8000	Canopy over Intersection	2,422,222
9000	Canopy over Sidewalk	2,877,128
150000	Canopy 15 Ft Scenario + above codes	
Xxx	The last three numbers are the unique CODE for sewershed.	

Street tree canopy data point file with a 20ft buffer (Figure 5) is overlaid onto the streetscape layer (Figure 6) to create the maximum opportunity for tree cover over the roads, sidewalks and intersection land cover types (Figure 7).

Figure 5: Street Tree Max Canopy

Figure 6: Impervious Surface Overlay

Figure 7: Canopy by Land Cover Type (Table 4)

4. DISCUSSION

The tree canopy analysis for this report is an innovative method to understanding the extent of tree canopy in Washington, DC. It is easily applied to this model for environmental management highlighting the District's storm water issues. Tree canopy is a vital and dynamic component to each city and should be considered in every environmental and economic agenda. This document provides an explanation of the methodology to do that.

Special Thanks to: Barbara Deutsch and Heather Whitlow of Casey Trees for their editing and formatting. To learn more about the Green Build Out Model and read the entire report, please visit our website at www.caseytrees.org.