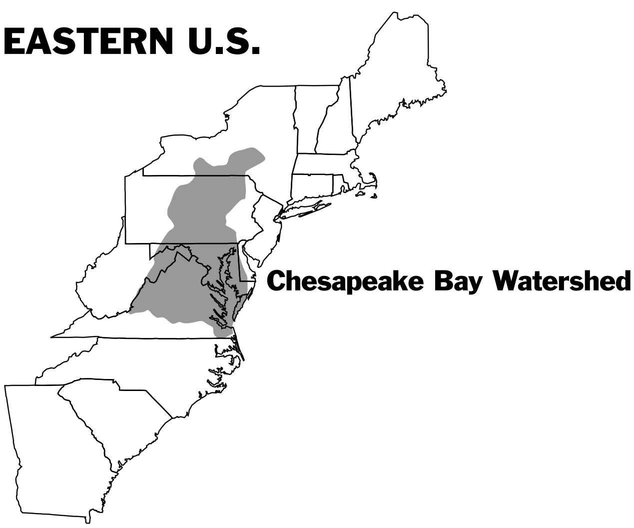
Final Report: 3/22/99

Regional Ecosystem Analysis Chesapeake Bay Region and the Baltimore-Washington Corridor

Calculating the Value of Nature

Report Contents

EASTERN U.S.



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Regional Ecosystem Analysis Chesapeake Bay Region

Project Overview

AMERICAN FORESTS conducted a Regional Ecosystem Analysis of the Chesapeake Bay Region to determine how the landscape has changed over time. The analysis assessed the value of ecological features using data from satellite images spanning a 24-year period from 1973 to 1997. The analysis covered approximately 11.4 million acres of land in the southeast portion of the Chesapeake bay watershed and a more detailed study of a 1.5 million acre area in the greater Baltimore-Washington area.

The analysis uses Geographic Information Systems (GIS) technology to measure the changing structure of the landscape, with emphasis on tree cover. Regional changes in the landscape are analyzed through remote sensing, while detailed site inventories and economic calculations are created by AMERICAN FORESTS' CITYgreen® software.

Major Findings

The ecology of the southeastern portion of the Chesapeake Bay watershed has changed dramatically since 1973. Forests have declined and urban development has expanded.

■ The dominant feature of the regional landscape in 1973 was forests. Areas with high vegetation and tree canopy coverage (with 50% or greater tree cover) comprised 55% of the area (6,295,000) acres). Developed areas and farmland (with tree cover of less than 20%) comprised 35% of the land (3,967,650 acres).

■ By 1997, areas with little tree cover became dominant, comprising over 50% of the area. These areas increased by 45% to 5,760,748 acres. Heavily forested areas declined to 4,383,624 acres, 38% of the area by 1997.

■ Average tree cover throughout the 11.4 million acre region declined from 51% to 39%.

An analysis of a 1.5 million acre area surrounding the Baltimore-Washington corridor shows similar trends.

■ Overall tree cover in the Baltimore-Washington area declined just slightly more than the larger region, from 51% to 37% of the land area.

■ Areas with heavy tree cover declined from 55% (820,569 acres) to 37% (555,090) -- a decline of 32%.

■ Areas with little or no tree cover increased from 31% to 49% (462,025 acres to 732,392 acres).

There are economic implications of tree loss for stormwater management and clean air in the Baltimore-Washington corridor.

■ Tree loss in the Baltimore-Washington area from 1973 to 1997 resulted in a 19% increase in runoff (from each 2-year peak storm event), an estimated 540 million cubic feet of water. Costs to build stormwater retention ponds and other engineered systems to intercept this runoff would cost $1.08 billion ($2/cubic ft. of storage).

■ The total stormwater retention capacity of this urban forest cover in 1997 was worth about $4.68 billion, down from 1973's value of $5.7 billion.

■ Lost tree canopy would have removed about 9.3 million pounds of pollutants from the atmosphere annually, at a value of approximately $24 million per year.

■ The urban forest improves air quality by removing: nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), and particulate matter 10 microns or less (PM_{10}).

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

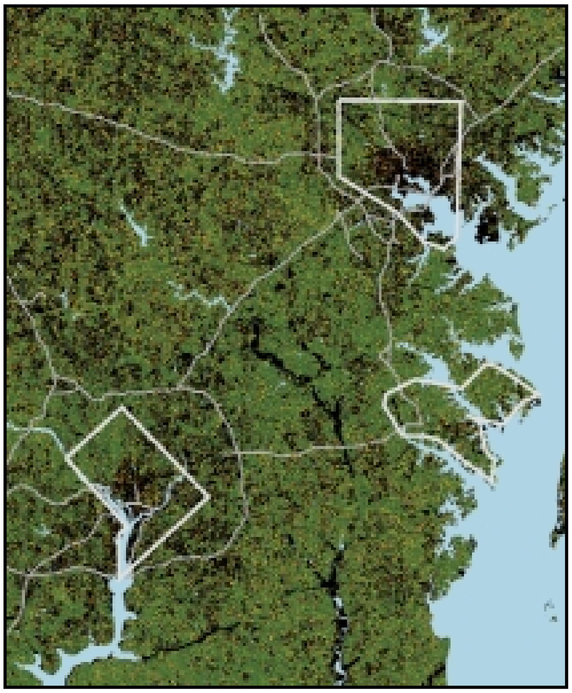
■ The natural landscape should be recognized for its economic, as well as ecological, value. Tree cover is a good measure of the ecological health of the landscape.

■ Sprawl development has large negative environmental and economic consequences.

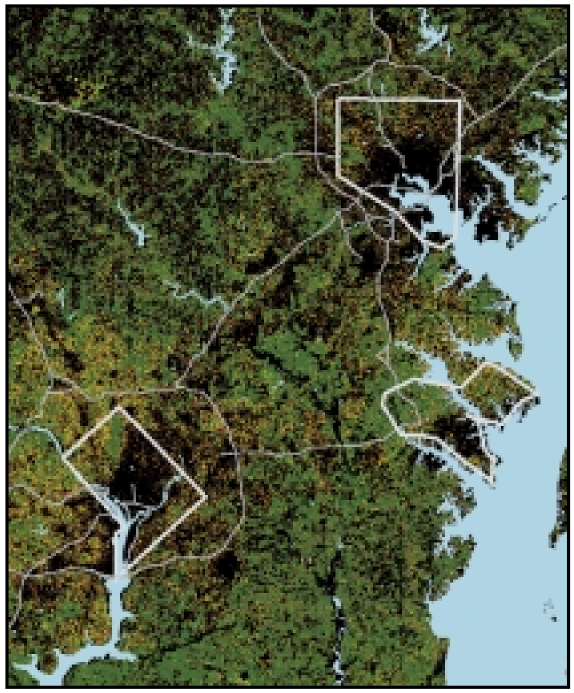
■ Increasing the average tree cover to 40% in urban areas would provide sizeable benefits.

■ Strategically planting trees in urban and suburban areas, and as buffers along streamsides throughout the region, would improve water quality in the Bay and its tributaries; improve air quality and wildlife habitat, conserve energy, sequester greenhouse gases, and improve the quality of life.

Regional Analysis

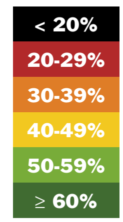


Landsat MSS 1973 *80 Meter Pixel Resolution*



Landsat TM 1997 *30 Meter Pixel Resolution*

Key: % Tree Cover



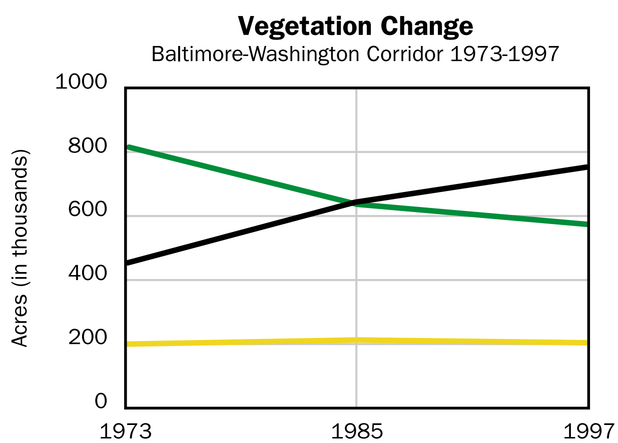
Chesapeake Bay Region Satellite Images

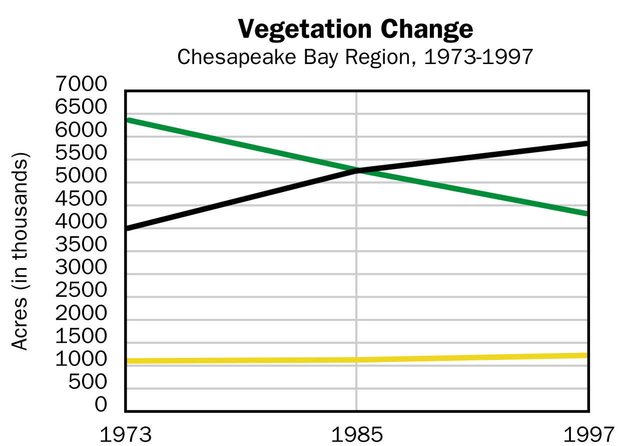
Landsat TM and MSS satellite images show the change in land cover in the Baltimore-Washington corridor of the Chesapeake Bay over a recent 24-year period. High tree cover is indicated in green and low tree canopy and impervious surfaces associated with urban areas are in black. The analysis measures nine categories of tree cover, and data from the detailed analysis is used in all calculations. The visual images above combine the nine categories into six groupings to accommodate the limitations of printing the images at this scale.

Graphing Change

The change in vegetation depicted in the satellite images above is represented in line graphs at the right. Both charts show the change in vegetative cover over a 24-year period for three categories. Natural forest cover is represented by a green line and indicates places with greater than or equal to a 50% tree canopy. Developed areas are represented by a black line and indicate areas where tree canopy is less than 20%. The yellow line represents land where the tree cover is between 20% and 49%. Open space, residential areas, and park land would all fall into this middle category.

- Low Vegetation (<20% Vegetated)
- Moderate Canopy (20-49%
- Vegetated)





Local Analysis

What is a Local Ecosystem Analysis?

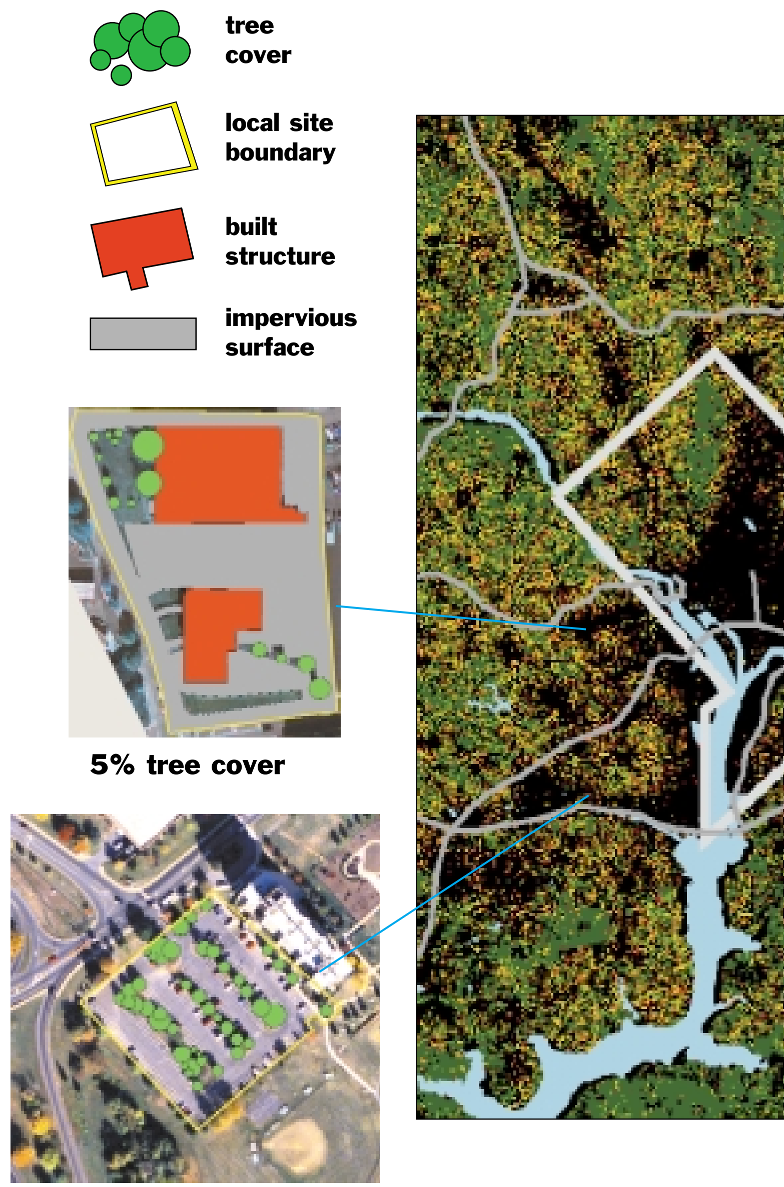
The local level analysis uses point-sampling to estimate the dollar value of ecosystem benefits. In the Baltimore-Washington corridor, it calculated values from 36 sample sites in Washington, DC; Arlington, VA; and Annapolis, Baltimore, Laurel, Rockville, and Waldorf, MD. The sample sites are 2-3 acres and include residential, commercial, and open areas. The sites represent land use patterns identified in the regional image. At right, five study sites are illustrated with different tree canopy cover percentages.

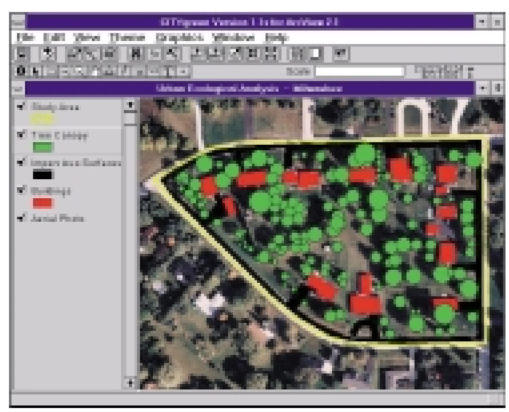
Using the land cover patterns identified from the regional image, sample sites are selected. Aerial photographs of each sample site provide data about trees, grass, and impervious surfaces. Additional information about tree species, soil types, rainfall patterns and land-use is collected. CITYgreen® software is used to calculate ecosystem benefits for each sample site. The results are then extrapolated to the Baltimore-Washington region based on the total area for each percentage canopy category.

Trees as Indicators of a Community's Ecological Health

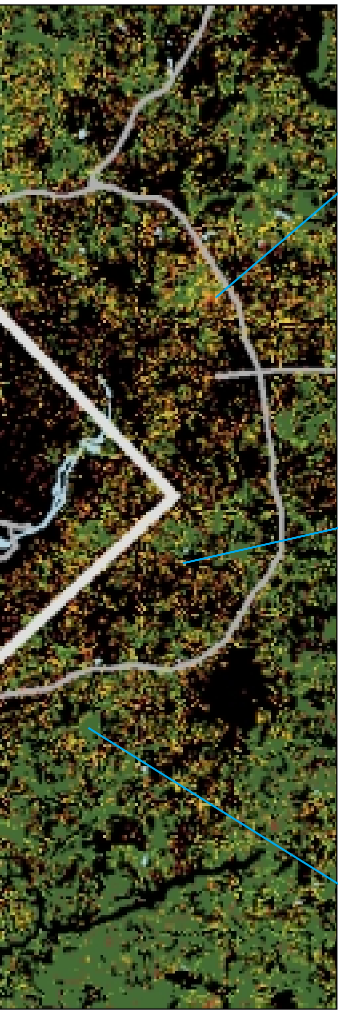
Urban ecology is more complex than tree cover. Nonetheless, trees are good indicators of the health of an urban ecosystem. The greater the canopy coverage, the less impervious surface and the more environmental benefits. Trees provide communities with many valuable services that can be measured in terms of dollar benefits. These include: 1) slowing stormwater runoff and reducing peak flow and 2) improving air quality. These quantifiable benefits can help community leaders recognize cost savings opportunities from increased tree cover.

Cities spend tremendous amounts of money installing stormwater control systems and repairing damage from flooding. Furthermore, cities that cannot meet EPA attainment levels for air and water quality jeopardize federal funding for capital improvements. Trees are an attractive non-built solution that reduces stormwater runoff and improves air quality. These benefits underscore the importance of maintaining and restoring the natural infrastructure of our communities.

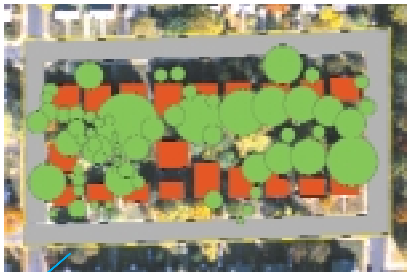




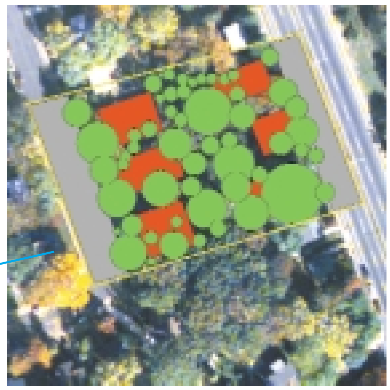
Low level aerial photography is used by CITYgreen® software to conduct a local ecosystem analysis.



Satellite images provide the framework for a regional ecosystem analysis. Geographic Information Systems (GIS) technology sorts the landscape into landcover categories and this ecological patchwork, called Ecostructures (see pg.8) is used with CITYgreen® software.



35% tree cover



45% tree cover

60% tree cover

How to Use CITYgreen® 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 connects research and engineering formulas to place a dollar value on the work trees do. With CITYgreen® we determined how various design strategies affect stormwater movement and air quality.

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 back 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 a containment facility must store. The TR-55 model, developed by the Natural Resources Conservation Service, measures stormwater movement in various storm events (see page 8).

Local governments are looking toward non-built stormwater management strategies, including trees, to reduce the cost of constructing stormwater control infrastructure. In this report, the value of trees for stormwater management is based on cost avoided 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 Baltimore-Washington corridor, the existing tree canopy reduces the need for retention structures by 540 million cubic feet. Using a $2.00/cubic foot construction cost, trees currently save the region $1.08 billion per construction cycle (maintenance costs are not included).

Air Quality

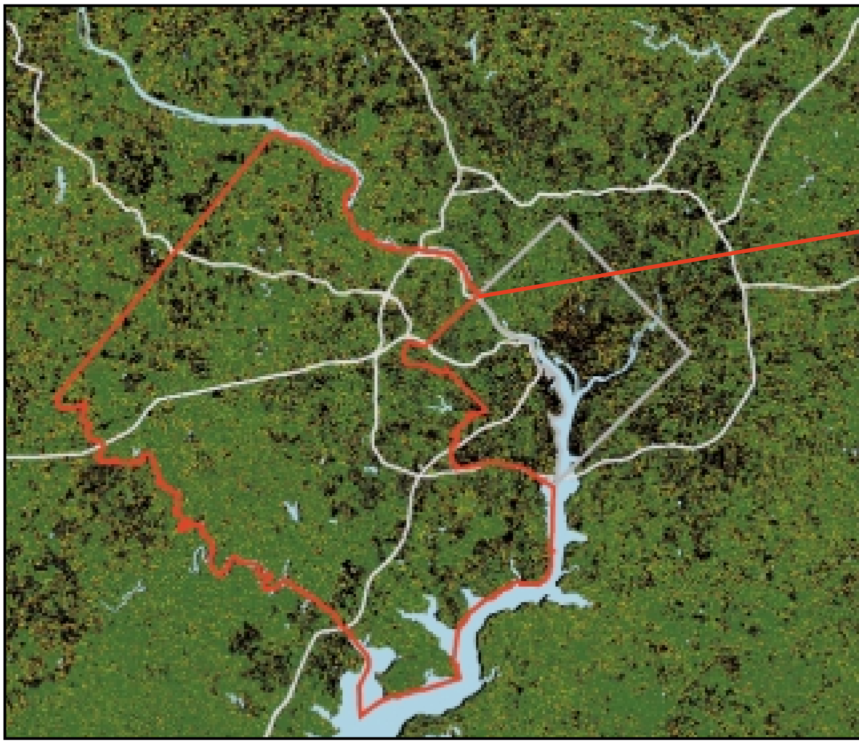
Trees provide air quality benefits by removing pollutants such as NO_2, CO, SO_2, O_3, and PM_{10}. To calculate the dollar value for these pollutants (see page 8), economists multiply the number of tons of pollutants by an "externality cost," or costs to society that are not reflected in marketplace activity. In the Baltimore-Washington corridor, the existing tree canopy removes 34 million pounds of pollutants, valued at $88 million. Tree cover as it existed in 1973 would have removed 43 million pounds of pollutants.

Summary Table
Baltimore-Washington Urban Forest Benefits, 1997

Air Quality Benefits (annual benefits)		**Stormwater Benefits** (capital improvement benefits)	
Pollutants Removed (lbs.)	$ Value	Cu/ft. Avoided	$ Saved
34 million lbs.	$88 million	540 million cu.ft.	$1.08 billion

The cost savings associated with NO_2 and O_3 are $6,750/t (metric ton), SO_2 is $1,650/t; CO is $950/t and PM_{10} is $4,500/t.

Using Regional Data for Local Analysis



Washington DC Metropolitan Area satellite data 1973 (right), Fairfax County 1997 clip of satellite data (above).

The regional level image contains a great deal of information 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. This coarse image can be divided or stratified into various tree cover zones. These zones form the basis for a more detailed analysis. There are about 1,000 municipalities in the watershed which can conduct their own analyses using clipped images from the Chesapeake Bay regional analysis.

For example, Fairfax County, Virginia was clipped from the larger regional image. In 1973, overall tree canopy was 40%; in 1997 it dropped to 37%. An analysis was conducted to determine tree canopy cover loss over time. In Fairfax, areas with dense tree canopy (≥50%) declined by 30% while areas with low tree canopy density (<20%) increased by 8.3% between 1973 and 1997.

What benefits are lost when tree cover is removed? By using aerial photography to point sample the different tree zones, a local level analysis using CITYgreen® software can be conducted. With this, a city can determine the economic value of its urban forest in terms of air quality and stormwater runoff reduction. American Forests recommends that all cities in the Chesapeake Bay Region conduct local analyses using aerial photography and incorporate the findings into their city planning process.

Aerial photograph of Fairfax County with CITYgreen® overlay

What's Next for the Chesapeake Bay Region?

Recommendations

These findings address 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 Chesapeake Bay Region and to chart a course of action for future improvement. We encourage local agencies and the community to incorporate this data into the regional planning process and to gather more detailed information for local analyses using aerial photographs, field surveys, and CITYgreen® software.

1. Expand the capacity and usefulness of this analysis for planning and growth management.

■ Incorporate a natural resource data layer into the regional and county planning processes.

■ Use the data from this analysis as a basis for building a regional model.

■ Obtain additional data for this model from city and county governments.

2. Recruit county and city governments as partners in creating a regional vegetation model.

■ Local governments should clip their data from the regional information and conduct a more detailed local analysis using aerial photography.

■ Establish local data collection plots.

■ Use local analyses for community planning.

■ Utilize CITYgreen® software and the AMERICAN FORESTS analysis technique to increase community participation.

3. Increase overall tree cover in the entire Bay region to over 50% (urban and rural).

■ Develop a comprehensive plan for the Chesapeake Bay watershed to protect, expand, and sustainably maintain our "green infrastructure" of urban and rural forests.

■ Meet or exceed the goals of major tree-planting initiatives in the Chesapeake Bay watershed. These include the Riparian Forest Buffer Initiative of the partners in the Chesapeake Bay Program to plant 2,020 miles of streamside forests by the year 2020, and AMERICAN FORESTS' Global ReLeaf for the Chesapeake Bay to plant 1 million trees in the Bay watershed for the new millennium.

4. Increase and conserve tree canopy cover in urban areas.

■ Develop urban tree canopy goals:
40% tree canopy overall
50% tree canopy in suburban residential
25% tree canopy in urban residential
15% tree canopy in the Central Business District

■ Implement innovative land-use planning techniques and engineering guidelines for saving existing trees and planting new ones.

■ Consider the dollar values associated with trees when making land-use decisions.

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

■ 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. The findings are used in the decision making process.

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 patterns. 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 Chesapeake Bay Region. Using the tree cover percentage categories to model the area's ecostructures, sample study sites within the Baltimore-Washington corridor were selected to further examine the effects of different tree canopy cover percentages on air quality and stormwater management. Additional local analysis using aerial photos of representative ecostructures is needed to refine the local values given in the analysis.

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-recified .tif images (aerial photos) at a 1 foot resolution. Fairfax County provided a shape file of the county so that local data could be clipped from the 11 million acre satellite data.

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 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 US 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.

Acknowledgments for this Study

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Fairfax County and Arlington County
ESRI for GIS software
ERDAS for remote sensing software
Emerge for low level digital imagery

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, 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. For further information contact:

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