Final Report: 7/25/98

Regional Ecosystem Analysis Puget Sound Metropolitan Area

Calculating the Value of Nature

Report Contents

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Regional Ecosystem Analysis Puget Sound Metropolitan Area

Project Overview

AMERICAN FORESTS conducted a Regional Ecosystem Analysis of the Puget Sound area to determine how the landscape has changed over time. It also assessed the value of the area's ecology. A regional level analysis was conducted of three satellite images spanning a 24 year period from 1972 to 1996. Landsat Multispectral and Thematic Mapper images were used to study an area approximately 100 by 70 miles in the Puget Sound watershed. This included 3.9 million acres (3.4 million acres of land and about .57 million acres of water) and encompasses the cities of Seattle, Tacoma, Seatac, Redmond, Bellevue, and Everett. Within the regional study area a smaller urban growth area of 422,446 acres around Seattle was also analyzed.

The Ecosystem Analysis uses Geographic Information System (GIS) technology to measure the changing structure of the landscape and analyze the scientific and engineering implications of the change. Neighborhood level computer models were developed using CITYgreen software, AMERICAN FORESTS' GIS application for calculating ecosystem benefits. The models represent five typical neighborhood landscapes and measure the effects of these landscapes on stormwater and air quality.

The purpose of this project is to document the value of tree-covered landscapes to urban areas. Furthermore, it provides urban decision makers with the information and tools they need to measure the value of natural landscapes and incorporate more trees into future development.

Major Findings

The ecology of the Puget Sound watershed has changed dramatically in the 24 year period from 1972 to 1996.

■ Areas with high vegetation and tree canopy coverage (those with 50% tree cover or more) have declined by 37% from 1.64 million acres to 1.04 million acres.

■ Areas with very low tree cover (less than 20%) have more than doubled from 25% of the region to 57%.

A dollar value can be placed on these regional ecological changes.

■ The loss in tree cover and increase in impervious surfaces increases the cost of stormwater management and the cost of air quality controls.

■ Stormwater flow during a peak storm event has increased by an estimated 1.2 billion cubic feet (29%). Replacing this lost stormwater retention capacity with reservoirs and other engineered systems would cost $2.4 billion ($2 per cubic foot).

■ Lost tree canopy would have removed about 35 million pounds of pollutants from the atmosphere annually, at a value of approximately $95 million.

■ Puget Sound's urban forest improves air quality by removing the following pollutants: nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), ozone, and particulate matter 10 microns or less (PM_{10}).

The rapid growth in the urban landscape is the biggest single factor affecting the Puget Sound ecosystem. The regional trends in tree cover loss are equally pronounced in the 422,446 acre urban growth area.

■ Heavily vegetated areas (50% or more) have declined from 208,166 acres to 101,166 acres.

■ Areas with very low tree cover (20% or less) have dramatically increased from 85,123 acres to 229,878 acres.

■ The loss of trees has resulted in a 35% increase in stormwater runoff.

■ The location and intensity of urban development has damaged salmon spawning streams.

Tree cover and natural resource information should be officially incorporated into the planning process.

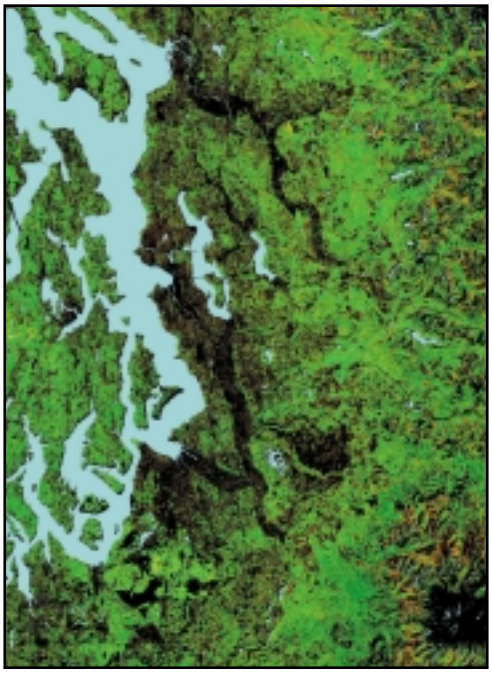
■ Existing landscapes should be recognized for their potential economic value.

■ Increasing the average tree cover to 40% in the urban areas would significantly improve the environment in stormwater management and air quality.

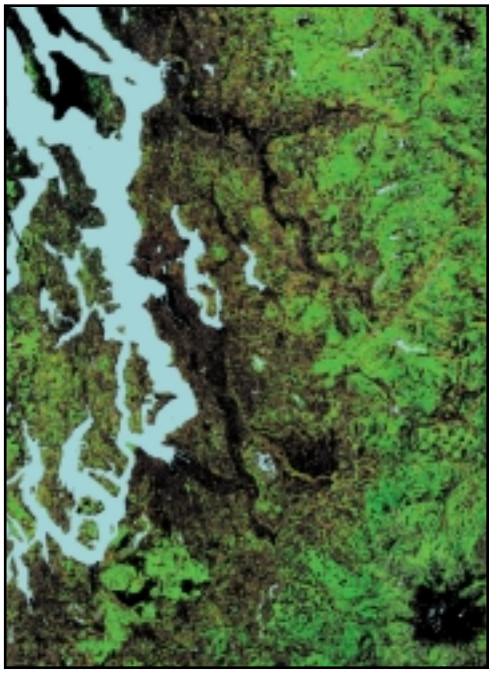
■ Strategically planting trees will accelerate stream restoration improving wildlife and fisheries habitat.

Regional Level Analysis

Landsat MSS 1972 *80 Meter Pixel Resolution*



Landsat TM 1986 *30 Meter Pixel Resolution*



Landsat TM 1996 *30 Meter Pixel Resolution*

Puget Sound Satellite Images

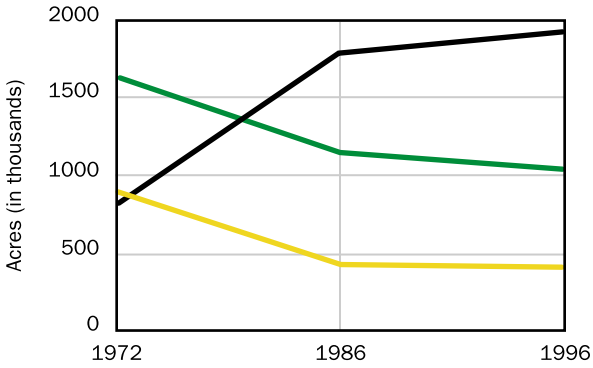
Landsat TM and MSS satellite images show the change in the landcover in the Puget Sound region over a recent 24 year period. Tree cover is indicated in green and the impervious surfaces associated with urban areas in black. The analysis measured eight categories of tree cover and the data from the detailed analysis is used in all calculations. The visual images above group the eight categories into three because additional detail is not visible to the human eye.

Graphing Change

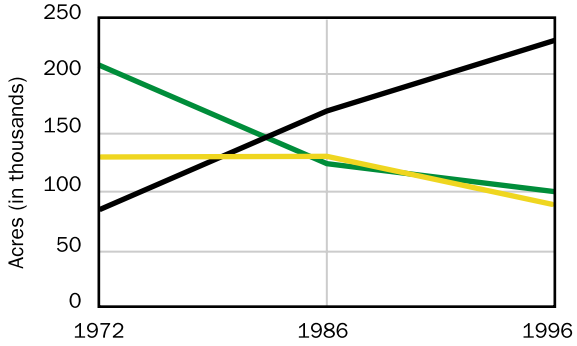
The change in vegetation depicted in the satellite images above is represented in line graphs at right. Both charts show the change in vegetative cover over a 24 year period for three categories. Natural forest cover is represented by a green line and indicates places with greater than a 50% tree canopy. 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 in the middle range between 20 and 50%. Open space, residential areas, and park land would all fall in this category.

- Low Vegetation (<20% Vegetated)
- Moderate Canopy (20-50% Vegetated)
- High Canopy (>50% Vegetated)

Vegetation Change
Puget Sound Area 1972-1996



Vegetation Change
Urban Growth Area 1972-1996



Neighborhood Level Analysis

What is a Neighborhood Level Analysis?

The Puget Sound Ecosystem Analysis has two levels of detail: one is regional scale, covering approximately 4.5 million acres, and the other is at a neighborhood scale covering about two to five acres.

Using the land patterns identified from the regional image, aerial photographs are used to document the landscape at the local or neighborhood scale. CITYgreen software is used to determine detailed measurements of the value of the local ecology.

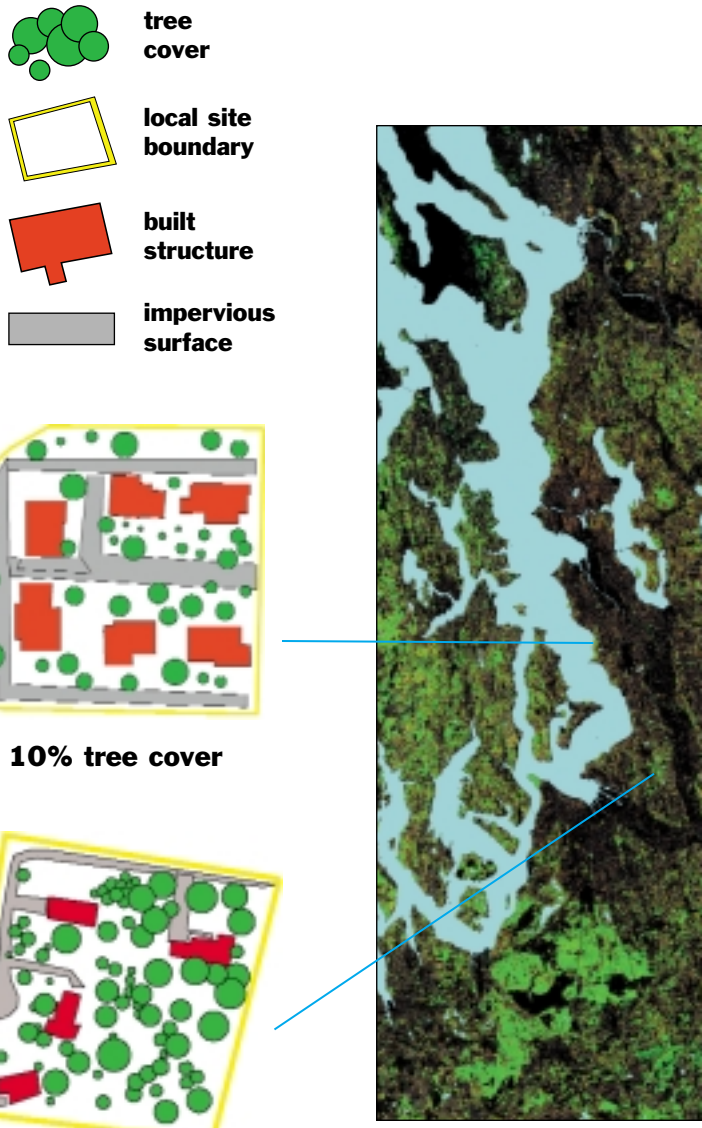
The neighborhood scale analysis is conducted in conjunction with local groups and agencies. This data is not yet available for the Puget Sound, therefore AMERICAN FORESTS has developed computer models to represent the structure of the landscape in various neighborhoods. Data gathered from local sample sites was used extensively in building these models.

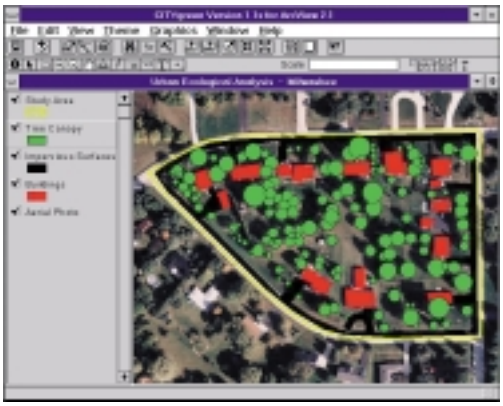
The models are designed to simulate Puget Sound's tree species, soil type, rainfall patterns and configurations of land use. In each model neighborhood, the greater the tree canopy percentage, the less impervious surface there is. The resulting benefits from these representative sample sites are multiplied by the total land area (identified in the regional summary). The findings from the neighborhood analysis are summarized in the table on page 5.

Trees as Indicators of a Community's Ecological Health

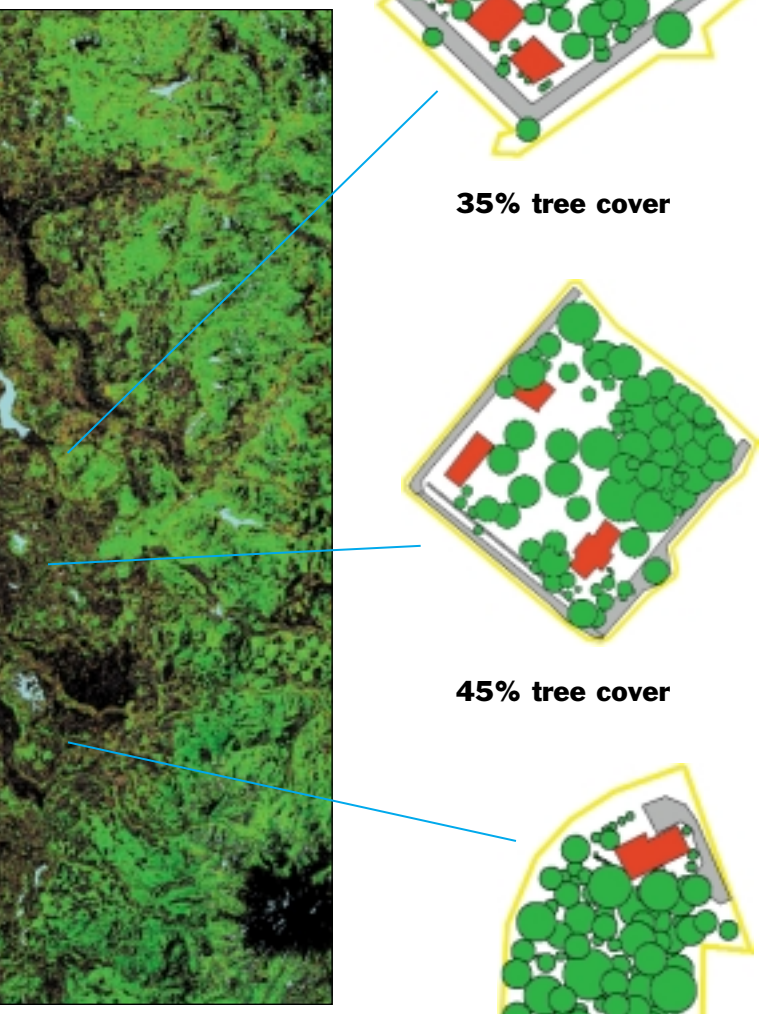
Even though urban ecology is much more complex than just trees, tree canopy cover is a good indicator of the health of an urban ecosystem. When urban forests are healthy, they provide communities with many valuable services that can be measured in dollar benefits. Two such services are: 1) slowing stormwater runoff and reducing peak flow and 2) improving air quality.

Cities spend tremendous amounts of money installing stormwater control systems and repairing damage from unmanaged water flow. In addition, cities that cannot meet EPA attainment levels for air and water quality, jeopardize federal funding for capital improvements. Nonstructural methods, including trees, can reduce stormwater runoff and improve air quality. The benefits they add increase the importance of maintaining and restoring the natural infrastructure of our communities.





Aerial photography is used by CITYgreen to conduct a neighborhood analysis.



35% tree cover

45% tree cover

60% tree cover

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.

How CITYgreen Analyzes Neighborhood Data

CITYgreen software conducts a detailed analysis of how the structure of the landscape affects its function. For example, how do various neighborhood layouts affect stormwater movement and air quality? Scientists and engineers have developed mathematical formulas which measure these functions and are incorporated into the CITYgreen software program.

Stormwater Runoff

Trees and soil function as one to reduce stormwater runoff. Trees reduce stormwater flow by intercepting rainwater on their leaves, branches, and trunk. The intercepted water evaporates back into the atmosphere, reducing the total amount of runoff that must be managed in urban areas. Trees also slow down storm flow reducing the volume of water that a containment facility must store. In addition, trees improve water infiltration characteristics of soil as biomass decomposes. The TR55 model was used to measure stormwater (see page 8).

Local governments are looking toward non-structural stormwater management strategies, including trees to reduce the costs of building stormwater control infrastructure. Trees' economic value for stormwater management is based on avoided storage of stormwater and thus the reduced construction costs of building retention ponds. Local construction costs are multiplied by the total volume of avoided storage to determine dollars saved.

In Puget Sound, the existing tree canopy reduces the need for retention ponds by 2.9 billion cubic feet per storm event (defined as the largest average 24 hour, 2 year storm). Using a $2.00/cubic foot construction cost, trees currently save $5.9 billion. In the urban growth area, trees save 355 million cubic feet in avoided storage, valued at $710 million.

Air Quality

Trees provide air quality benefits by removing pollutants such as NO_2, CO, SO_2, ozone 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 what these pollutants cost to society in terms of rising health care. For example, NO_2 and ozone are $6,750/t (metric ton), SO_2 is $1,650/t; CO is $950/t and PM_{10} is $4,500/t. In Puget Sound, the existing tree canopy removes 78 million pounds of pollutants, valued at $166.5 million. Tree cover as it existed in 1972 would save an estimated $266 million. In the urban growth area, trees remove 9.2 million pounds, valued at $19.5 million. Tree cover in this area as it existed in 1972 would save an estimated $34 million.

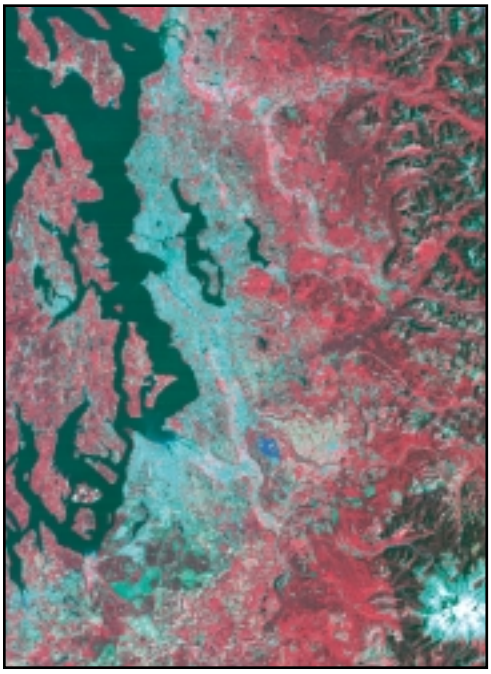
Summary Table, Puget Sound Area, 1996

Air Quality Benefits		Stormwater Benefits	
Pollutants Removed (lbs.)	$ Value	Cu/ft. Avoided	$ Saved
78 million	$166.5 million	2.9 billion	$5.9 billion

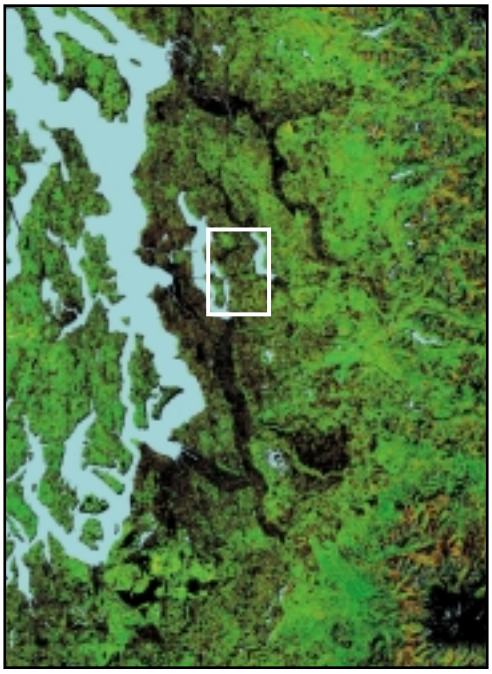
Summary Table, Urban Growth Area, 1996

Air Quality Benefits		Stormwater Benefits	
Pollutants Removed (lbs.)	$ Value	Cu/ft. Avoided	$ Saved
9.2 million	$19.5 million	355 million	$710 million

From Raw Satellite Data to Neighborhood Level Information



Raw Satellite Data 1986



1986 Regional Analysis *white box indicates Bellevue area (enlarged to the right)*

1986 Bellevue Area *white box indicates area of aerial photogrpah below.*

Combining Regional and Neighborhood Level Analysis

American Forests ecosystem analysis starts with raw satellite data as displayed upper left. The raw image shows vegetation in red and urban areas in aqua. The image produced from the raw satellite data does not show percent changes in vegetative cover. To determine tree cover, the raw satellite image is analyzed using Geographic Information Systems (GIS) (middle image). American Forests uses ERDAS Imagine software and a subpixel classification technique to determine eight categories of tree cover and one category of less than 20% tree cover. Green areas are at one end of this spectrum and represent tree cover over 50%; urban areas are black.

The regional level image contains a great deal of data. The image above right provides an enlarged view of the landscape between Lake Washington and Lake Sammanish (see box insert in middle image). The image at the lower right shows how regional satellite data is connected to aerial photography and used for neighborhood level analysis. This aerial photograph represents a neighborhood in Bellevue. Citizens from Advance Bellevue used these images along with CITYgreen software to conduct a detailed analysis of the tree cover in their city. American Forests recommends that all cities in the Puget Sound conduct a neighborhood level analysis like the one conducted by the citizens of Bellevue.

Aerial Photograph of a Bellevue Neighborhood

What's Next for the Puget Sound Metropolitan Area

Recommendations

The Regional Ecosystem Analysis provides detailed information about the value of natural resources to local governments. It is a public policy tool designed to assist in land-use planning and growth management. The recommendations below focus on tree cover because trees are a visible measure of the quality of the community environment. When urban trees are large and healthy, the ecology that supports them is also healthy. Large healthy trees are the result of healthy soils, adequate water, and healthy air. This report and the recommendations that follow bring together the expertise of ecologists, scientists, and engineers with modern computer technology to evaluate the environment in the Puget Sound and chart a course of action to improve it in the future. We encourage the agencies and community to act on these recommendations.

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

■ Incorporate a natural resource data layer into the regional planning process.

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

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

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

■ Establish neighborhood scale data collection plots in local jurisdictions.

■ Use information from the local level analysis for community planning.

■ Use the City of Bellevue as a demonstration area and model for other communities to follow.

■ Utilize CITYgreen and the AMERICAN FORESTS analysis technique as a model for community participation.

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

■ Develop urban tree canopy goals for the region and local areas:
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.

■ Incorporate 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 the value of trees into the land-use planning process by collecting data on the tree cover and analyzing 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 Puget Sound Metropolitan Area. Using the 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. Further neighborhood analysis using aerial photos of representative Ecostructures is needed to refine the values given in the model analysis.

Data Used in this Study

Landsat satellite TM (30 meter pixel) and MSS (80 meter pixel) images were used as the source of land cover data to determine the change in landcover from 1972-1996. To provide more detail to the analysis we used a subpixel technique and divided the land cover change into eight vegetation categories plus a ninth category of 0-20% tree cover.

AMERICAN FORESTS developed CITYgreen as a Geographic Information System (GIS) software to analyze the value of trees and other natural systems as part of urban infrastructure. CITYgreen is an application of ArcView, a GIS desktop software developed by ESRI.

Analysis Formulas

TR-55 for Stormwater Runoff: The stormwater runoff calculations incorporates formulas from the Urban Hydrology for Small Watersheds model, (TR-55) developed by the US Natural Resource Conservation Service (NRCS), formerly 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, for the US Forest Service, which calculates 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 externality costs or the costs to society such as rising health care costs per pollutant. For example, ozone is valued at $1,650 per ton and nitrogen dioxide is $6,750.

Acknowledgments for this Study

We gratefully acknowledge the support of the following agencies and business partners in conducting this study:

The USDA Forest Service
The City of Bellevue
ESRI for Geographic Information System software
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 for the Puget Sound is a regional campaign of AMERICAN FORESTS and part of its Global ReLeaf 2000 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 provides 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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