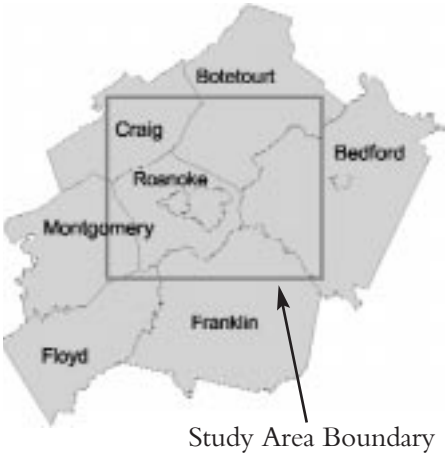
Urban Ecosystem Analysis Roanoke Area, Virginia

Calculating the Value of Nature

Report Contents

ROANOKE REGION



AMERICAN FORESTS®

PEOPLE CARING FOR TREES AND FORESTS SINCE 1875

Urban Ecosystem Analysis Roanoke Area

Project Overview

AMERICAN FORESTS conducted an Urban Ecosystem Analysis of the Roanoke area, which includes Roanoke County and portions of Bedford, Botetourt, Craig, Franklin, and Montgomery Counties 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 approximately 763,000 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. Detailed site inventories were analyzed using low-level digital imagery and AMERICAN FORESTS' CITYgreen® software to calculate the economic values of the area's urban forest.

Major Findings

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

■ By 1973 the Roanoke Valley had already experienced significant development and loss of tree cover. Areas with high vegetation and tree canopy coverage (with 50% or greater tree cover) comprised 41% of the area (314,000 acres). Developed areas and farmland (with tree cover of less than 20%) comprised 53% of the land (399,000 acres).

■ By 1997, areas with less than 20% tree cover became even more dominant, comprising over 64% of the project's land area. These areas increased by 23% to 489,000 acres. Heavily forested areas declined by 24% to 240,000 acres, and now represent 32% of the land area studied.

■ Average tree cover throughout the project area declined from 40% to 35%.

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

■ Tree loss in the Roanoke area from 1973 to 1997 resulted in a 17% increase in runoff--an estimated 515 million cubic feet of water (based on an average annual 2-year 24-hour storm event). Assuming a $2/cubic foot construction cost to build stormwater retention ponds and other engineered systems to manage this runoff would total $419 million.

■ The total stormwater retention capacity of this urban forest cover in 1997 was worth about $2.04 billion, down from 1973's value of $2.46 billion, based on avoided stormwater retention facility construction.

■ Lost tree canopy would have removed about 2.93 million pounds of the pollutants: sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), and particulate matter 10 microns or less (PM_{10}) from the atmosphere annually, at a value of approximately $8.2 million per year.

Maintaining and restoring tree cover is a cost-effective way to improve the environment.

■ 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.

■ Development that removes a high percentage of tree cover has large negative environmental and economic consequences.

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

■ Strategically planting trees in urban and suburban areas would substantially improve tree cover and the quality of air and water resources, enhance wildlife habitat, conserve energy, sequester greenhouse gases, and improve the quality of life.

Table 1. The Roanoke Area Vegetation Change and Associated Benefits *

	1973	1997	Loss/Gain 1973-1997
Acres with more than 50% tree cover	314,337	240,353	-24%
Acres with 20%-50% tree cover	48,931	33,082	-32%
Acres with less than 20% tree cover	399,419	489,252	23%
Stormwater Management Value**	$2.46 billion	$2.04 billion	-$419 million
Air Pollution Removal Value (annually)	$48.7 million	$40.5 million	-$8.2 million

* Numbers may not add due to rounding
** Represents a one time savings, and does not include additional savings from annual maintenance

Regional Analysis

The Roanoke Area Satellite Images

Classified satellite images show the change in land cover in the Roanoke region over a recent 24-year period. High density tree cover (≥50%) is indicated in green and low density tree canopy (<20%) and impervious surfaces associated with urban areas are in black. The analysis measures nine categories of tree cover. The images combine the nine categories into five groupings to accommodate the limitations of printing the images at this scale.

Graphing Change

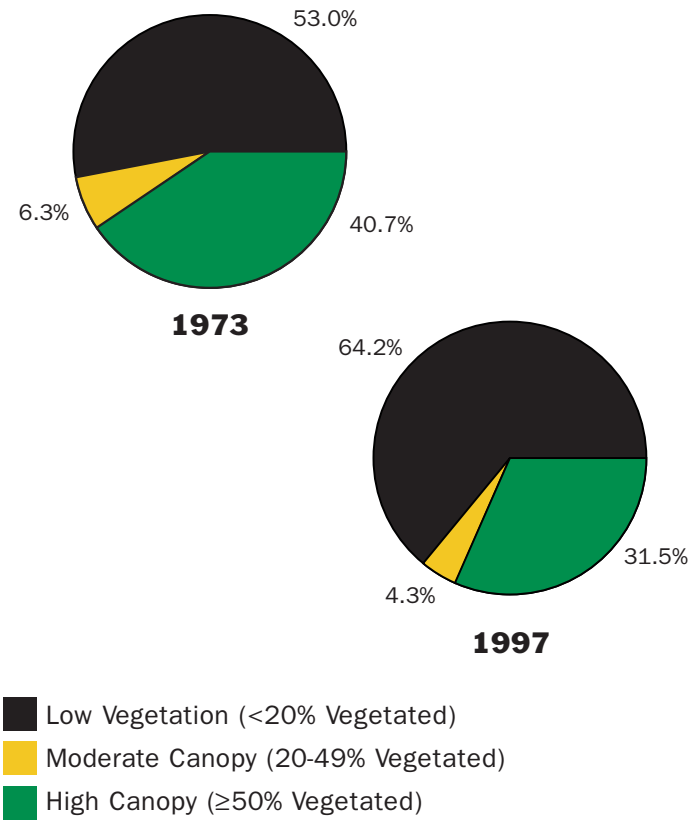
The changes in vegetation depicted in the satellite images *(right)* are represented by pie charts *(below)*. The charts show changes in vegetative cover over a 24-year period for three categories. Natural forest cover is represented in green and indicates areas with more than or equal to 50% tree canopy. Developed areas are represented in black and indicate areas where tree canopy is less than 20%. The yellow area represents land where the tree cover is between 20% and 49%.

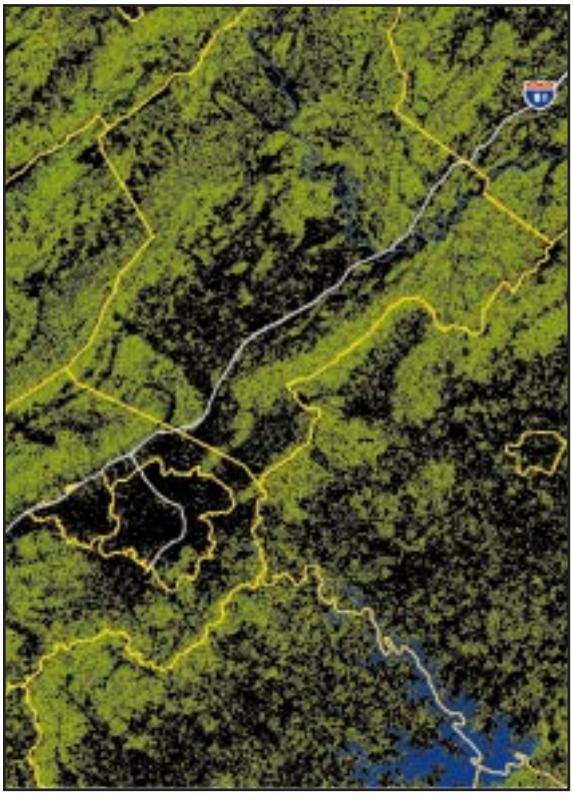
< 20%
20-29%
30-39%
40-49%
≥ 50%

Key:
% Tree Cover

Landsat MSS 1973 80 Meter Pixel Resolution

Vegetation Change, Roanoke Area, 1973-1997





Landsat TM 1997 30 Meter Pixel Resolution

Local Level Analysis

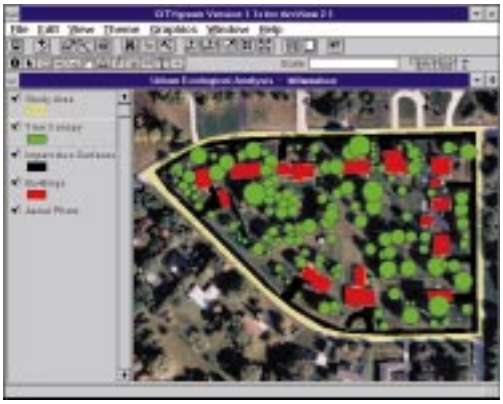
Using canopy cover classes identified from the regional image, point samples consisting of low-level aerial imagery were used along with CITYgreen® software to determine the value of the local ecology.

Sixteen sites (each 1/3 to 4 acres in size) were selected within Roanoke County and analyzed for their ecological value. Sites were divided into five canopy classes and the values of all sites within a class were averaged together for analysis. The resulting benefits from the sites were multiplied by the total land area. Five of the study sites, representing different canopy classes, are illustrated at right.

Aerial images of each sample site provide information about trees, grass, and impervious surfaces. Tree inventory data were collected in the field by Jim Watkins of Virginia Polytechnic Institute, while other data sources provided information 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 category.

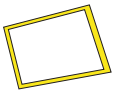
How CITYgreen® is Used to Analyze Local Data

AMERICAN FORESTS uses CITYgreen® software to conduct a detailed analysis of how the structure of the landscape affects its function. This tool 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 classes affect stormwater movement and air quality.



Low level aerial photography is used by CITYgreen® software to conduct a local ecosystem analysis.

tree cover



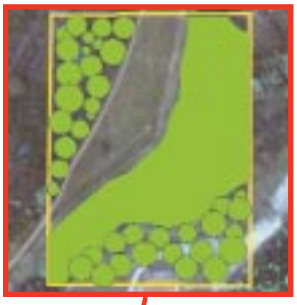
local site boundary

built structure

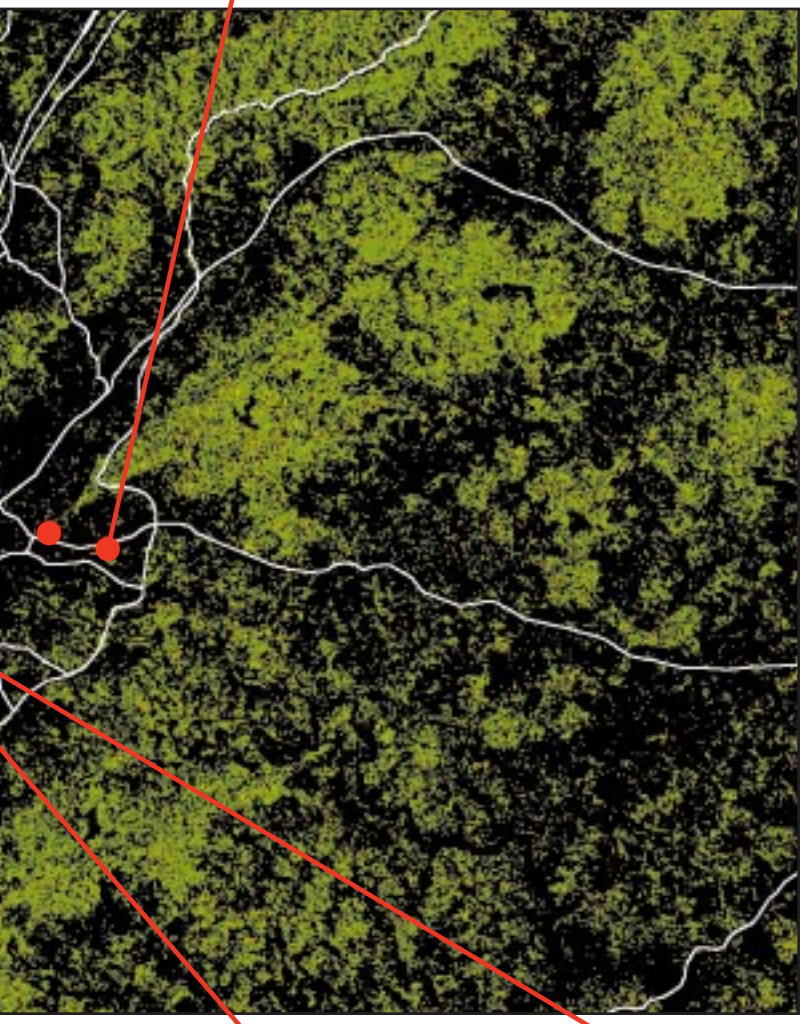
impervious surface

10% tree cover

25% tree cover



55% tree cover



35% tree cover

45% 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 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 was used to measure stormwater (see page 8).

Local governments are looking toward non-built stormwater management strategies, including trees, to reduce the cost of constructing stormwater control infrastructure. The value of trees for stormwater management is based on avoided costs for storage of stormwater in retention ponds. Local construction costs for building containment facilities are multiplied by the total volume of avoided storage to determine dollars saved by trees.

In the Roanoke area, the existing tree canopy reduces the need for retention structures by 1.02 billion cubic feet. Using a $2/cubic foot construction cost, trees currently save the region $2.04 billion per construction cycle (maintenance costs are not included).

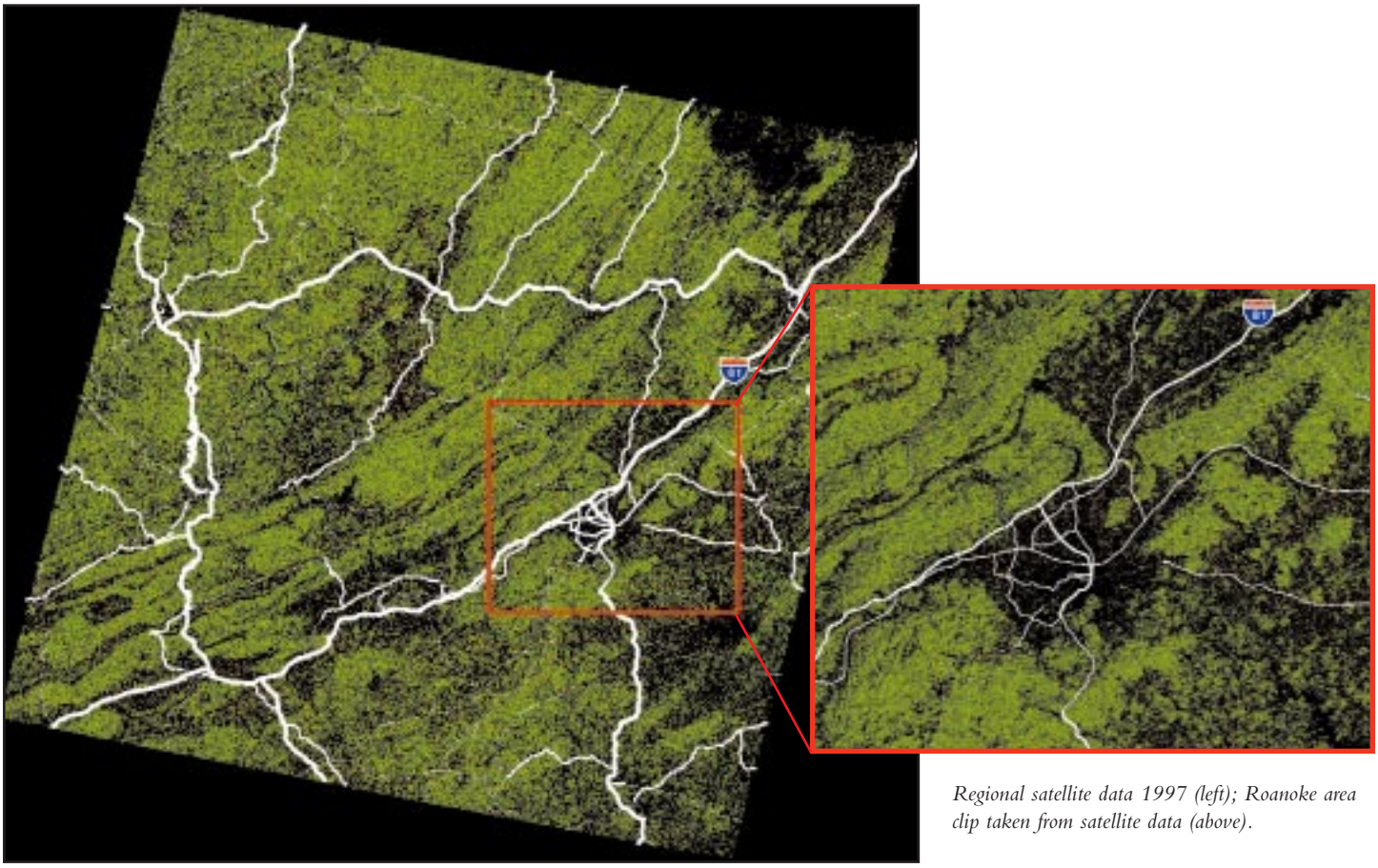
Air Quality

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 Roanoke area, the existing tree canopy removes 14.5 million pounds of pollutants, valued at $40.5 million. Tree cover as it existed in 1973 would have removed 17.4 million pounds of pollutants at a value of $48.7 million.

Carbon

The carbon-related function of trees is measured in the amount of carbon currently stored as biomass and in sequestration, the rate of absorption per year. To estimate the amount of carbon stored and sequestered, the average amount of carbon per acre was multiplied by the total number of acres. The Roanoke Area currently stores 9 million tons of carbon and sequesters an additional 41,000 tons of carbon annually. The lost value of carbon storage over the last 24 years is almost 2 million tons (see page 8).

Using Regional Data for Local Analysis



Regional satellite data 1997 (left); Roanoke area clip taken from satellite data (above).

A regional level image contains a great deal of information that can be used by local governments. A city or county can obtain a sub-set of the regional data from AMERICAN FORESTS showing the land area within their boundaries. With this information, a local government can determine their tree canopy cover. This coarse image can be divided or stratified into various tree cover zones. These zones form the basis for a more detailed analysis.

The Roanoke area's findings can be compared to another east coast analysis. In a larger, separate study, AMERICAN FORESTS analyzed tree canopy cover and ecological change for the southeastern portion of the Chesapeake Bay watershed (11.4 million acres). The findings show that Roanoke's vegetation change is consistent with changes that occurred in the larger Chesapeake Bay area, although the loss is not quite as dramatic.

In the Chesapeake Bay in 1973, areas with high tree canopy coverage (with 50% or greater tree cover) comprised 55% of the area. Developed areas and farmland (with tree cover of less than 20%) comprised 35% of the land. By 1997 areas with little tree cover became dominant, comprising over 50% of the area and heavily forested areas declined to 38% of the area.

In the Chesapeake Bay region, average tree cover declined from 51% to 39%. In the Roanoke area, average tree cover declined from almost 40% to 35%.

Table 2. Chesapeake Bay Region and Roanoke Area Landscape Change Comparison

Average Tree Canopy Cover	1973 %	1997 %	Loss %
Chesapeake Bay	51%	39%	-12%
Roanoke Area	40%	35%	-5%

What's Next for The Roanoke Area?

Recommendations

These findings raise public policy questions for land-use planning and growth management, using tree cover as a measure and indicator of environmental quality. 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 Roanoke area and chart a course of action for future improvement. We encourage the Roanoke area 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 resource management should capture these benefits.

■ Incorporate a natural resource data layer into the local planning and zoning process.

(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 Roanoke area based on urban forest canopy cover patterns in US cities include striving for:

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) Implement GIS for land-use planning techniques.

■ 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 building and development tools to increase tree cover in new developments.

■ Develop standards for tree protection measures.

(6) Conduct additional analyses 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 and thus provides different values. For example, a site with a heavy tree canopy provides more stormwater reduction benefits than one with a light tree canopy.

In this study, the regional analysis provided an overview of tree cover change in the Roanoke area. Using the tree cover percentage categories to model the area's ecostructures, sample study sites from Roanoke County 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 (aerial photos) at a one foot resolution. The City of Roanoke provided a shape file of the surrounding counties so that specific data could be clipped from AMERICAN FORESTS large satellite data set. Field data was collected by Jim Watkins, Virginia Polytechnic Institute, Blacksburg.

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, PM10, 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.

Carbon: A method to assess a dollar value for carbon is evolving; it is premature to assign a dollar value at this time.

Acknowledgments for this Study

We gratefully acknowledge the support of the State of Virginia, the City of Roanoke, the USDA Forest Service, ESRI for GIS software, Emerge for aerial imagery and ERDAS for remote sensing software.

For More Information

AMERICAN FORESTS, founded in 1875, is the oldest national nonprofit citizen conservation organization. Its three centers—Global ReLeaf, Urban Forestry, 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.

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 are available by contract.

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