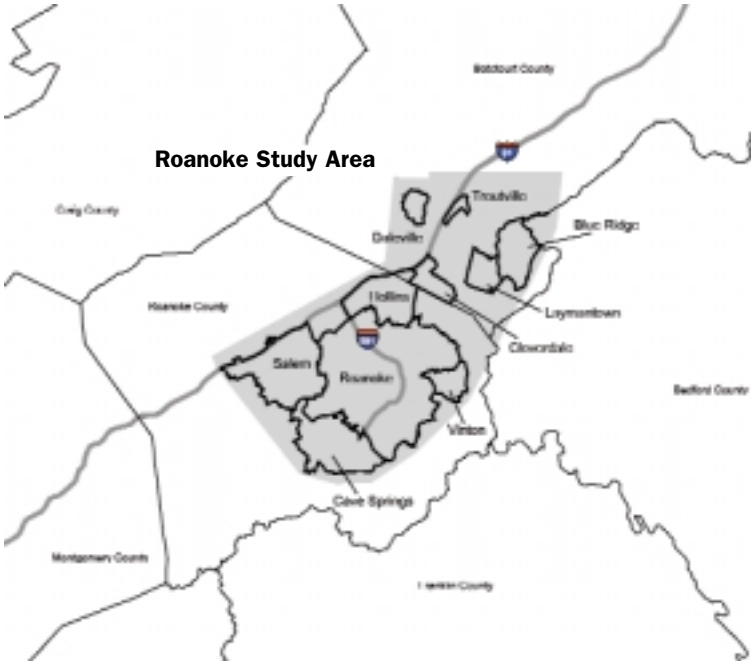
June 2002

Urban Ecosystem Analysis Roanoke, Virginia

Calculating the Value of Nature

Report Contents



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Project Overview

AMERICAN FORESTS and the City of Roanoke have conducted a detailed assessment of the tree cover in Roanoke, Virginia and the surrounding communities. Covering nearly 118,000 acres, the study area covered parts of Roanoke and Botetourt Counties and included the cities of Blue Ridge, Cave Springs, Cloverdale, Daleville, Hollins, Laymantown, Roanoke, Salem, Troutville, and Vinton. The analysis used Geographic Information Systems (GIS) technology to measure the structure of the landscape with emphasis on tree cover. High-resolution satellite imagery was used to produce a land cover classification data layer for the entire study area, while AMERICAN FORESTS' CITYgreen software was used to calculate the environmental and economic values of the Roanoke area's urban forest.

The study produced a rich data set describing the environment. The data coupled with its relevance and accessibility to those working at the local level, offers the opportunity for much better land use and development decisions than in the past. These data provide an important new resource for those working to build better communities—ones that are more livable, produce fewer pollutants, and are more cost effective to operate.

The data are unique because they contain both green infrastructure—areas covered with trees, shrubs, and grass and gray infrastructure—areas covered by buildings, roads, utilities, and parking lots. While many municipalities commonly use GIS to map and analyze their gray infrastructure, they typically do not integrate trees and other elements of the green infrastructure into their day-to-day planning and decision-making processes. Reasons for this include 1) the lack of understanding of the ecological and economic value of trees and other environmental features, 2) the absence of a means to readily use this information in commonly used GIS systems.

This study addresses both of these impediments. Data documenting the environmental characteristics of trees are now available thanks to research from the USDA Forest Service and the Natural Resources Conservation Service. As a result of this study, an accurate green data layer has been constructed for use in Roanoke and the surrounding communities' GIS systems. Today we have a clear understanding of the active role trees play improving our urban environment. Those working in planning, urban forestry, and related natural resource issues can now readily calculate the dollar value of these ecological benefits in their communities using CITYgreen software and these data.

A planimetric map of a Roanoke neighborhood's gray infrastructure including buildings and roads (left). Classified high-resolution satellite imagery created for the city's GIS, adds a green infrastructure data layer (right), with its associated environmental benefits, to use in planning decisions.

Creating a Green Infrastructure

Adding a green infrastructure data layer to the decision making process introduces a new dimension to planning and development discussions, one that considers how to work with the natural environment instead of building costly infrastructure to manage air, water and energy systems. By developing and using a green data layer, future decisions will include better information about the full range of community resources.

The first step in creating a green layer for use in GIS is to acquire land cover data from satellites or specially equipped airplanes. The data are acquired during the growing season, when the leaves are on the trees. Specialists classify the images into useable data (see page 8). They analyze the images to determine the different land cover types—areas covered in trees, grass or open space can be distinguished from parking lots, buildings and roads. This analysis produces a green infrastructure data layer that can be added to the gray infrastructure which is commonly used in GIS for local planning.

Adding a green data layer to the community's infrastructure pays big dividends. Trees reduce pollution and erosion from stormwater by slowing it and by reducing its peak flow, and they improve air quality by filtering pollutants from the air. The stormwater control value of an area's trees, for example, can be calculated using the green data layer. Thus, the greater the canopy coverage and the less impervious surface, the more environmental benefits. Communities can then devise strategies to increase tree cover and recognize their environmental benefits and management cost savings.

A classified high-resolution satellite image of Roanoke, VA shows the landcover features needed to calculate the air quality and stormwater benefits of trees. Dark green represents tree cover, light green represent grass and open space, and gray designates impervious surface.

City of Roanoke - Landcover by Zone

	Acres	% Tree Cover	% Impervious Surfaces	% Open Space
Commercial Areas	2,889	16%	64%	21%
Industrial Areas	6,012	18%	53%	28%
Residential Areas	18,570	39%	26%	34%

*Numbers may not sum to 100 due to rounding

Commercial (orange), industrial (blue), and residential (purple) zoning in Roanoke, Virginia.

Findings for the Roanoke Area

In the greater Roanoke area, American Forests used high-resolution (4 meter multispectral and 1 meter panchromatic) satellite imagery. From this data set, American Forests calculated stormwater runoff and air quality benefits of the tree cover in 10 communities: Blue Ridge, Cave Springs, Cloverdale, Daleville, Hollins, Laymantown, Roanoke, Salem, Troutville, and Vinton. The analysis revealed that the tree cover varies from a high of 50% coverage in Cave Springs to a low of 26% in Daleville. While this study presents general findings for the areas in question, the real value of this project is to show how local communities can apply the data to their specific issues.

The greater Roanoke area's urban forest provides ecological benefits for managing stormwater, and mitigating air pollution.

■ The region is comprised of 54,929 acres of tree canopy (47%), 26,345 acres of impervious surfaces (22%), 35,885 acres of open space (30%), and 562 acres of water (less than 1%).

■ The total stormwater retention capacity of this urban forest is 313 million cubic feet. Without these trees, the cost of building the infrastructure to handle the increase in stormwater runoff would be approximately $626 million (based on construction costs estimated at $2 per cubic foot).

■ Urban forests provide air quality benefits by removing nitrogen dioxide, sulfur dioxide, carbon monoxide, ozone, and particulate matter of 10 microns or less. The greater Roanoke area's urban forest removes 5.9 million pounds of pollutants from the air each year—a benefit worth $14.6 million annually.

The city of Roanoke—the largest jurisdiction in the study area has a rather even distribution of landcover—but still falls short of AMERICAN FORESTS' recommended tree cover goals (see page 7).

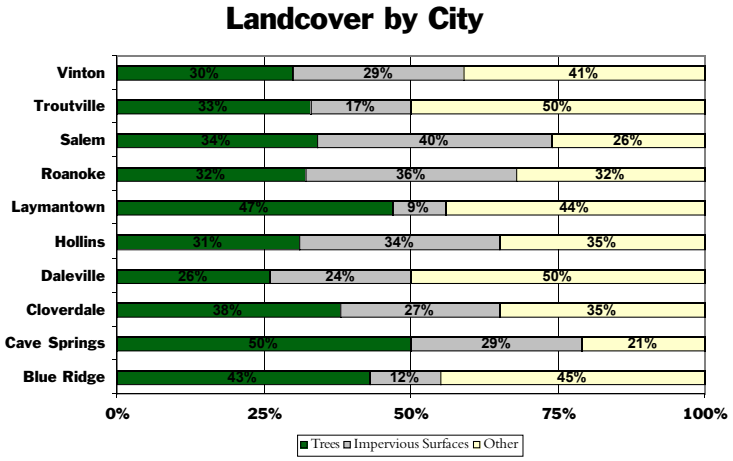
■ Covering 9,893 acres (36%), the dominant landcover features in Roanoke are impervious surfaces. Tree canopy is currently at 32% (8,822 acres)—AMERICAN FORESTS recommends an average tree canopy of 40%. Open space also comprises 32% of the city.

■ The total stormwater retention capacity of Roanoke's existing urban forest is more than 64 million cubic feet. This translates into a value of $128 million (based on construction costs estimated at $2 per cubic foot to build equivalent retention facilities.

■ Every year, the tree cover in Roanoke sequesters more than 948,000 pounds of pollutants from the air, with a value of more than $2.3 million.

A Beginning

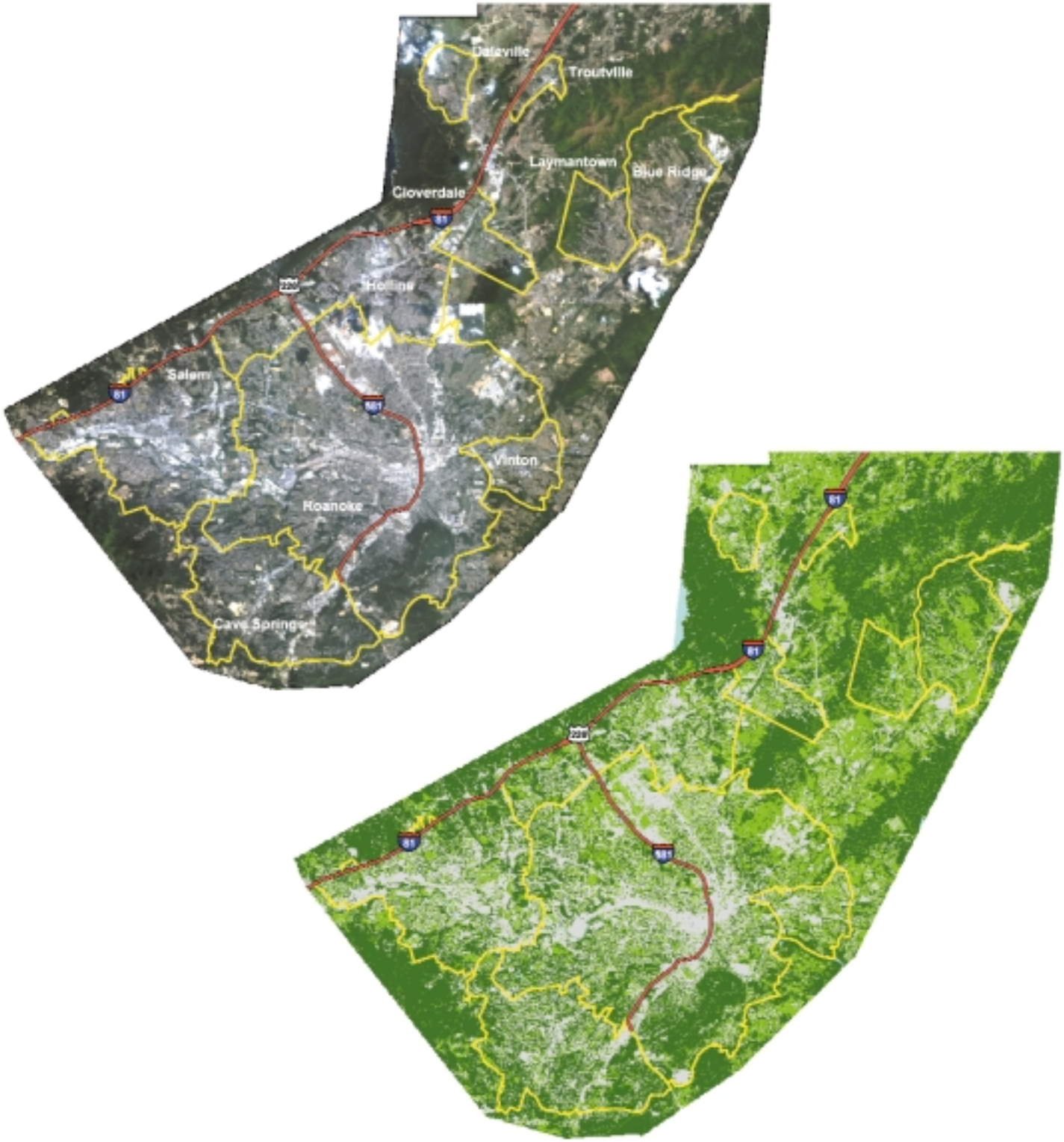
Though this report provides valuable information regarding the tree cover and its benefits throughout the Roanoke area, the true strength of this project is in the data it provides and for those planners, engineers, environmentalists, and decision-makers who use it for additional analyses as needed for local planning. With the land cover data set (pictured on page 5), communities in the Roanoke valley now have the tools they need to put trees back in the decision making process. By using CITYgreen software in conjunction with this highly accurate green data layer, community leaders can now integrate green and gray infrastructure on a daily basis.



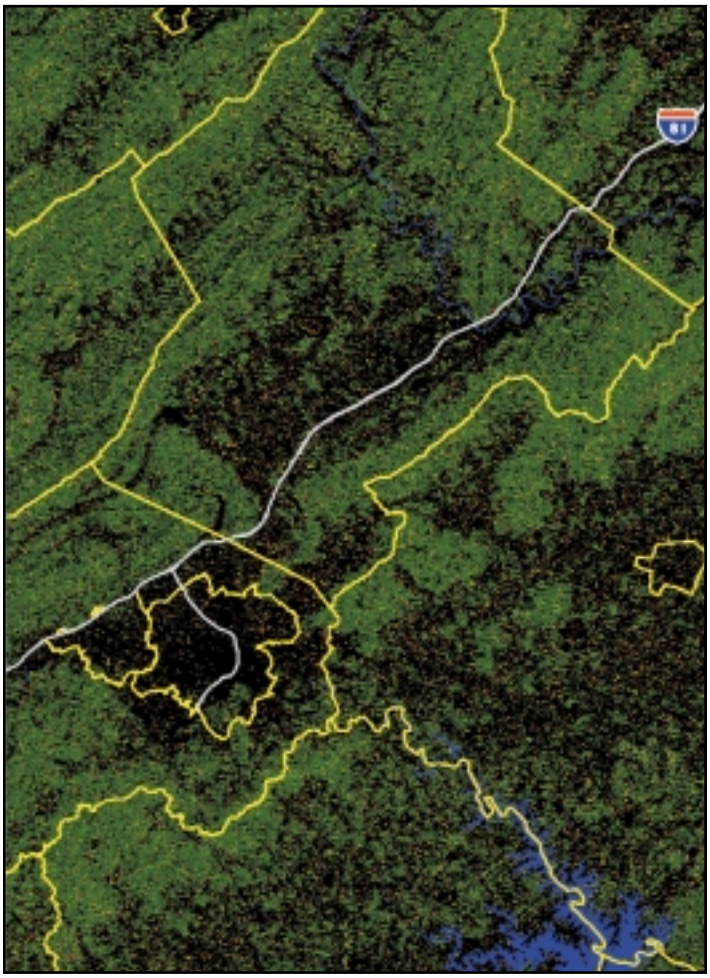
This bar graph illustrates the distribution of land cover in the ten communities included in the study.

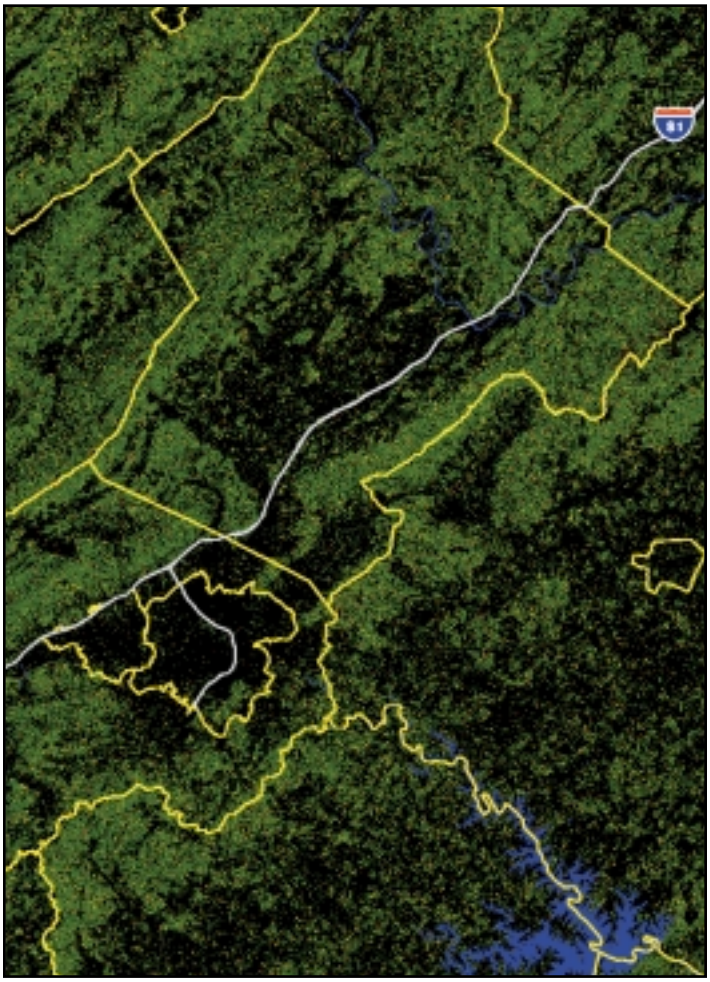
The land cover data set produced for this study can be subdivided and analyzed according to any boundary—be it political, social, or ecological. The above image is a clip of the Lick Run Creek subwatershed in Roanoke. The 25% tree cover in this watershed is worth more than $76,000 in annual air quality benefits and $3.8 million in stormwater management benefits.

Green Data Layer for the Roanoke Area



A true color satellite image of the Roanoke study area (above). The ten communities included in the study are outlined in yellow. A high-resolution classified satellite image (below) of the study area highlights different land covers. Dark green represents tree cover, light green represent grass and open space, and gray designates impervious surface. Clips of this data set are available to the ten communities to use in conjunction with CITYgreen software and on a daily decision-making basis.





The classified Landsat images above illustrate tree density throughout the Roanoke Valley in 1973 (left) and 1997 (right).

Key: Tree Canopy Density

<20%	30-39%	≥50%
20-29%	40-49%	

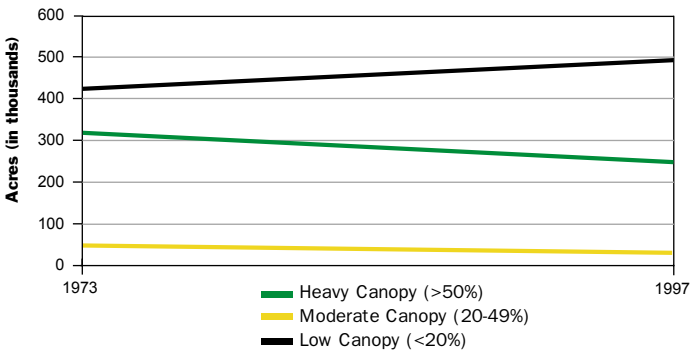
Lessons from Landsat

Landsat satellites have been in orbit around the Earth since 1972 and data from them allow us to look at changes in landcover over time. In 1998 AMERICAN FORESTS conducted a Regional Ecosystem analysis of the area surrounding Roanoke, Virginia. This initial study covered all of Roanoke County, as well as portions of Bedford, Botetourt, Craig, Franklin, and Montgomery Counties and determined how the landscape had changed over time. The analysis assessed the loss of tree canopy and its associated values using Landsat satellite images spanning a 24-year period from 1973 to 1997.

Throughout the 763,000-acre study area, the Roanoke Valley saw significant development and loss of tree cover. By 1997 areas with less than 20% tree cover (developed areas and farmland) had increased from 53% to 64%. Over this same time period, areas of heavy tree canopy (greater than 50%) declined from 41% to 32%. Overall, average tree canopy fell from 40% to 35%.

The Landsat images provide valuable public policy information showing general trends, but do not provide the high-resolution data required for local planning and management activities. High-resolution satellite imagery (like that which is used in this study) produces a 4-meter or better resolution (compared to 30 meter with Landsat) and is necessary to see individual trees.

Roanoke Area Vegetation Change 1973-1997



Recommendations

The Urban Ecosystem Analysis that AMERICAN FORESTS conducted in 1998 from Landsat satellite and aerial imagery gave us our first look at tree canopy trends over the last few decades in the Roanoke Valley. The message from the analysis was clear; the region had lost about 25% of its heavy tree cover, the ecology was in a state of decline and this declining natural system was costly to residents.

From this earlier study, AMERICAN FORESTS also learned that communities need more detailed information in order to incorporate a green data layer into their decision-making. Our current analysis uses high-resolution imagery to do just that. This study provides a detailed assessment of the tree cover and quantifies ecological benefits for ten growing communities in the Roanoke area. The data from the analysis can and should be used by community leaders to make better land use, development, and community management decisions. Trees are a valuable community resource and need to be incorporated into the decision making process.

The data from this analysis are available at no cost to communities who use it in conjunction with CITYgreen software for local planning and development. AMERICAN FORESTS recommends that communities establish tree canopy goals tailored to their administrative areas and then use CITYgreen to plan and manage their progress. New tree canopy goals can be accurately determined every few years by updating the images. AMERICAN FORESTS has provided generalized target goals, but realizes that every community is different and needs to set their own goals. Armed with this green data layer and CITYgreen software, communities can better assess their urban forest as a community asset and incorporate this green infrastructure into future planning.

Setting Tree Canopy Goals

Local communities should set specific tree cover targets for various land use areas. They should be established with an understanding of current and future ecological and land use objectives. Though agriculture and development will continue in the Roanoke Valley, a balance can be achieved between the natural and the built landscape.

AMERICAN FORESTS' General Tree Canopy Goals
40% tree canopy overall
50% tree canopy in suburban residential
25% tree canopy in urban residential
15% tree canopy in central business districts

Roanoke Area Communities' Land Cover and Ecological Benefits

Community	Acres	% Trees	% Impervious	% Open Space	% Water	Air Pollution lbs. Removed Annually	Air Quality Value Annual	Retention volume (cubic ft.) required to mitigate loss of trees	Stormwater Control Value (One time Saving)
Blue Ridge	4,044	43	12	44	0	188,430	$465,022	9,586,412	$19,172,824
Cave Springs	7,567	50	29	21	0	410,041	$1,011,930	19,988,536	$39,977,072
Cloverdale	1,999	38	27	35	0	82,629	$203,919	4,879,829	$9,759,658
Daleville	1,219	26	24	49	1	33,743	$83,275	1,725,370	$3,450,740
Hollins	5,549	31	34	35	0	182,471	$450,316	9,176,742	$18,353,484
Laymantown	2,104	47	9	43	1	107,094	$264,296	5,199,729	$10,399,458
Roanoke	27,481	32	36	32	0	948,839	$2,341,617	64,002,536	$128,005,072
Salem	9,307	34	40	26	1	335,904	$828,970	19,152,257	$38,304,514
Troutville	568	33	17	50	0	19,948	$49,319	892,891	$1,785,782
Vinton	2,037	30	29	41	1	66,040	$16,978	3,993,711	$7,987,422
Total Study Area*	117,741	47	22	30	0	5,907,631	$14,579,297	313,258,248	$626,516,496

* Refers to the total area covered by the analysis, not the sum of all cities included.

About the Urban Ecosystem Analysis

Ecological Structure Classification

AMERICAN FORESTS Urban Ecosystem Analysis is based on the assessment of ecological structures—unique combinations of land use and land cover patterns. Each combination performs "ecological functions" differently and is therefore assigned a different value. For example, a site with heavy tree canopy provides more stormwater reduction benefits than one with lighter tree canopy and more impervious surface.

Data Used

For the original study conducted in 1998, 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 this Urban Ecosystem Analysis, high-resolution (4-meter pixel) multispectral satellite imagery was used. One-meter panchromatic imagery was used to groundtruth the multispectral imagery and for purposes of presentation. American Forests used a full-pixel "knowledge based" classification technique to categorize different land covers such as trees, impervious surfaces, open space, and water. For areas affected by cloud cover in the satellite imagery, the USGS's National Landcover Data Set was used to fill in the gaps.

Analysis Formulas

A CITYgreen analysis was conducted for each of the ten communities within the Roanoke study area as well as for the area as whole. CITYgreen version 5.0 used the raster data land cover classification from the high-resolution imagery for the analysis. The following formulas are incorporated into CITYgreen software.

TR-55 for Stormwater Runoff: The stormwater runoff calculations incorporate formulas from the Urban Hydrology of 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 USDA Forest Service. The model estimates how many pounds of ozone, sulfur dioxide, nitrogen dioxide, 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 the indirect costs to society, such as rising health care expenditures as a result of air pollutants' detrimental effects on human health.

Acknowledgements for this Study

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The City of Roanoke
USDA Forest Service
ESRI for GIS software
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.

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. For further information contact:

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