Urban Ecosystem Analysis
The District of Columbia

Calculating the Value of Nature

Report Contents

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Supported by the USDA Plan of Action for the District of Columbia

Urban Ecosystem Analysis The District of Columbia

Project Overview

AMERICAN FORESTS conducted an Urban Ecosystem Analysis of the District of Columbia to determine how the landscape has changed over time. The analysis assessed the loss of tree canopy and its associated values using data from satellite images spanning a 24 year period from 1973 to 1997. The analysis covered 43,938 acres of land. A more detailed study of the area was also conducted to determine the economic value of these changes.

The analysis used Geographic Information Systems (GIS) technology to measure the structure of the landscape, with emphasis on tree cover. Regional changes in the landscape were analyzed using satellite images. A more detailed look at the urban forest's economic value was conducted using 1997 low-level aerial imagery and AMERICAN FORESTS' CITYgreen® software. CITYgreen® is a desktop GIS software used by local government agencies and engineering groups for decision support.

Major Findings

From a regional perspective, the ecology of the District of Columbia has changed dramatically since 1973. Forests have declined and urban development has expanded.

■ From an analysis of satellite imagery, average tree canopy cover declined from 37% in 1973 to 21% in 1997.

■ In 1973, areas with heavy tree canopy (50% or greater tree cover) covered 37% of the area (16,440 acres). Developed areas and land, with tree cover less than 20%, covered 51% of the land (22,411 acres).

■ By 1997, areas with low tree canopy (less than 20%) became more prevalent, expanding to 72% of the land area (31,557 acres), an increase of 41%. Heavy tree canopy declined by 64%, representing just 13% of the land area studied (5,871 acres).

There are economic implications of tree loss for stormwater management and clean air in the District of Columbia.

■ From 1973 to 1997, tree loss in the District of Columbia resulted in a 34% increase in runoff—an estimated 29 million cubic feet of water (based on an average 2-year 24-hour storm event). Using the District's cost estimate of $7.80/cubic foot to manage stormwater using sand filters, vegetation loss is equivalent in value to $226 million.

■ The total stormwater retention capacity of this urban forest cover in 1997 is an estimated $440 million, down from 1973's value of $666 million, based on the avoided cost of having to manage this stormwater.

■ Lost tree canopy would have removed about 354,000 pounds of the pollutants: sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), and particulate matter 10 microns or less (PM_{10}) from the atmosphere annually, at a value of approximately $996,000 per year.

Maintaining and restoring tree cover is a cost-effective way to improve urban infrastructure.

■ The natural landscape should be recognized for its economic, as well as its ecological, value. Tree cover is a good measure of the ecological health of the landscape.

■ Increasing the average tree cover to 40% in the area would provide sizeable benefits.

■ Strategically planting trees in urban and suburban areas would improve the effectiveness of tree cover for energy savings, air and water quality, as well as for wildlife habitat.

Table 1. The District of Columbia Vegetation Change and Associated Benefits*

	1973	1997	Loss/Gain 1973-1997
Acres with 50% or more tree cover	16,440 (37.4%)	5,871 (13.4%)	-64%
Acres with 20%-49% tree cover	5,087 (11.6%)	6,510 (14.8%)	28%
Acres with less than 20% tree cover	22,411 (51%)	31,557 (71.8%)	41%
Stormwater Management Value**	$666 million	$440 million	$226 million
Air Pollution Removal Value (annually)	$3 million	$2 million	$1 million

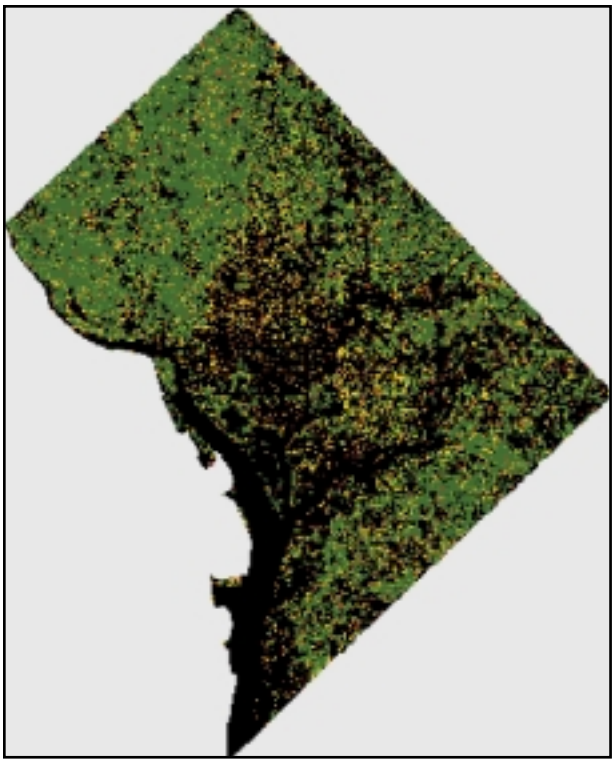
* Numbers may not add to 100% due to rounding

** Represents a one time construction savings, and does not include additional annual savings from avoided maintenance.

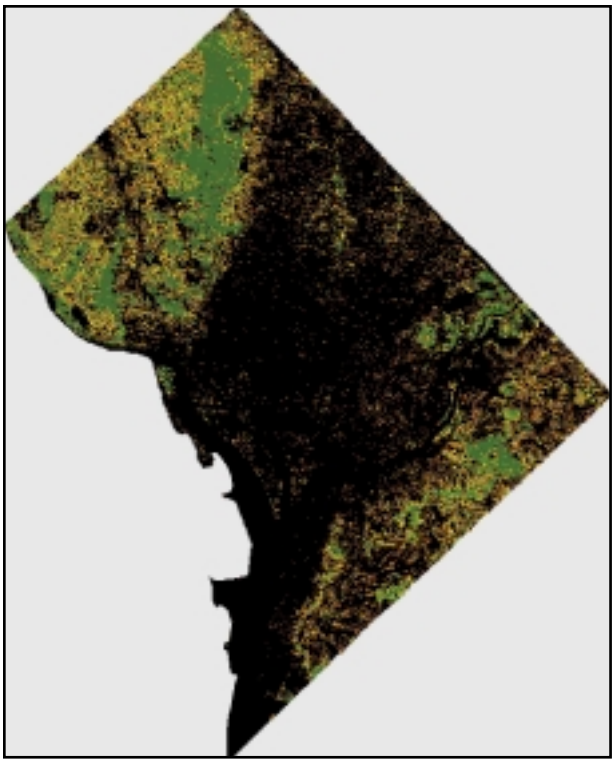
Regional Analysis

Key: % Tree Cover

< 20%	20-29%	30-39%	40-49%	≥ 50%



Landsat MSS 1973 80 Meter Pixel Resolution



Landsat TM 1997 30 Meter Pixel Resolution

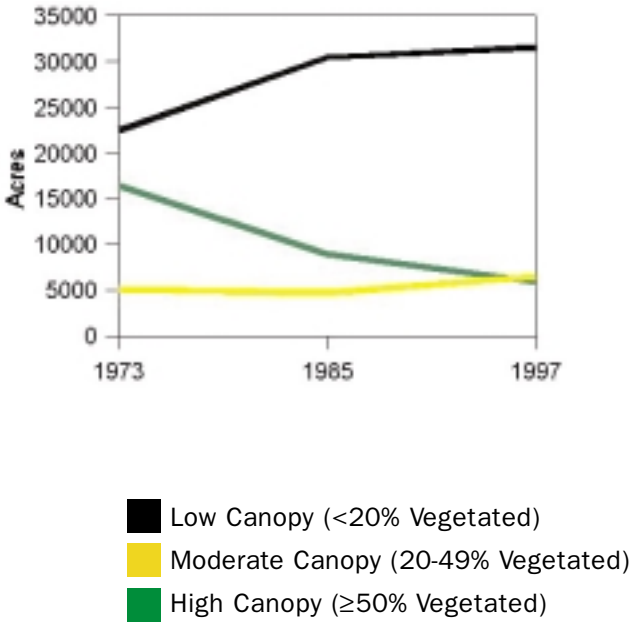
The District of Columbia Satellite Images

Classified satellite images show the change in land cover in the District of Columbia over a recent 24 year period. Heavy tree canopy cover (≥50%) is indicated in green while low tree canopy cover (<20%) and impervious surfaces associated with urban areas are in black. The GIS analysis measures nine categories of tree cover. Canopy categories are displayed in five groupings to accommodate the limitations of printing the images at this scale.

Graphing Change

The changes in vegetation depicted in the satellite images *(above)* are represented by a line graph *(right)*. The chart shows the change in vegetation cover over a 24-year period for three categories. Dense, natural forest cover is represented by a green line and indicates areas with 50% or greater tree canopy. Developed areas are represented by a black line and indicate areas where tree canopy is low, less than 20%. The yellow line represents land where the tree cover is between 20% and 49%.

Vegetation Change
District of Columbia, 1973-1997

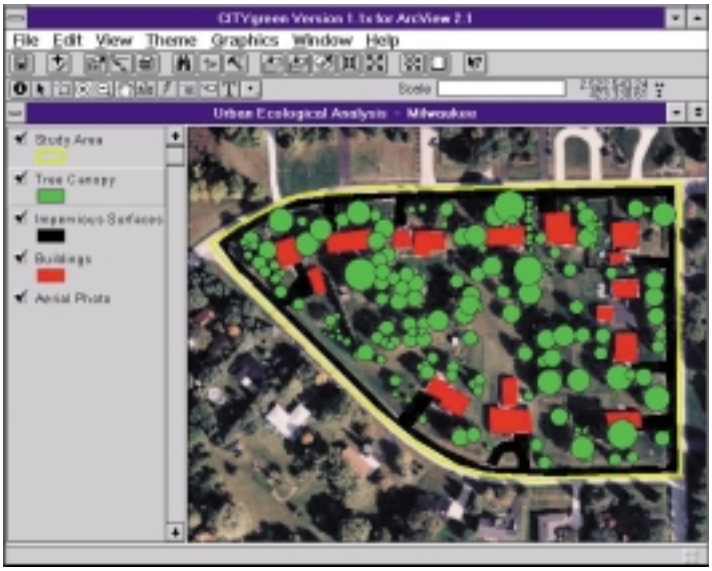


Local Level Analysis

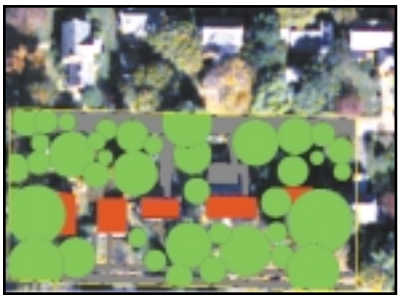
Using canopy cover classes identified from the satellite image, point samples were selected and low level aerial imagery was used along with CITYgreen® software and field surveys to calculate the value of the local ecology.

Twelve sites were selected within the District of Columbia and analyzed for their ecological value. Sites were selected to represent different land uses (residential, commercial/industrial, and open space). Within each category the sites were also divided into four canopy classes by density (0-19%, 20-29%, 30 39%, 40-49%). A 50% or greater density is considered a natural forest condition. The values of all sites within a class were averaged together for analysis. The resulting average benefits from the sites within each class were multiplied by the total land area of each class. Four of the study sites, representing different land uses and canopy classes are illustrated at right. Study sites in the southeastern part of the District were unavailable because of restricted access to airspace over federal facilities.

Aerial imagery of study sites provide information about trees, grass, and impervious surfaces. Tree inventory data were collected in the field while other data sources provided data on soil types, rainfall patterns, and land-use configurations. CITYgreen® software was used to calculate ecosystem benefits for each sample site. The results were then extrapolated to the entire project area based on the total area for each percentage canopy/landuse category.

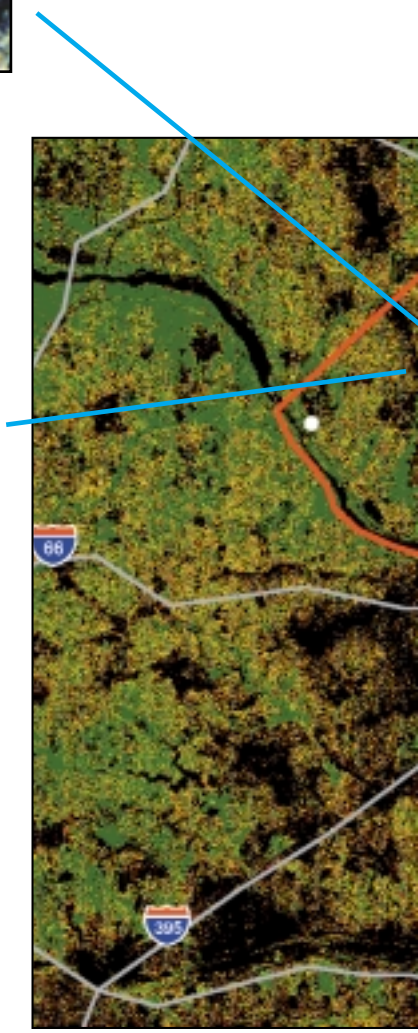


Low level aerial photography is used by CITYgreen® software to conduct an analysis of local ecology.

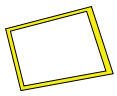


45% tree cover

35% tree cover



tree cover



local site boundary

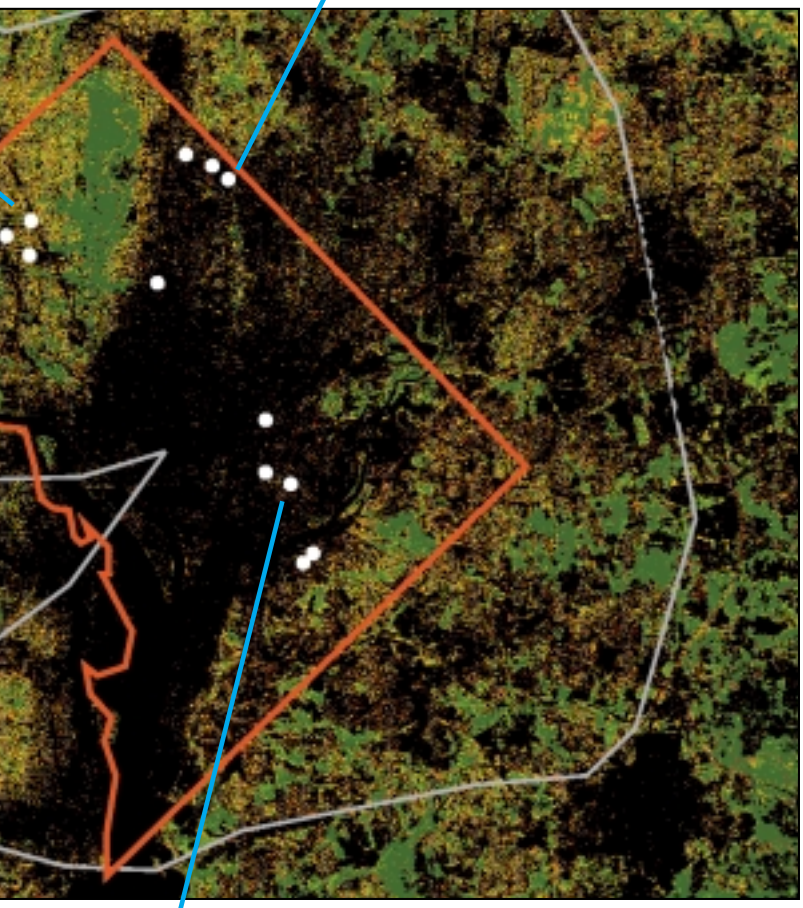
built structure

impervious surface

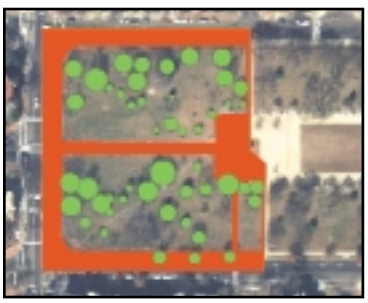
How CITYgreen® is Used to Analyze Local Data

AMERICAN FORESTS uses CITYgreen® software to conduct a detailed analysis of the structure of the landscape and to calculate the dollar benefits of trees. This analytical technique incorporates research and engineering formulas to place a dollar value on the work trees do. With CITYgreen® it is possible to determine how various canopy cover configurations affect stormwater movement and air quality.

25% tree cover



Twelve sample sites were chosen throughout the District if Columbia to represent a range of neighborhoods and canopy conditions. Four of the twelve sites are shown in detail here, illustrating canopy coverage from10-45%.



10% tree cover

Stormwater Runoff

Trees and soil function together to reduce stormwater runoff. Trees reduce stormwater flow by intercepting rainwater on leaves, branches, and trunks. Some of the intercepted water evaporates into the atmosphere, and some soaks into the ground, reducing peak flows and thus reducing the total amount of runoff that must be managed in urban areas. Trees also slow storm flow, reducing the volume of water that must be managed at once. The TR-55 model, developed by the Natural Resources Conservation Service, provides a quantitative measure of stormwater movement called an "event model.", *(see page 8)*.

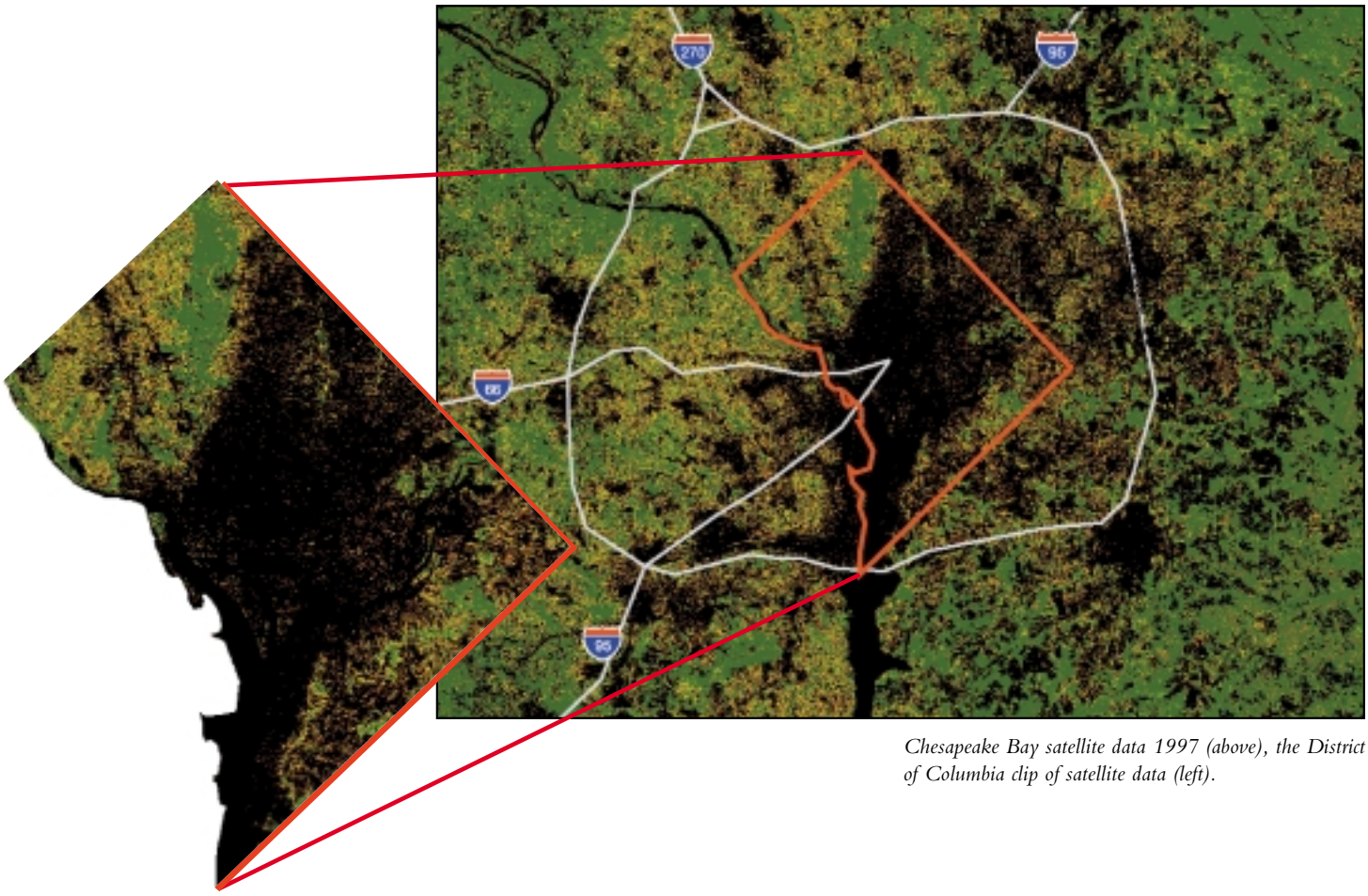
Communities that employ non-structural stormwater management strategies can reduce the cost of constructing stormwater control infrastructure. The value of trees for stormwater management has been calculated based on avoided costs of handling stormwater runoff. Local costs are multiplied by the total volume of avoided storage to determine dollars saved by trees.

In the District of Columbia, the existing tree canopy reduces the need for stormwater management by 56 million cubic feet. Using a $7.80/cubic foot stormwater treatment cost, trees currently save the city $440 million.

Air Quality

Trees provide air quality benefits by removing pollutants such as nitrogen dioxide, carbon monoxide, sulfur dioxide, ozone, and particulate matter less than 10 microns in size. To calculate the dollar value for these pollutants *(see page 8)*, economists multiply the number of tons of pollutants removed by "externality costs,"or costs to society not reflected in marketplace activity, as established by state public service commissions. This figure represents costs that society would have pay, in areas such as health care, if trees did not remove these pollutants. In the District of Columbia, the existing tree canopy removes 724,000 pounds of pollutants, valued at $2 million. Tree cover as it existed in 1973 would have removed 1,07 million pounds of pollutants at a value of $3 million.

Using Regional Data for Local Analysis



Chesapeake Bay satellite data 1997 (above), the District of Columbia clip of satellite data (left).

A regional level image contains a great deal of data that can be used by individual local governments. A city or county can obtain a sub-set of the regional data by cutting its boundaries from the regional view. With this information, a local government can determine tree canopy cover.

The District of Columbia image was clipped from a larger regional image of the southeastern portion of the Chesapeake Bay watershed (11.4 million acres). The regional analysis shows general trends; the more detailed local analysis is used for planning.

In a larger, separate study, AMERICAN FORESTS analyzed tree canopy cover and ecological change in the southeastern Chesapeake Bay region (March 1999). During the same time period, the District of Columbia experienced a greater rate of decline in tree canopy than the southeastern Chesapeake Bay region did as a whole. This perspective allows regional and local planners to consider how the region and the city affect one another.

In the southeastern Chesapeake Bay region in 1973, areas with heavy tree canopy coverage (with 50% or greater tree cover) covered 55% of the area. Developed areas and farmland (with tree cover of less than 20%) comprised 35% of the land. By 1997 areas with low tree cover became dominant, expanding to over 50% of the area and heavily forested areas declined to 38% of the area. Average canopy declined from 51% to 39%.

Table 2. Tree Canopy Loss: Chesapeake Bay Region vs. the District of Columbia

Average Tree Canopy Cover	1973	1997	Loss %
Chesapeake Bay (S.E. region)	51%	39%	-12%
The District of Columbia	37%	21%	-16%

What's Next for the District of Columbia?

Recommendations

The Urban Ecosystem Analysis uses CITYgreen® to measure tree cover as an indicator of environmental quality and to guide land-use planning and growth management. When urban trees are large and healthy, the ecological system that supports them is also healthy. Healthy trees require healthy soils, adequate water, and clean air. This report brings together the expertise of ecologists, scientists, and engineers with computer mapping technology to evaluate the environment in the District of Columbia and chart a course of action for future improvement. We encourage Mayor Williams and the District of Columbia's City Council to incorporate this data into the local planning process.

(1) Use the findings of this study to address public policy questions for land-use planning and growth management

■ Consider the financial value of natural resources during the public policy decision-making process. Urban ecosystems provide concrete financial benefits to municipalities. Investment in natural resource management should capture these benefits.

■ Incorporate a natural resource data layer into the local planning and zoning process. Before decisions are made that change the landscape, consider the benefits of conserving existing trees and increasing tree canopy cover.

(2) Consider the dollar values associated with trees when making land-use decisions.

■ Use CITYgreen® software as a decision support tool to increase community participation.

■ Implement innovative land-use planning techniques and engineering guidelines to save existing trees and plant new ones.

■ Use trees as a valuable and essential element of the urban environment.

(3) Increase and conserve the tree canopy cover in urban areas.

■ Develop measurable urban tree canopy goals. Recommended goals for the District of Columbia based on urban forest canopy cover patterns in US cities:

40% tree canopy overall
50% tree canopy in suburban residential zones
25% tree canopy in urban residential zones
15% tree canopy in the Central Business Districts

(4) Use additional GIS applications for land-use planning.

■ Use CITYgreen® software as a tool to incorporate trees into land-use planning by collecting data on tree cover and quantifying the value of the trees. Use the findings in the decision making process.

(5) Develop best practices to increase tree cover in new developments.

■ Develop standards for tree protection.

(6) Provide the District of Columbia's planning department with training on how to conduct local analyses.

■ Increase the number of study sites to obtain more accurate results and to use for specific planning projects.

■ Update the local analysis every five years to track future trends in forest canopy and associated benefits.

About the Urban Ecosystem Analysis

Ecostructure Classification

AMERICAN FORESTS' Urban Ecosystem Analysis is based on the assessment of *ecostructures*, unique combinations of land use and land cover present in a city. Each ecostructure performs ecological functions differently, providing different benefits and values. For example, a site with heavy tree canopy provides more stormwater runoff reduction benefits than one with minimal tree cover.

In this study, the regional analysis provided an overview of tree cover change in the District of Columbia. Using land use and tree cover percentage categories to model the area's ecostructures, sample study sites were selected to further examine the effects of different tree canopy cover percentages on air quality and stormwater management.

Data Used in this Study

For regional analysis, Landsat satellite TM (30 meter pixel) and MSS (80 meter pixel) images were used as the source of land cover data. AMERICAN FORESTS used a subpixel classification technique and divided land cover into nine vegetation categories. For the local analysis, AMERICAN FORESTS used geo-rectified .tif images (digital aerial photos) at a one foot resolution. The Washington GIS Partnership and the National Capital Planning Commission provided some of the aerial photography used in the local analysis. Field data was collected by AMERICAN FORESTS with assistance from University of the District of Columbia students.

AMERICAN FORESTS developed CITYgreen® software to help communities analyze the value of local trees and vegetation as part of urban infrastructure. CITYgreen® is an application of ArcView for Windows, a Geographic Information Systems (GIS) software developed by ESRI.

Analysis Formulas

TR-55 for Stormwater Runoff: The stormwater runoff calculations incorporate formulas from the Urban Hydrology for Small Watersheds model, (TR-55) developed by the US Natural Resources Conservation Service (NRCS), formerly known as the US Soil Conservation Service. Don Woodward, P.E., a hydrologic engineer with NRCS, customized the formulas to determine the benefits of trees and other urban vegetation with respect to stormwater management.

UFORE Model for Air Pollution: CITYgreen® uses formulas from a model developed by David Nowak, PhD, of the US Forest Service. The model estimates how many pounds of ozone, sulfur dioxide, nitrogen dioxide, PM_{10}, and carbon monoxide are deposited in tree canopies as well as the amount of carbon sequestered. The urban forest effects (UFORE) model is based on data collected in 50 US cities. Dollar values for air pollutants are based on averaging the externality costs set by the State Public Service Commission in each state. Externality costs are indirect costs to society, such as rising health care expenditures.

Acknowledgments for this Study

We gratefully acknowledge the support of the **Natural Resources Conservation Service**; the **USDA Forest Service**; the Water Quality Division of the Environmental Health Administration, District of Columbia; The University of the District of Columbia; ESRI for GIS software; Emerge for aerial images and ERDAS for remote sensing software.

For More Information

AMERICAN FORESTS, founded in 1875, is the oldest national nonprofit citizens conservation organization. Its three centers–Global ReLeaf, Urban Forests, and Forest Policy—mobilize people to improve the environment by planting and caring for trees. Global ReLeaf 2000 is AMERICAN FORESTS' campaign to plant 20 million trees for the new millennium, including 1 million trees to be planted in the Chesapeake Bay watershed.

AMERICAN FORESTS' CITYgreen® software provides individuals, organizations, and agencies with a powerful tool to evaluate development and restoration strategies and impacts on urban ecosystems. AMERICAN FORESTS offers regional training workshops and technical support for CITYgreen® and is a certified ESRI developer and reseller of ArcView products. Prepared analyses such as this report and GIS land cover data sets for other municipalities within the southern Chesapeake Bay watershed are available by order.

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