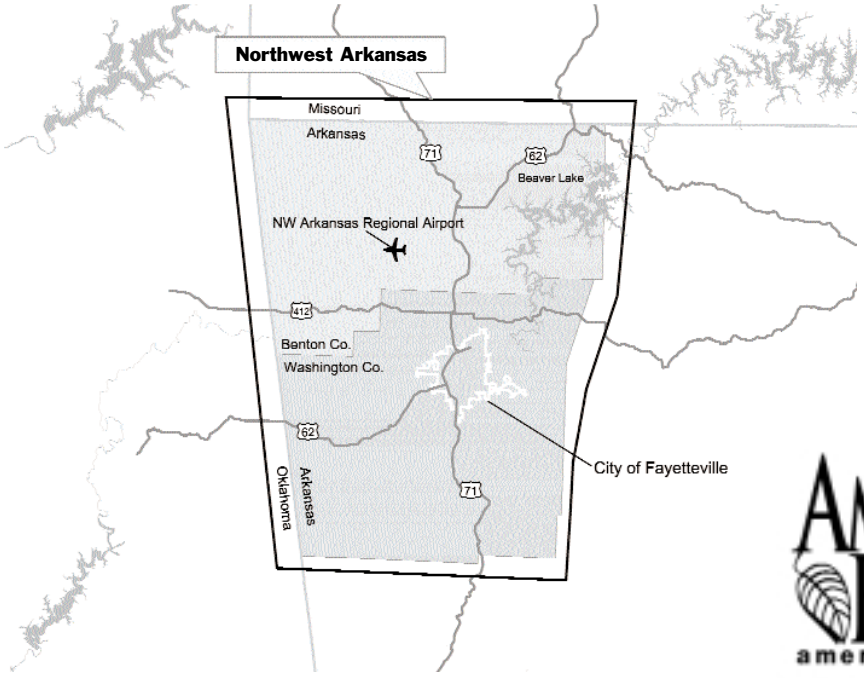
September 2002

Urban Ecosystem Analysis Benton and Washington Counties, Arkansas

Calculating the Value of Nature

Report Contents



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Project Overview

AMERICAN FORESTS conducted an urban ecosystem analysis of Northwest Arkansas using Geographic Information Systems (GIS) technology to assess tree cover change trends over the last 15 years and to create a "green data layer" to be used for future planning. The 1.4 million acre analysis covered Benton and Washington Counties and the communities within 20 miles of and including the NWA Regional Airport. The Northwest Arkansas region is at the brink of major development as a result of the new NWA Regional Airport, designed in part as the future international cargo hub of Federal Express. The anticipated growth will have a tremendous impact on the surrounding communities and landscape. As community leaders plan for future development, the information and tools provided in this project will become even more useful. The urban ecosystem analysis gives the region the opportunity to plan with nature—utilizing the environmental and economic benefits of the area's urban forest.

Overall, regional landcover changes over the last 15 years, including forests, urban development and agriculture, are difficult to decipher. It is apparent that changes have occurred, but at this scale, the net effect doesn't show significant regional tree loss trends. However the Landsat analysis did reveal several forest cover change hotspots, indicative of development, including the NWA Regional Airport, Bentonville and I-540 Freeway. The Landsat analysis pinpointed these and other areas to look at in greater detail. For example, the I-540 Freeway corridor was analyzed using multispectral high resolution imagery to show how communities can calculate current tree cover benefits. This report also demonstrates how different development scenarios can be modeled to reflect how air and water environmental benefits are affected by changes in tree canopy cover and impervious surfaces.

AMERICAN FORESTS has developed a technique that uses Geographic Information Systems (GIS) technology and satellite and aerial imagery to measure the structure of the landscape so that the Northwest Region can use the data and findings for planning future growth and development. Three different kinds of imagery were used. First regional change trends in the landscape between 1985 and 2000 were mapped through remote sensing image analysis of Landsat Satellite imagery.

Second, high-resolution multi-spectral imagery taken in 2001 was used along with a classification technique to create a "green data layer" to analyze these hotspots in greater detail. The third type—aerial imagery, available from the State of Arkansas, demonstrated how analyses could be conducted at the site-level.

AMERICAN FORESTS used these data with CITYgreen® software to assess the economic and environmental impacts of the urban forest and to model scenarios for future growth. This project provides those working in Benton and Washington Counties with the findings of these analyses, trains staff in the use of the imagery and software used in the analyses, and most importantly, offers tools for evaluating and integrating the urban forest into the future planning of this region.

Major Findings

1. The Urban Ecosystem Analysis provides a baseline of the region's urban forest resources in anticipation of major urban development along such growth areas as the new airport corridor.

■ Overall, Washington and Benton Counties', heavy, undisturbed forest cover (50% or greater) dominates the forested landscape of the region. In 1985 heavily canopied areas comprised 48% of the area (677,709 acres). Developed areas and farmland (with tree cover of less than 20%) comprised 33% of the land (462,891 acres). Medium canopy density (20-49% cover) made of the balance and comprised of 20% (282,631 acres).

■ By 2000, even though the airport had been built, tree canopy had not yet changed dramatically. Areas of heavy tree canopy (greater than 50%) declined by less than 1% (.89) while low canopy and urban areas (less than 20%) increased by 2.6%. Medium canopy (20-49%) declined by 2.11% (276,649acres).

■ The Landsat Image analysis of the region shows that compared to tree canopy, other land cover types, such as agriculture, open space and urban are large and diverse. Thus the change in the region's tree cover over the last 15 years is less than 1%.

2. The City of Fayetteville experienced a significant 18% decline in heavy tree canopy over the last 15 years.

■ Heavy tree cover (50% or greater) in the City of Fayetteville's 29,000 acres declined from 2,525 acres to 2,130 acres—an 18.3% change. During this same time period, the City saw a 40% increase in moderate tree cover (20-49%), from 240 to 336 acres.

■ The category with the most cover, low tree canopy (areas with less than 20% tree cover and urban areas) increased 3% from 24,550 acres to 25,207 acres.

■ Change in heavy tree cover is an indicator of ecological change resulting from urban development

3. Tree canopy provides stormwater management and air quality benefits. AMERICAN FORESTS measured and calculated these ecological and economical benefits.

■ Trees slow stormwater runoff (measured from each 2-year peak storm event), reducing the amount of peak flow and storage volume that the City must build and maintain. The City of Fayetteville's urban forest as of 2000, provided stormwater containment for almost 50 million cubic feet of water at a value of $92 million. This represents the cost to build stormwater retention ponds and other engineered systems to intercept this runoff ($2/cubic ft. of storage).

■ Trees improve air quality by removing nitrogen dioxide (NO2), sulfur dioxide (SO2), carbon monoxide (CO), ozone (O3), and particulate matter 10 microns or less (PM10). Fayetteville's tree canopy currently removes approximately 731,000 pounds of air pollutants annually, at a value of $1.64 million per year.

■ Trees also absorb atmospheric carbon and store it in their trunks and wood. Total storage and the rate at which carbon is stored (sequestration) can be measured. The City's urban forest currently stores 330,000 tons of carbon and sequesters 2,568 tons per year.

4. Hotspots of tree canopy decline have been identified in the Landsat analysis using a process called NDVI (Normalized Difference Vegetation Index), particularly in Bentonville and around the new airport. These areas are indicators of future development if conventional patterns continue.

5. If the City of Fayetteville increased its tree canopy from 27% to 40%, the environmental benefits would be significant. Stormwater benefits alone would be $135 million—a 47% increase and air quality would increase to $2.5 million annually, a 52% increase.

■ Setting tree canopy goals to maximize the benefits of tree cover in urban areas 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 Fayetteville.

■ Sprawl development has large negative environmental and economic consequences.

■ Strategically conserving forest cover and planting trees in urban and suburban areas, as the area develops will maintain ecological functions that the region enjoys now.

City of Fayetteville's Projected Tree Decline Trends and Loss of Environmental Benefits

Benefit	2000 Tree canopy	Projected at 15 years	Projected at 30 years
Air Quality (annual dollar benefits)	$1.64 million	$1.36 million	$1.11 million
Carbon Storage (total benefits)	330,000 tons	273,000 tons	233,000 tons
Carbon Sequestration (annual benefits)	2,568 tons	2,127 tons	1,740 tons
Stormwater savings (total dollar benefits)	$92 million	$89 million	$83 million

The loss of heavy tree canopy between1985-2000 was 18%. If Fayette continues to lose its heavy tree canopy cover at its current 18% rate, the loss of environmental benefits is significant when projected 15 and 30 years into the future.

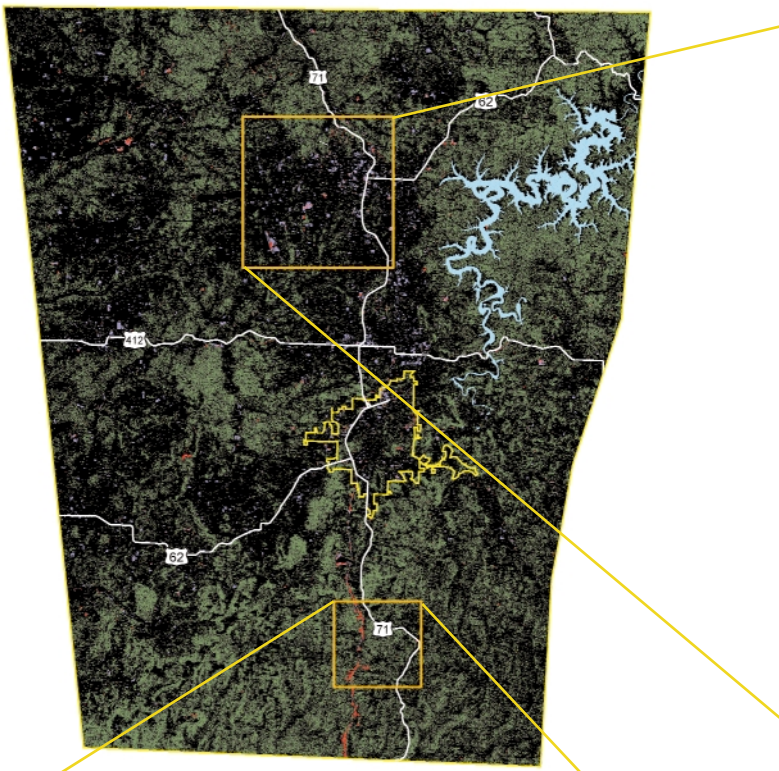
City of Fayetteville Tree Canopy Benefits– Current and With Increased Canopy

Benefit	2000 Tree canopy at 27%	Canopy Projected at 40%
Air Quality (annual dollar benefits)	$1.64 million	$2.5 million
Carbon Storage (total benefits)	330,000 tons	497,000 tons
Carbon Sequestration (annual benefits)	2,568 tons	3,867 tons
Stormwater savings (total dollar benefits)	$92 million	$135 million

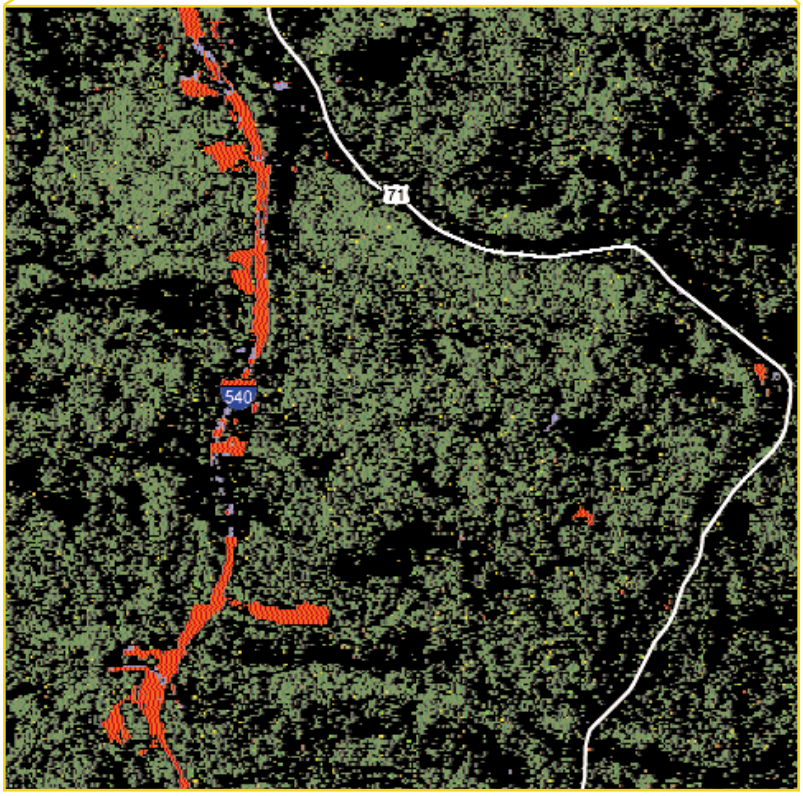
Regional Ecosystem Analysis

AMERICAN FORESTS conducted a Landsat image analysis to determine tree cover trends for the entire 1.4 million acre study area including Benton and Washington Counties and trends for the City of Fayetteville. The image at right is a classified Landsat TM image of the entire study area in 2000. High tree cover is indicated in green and low tree canopy associated with urban areas and agriculture is in black. Areas of intermediate tree canopy values are represented in yellow and red. The analysis measures nine categories of tree cover, though these have been combined into six groupings to accommodate the limitations of printing at this scale.

Using an NDVI (Normalized Difference Vegetation Index) classification to compare tree canopy changes between 1985 and 2000, heavy and medium tree canopy decline areas are highlighted. These indicate areas of development over the last 15 years. Hotspot areas include The NWA Airport, Bentonville, Rogers, Lowell, Springdale, Fayetteville. To the west are Farmington, Tonitown and Siloam Springs. The I-540 Freeway appears as a hotspot of tree decline. These areas can be analyzed in more detail using a "green data layer" created from high resolution multispectral imagery.



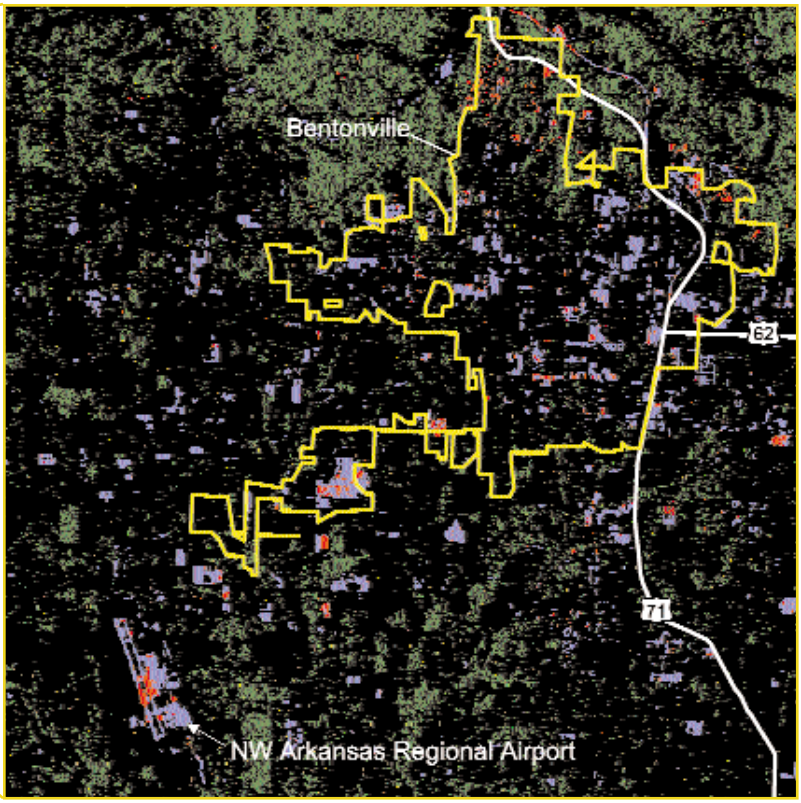
2000 Landsat classified image of the region with hotspots of tree cover change over 15 years



I-540 Freeway

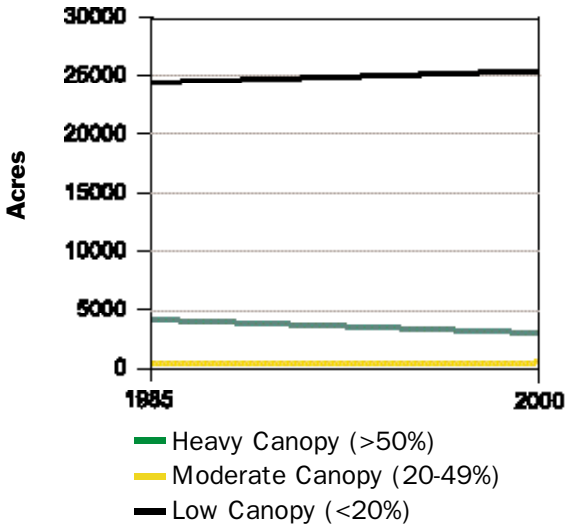
Areas of Tree Canopy Decline

- Heavy decline
- Medium decline

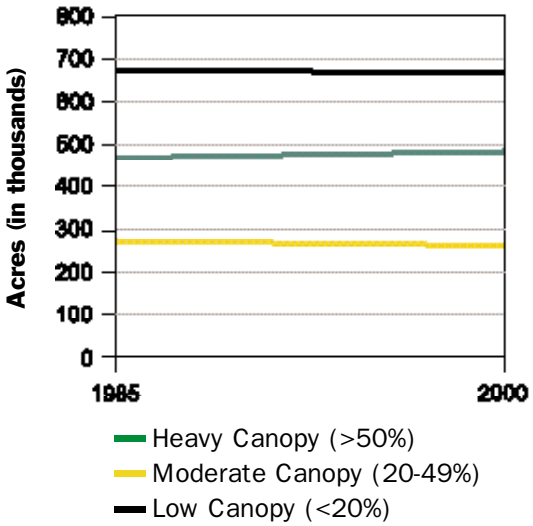


NWA Regional Airport and Bentonville

Tree Cover Change
City of Fayetteville, 1985-2000



Tree Cover Change
Benton and Washington Counties, 1985-2000



Graphing Change

The change in vegetation measured in the Landsat study is represented by two line graphs, one of the region and one of the City of Fayetteville. Heavy forest cover is represented by a green line and indicates places with greater than or equal to 50% tree canopy. Developed and agricultural areas are represented by a black line and indicate where tree canopy is less than 20%. The yellow line represents a mix of development and the natural environment where tree cover is between 20% and 49%. Open space, residential areas, and parkland would fall into this middle category.

Overall, the regional chart shows little change in vegetation cover for three categories over the 15-year span of the study. For a more complete understanding, parcel maps can be overlaid onto these images to distinguish agriculture and open space from urbanized areas.

However, when viewed at a community scale, heavy tree canopy decline trends become apparent as well as hotspots of decline. Areas with heavy tree canopy (red) and medium (purple) canopy decline are identified around the airport and communities to its north and in Bentonville. Also the new I-540 Freeway shows change in heavy vegetation and can be an indicator of future development.

Fayetteville Ecosystem Analysis

While Landsat images, at a 30 meter pixel resolution, allow us to document tree cover in clumps the size of a Wal-Mart, and can identify general trends of tree canopy cover change over time, high resolution multi-spectral imagery allows us to see trees more closely. Not only can we see the urban forest more clearly, but a classified 4-meter multi-spectral image allows tree cover data to be analyzed for its benefits. We call this the green data layer. When used with CITYgreen software, a 100% stormwater runoff and air quality benefit analysis for the entire urban forest can be conducted instead of extrapolating benefits from sample plots.

Adding a green data layer to the decision making process introduces a new dimension to planning and development discussions, one that considers the dollar benefits of trees and associated natural resources. Planning with the green layer provides a way to take advantage of the natural cycles of air, water and energy instead of solely building costly infrastructure to manage these systems. By developing and using a green data layer, future decisions will include better information about the full range of community resources.

Creating Fayetteville's Green Data Layer

The first step in creating a green layer for use in GIS is to acquire multi-spectral imagery from satellites. A 4-meter pixel resolution image of the City of Fayetteville was captured in 2001 during the growing season, when the leaves were on the trees. Next, AMERICAN FORESTS' GIS analysts classified the images into different land cover types—areas covered in trees, grass and open space as well as impervious surfaces.

Using Aerial Imagery

Aerial imagery along with tree-specific information collected in the field can be used to conduct additional analyses. With CITYgreen, users can run energy conservation, avoided carbon and growth modeling analyses. Aerial imagery at a recommended 1/2 to 2 foot scale, leaf on, and true color would be most appropriately used on an individual site level, to assess benefits of existing site conditions and to model future development scenarios.

The City of Fayetteville has one-meter, color infrared aerial imagery available to conduct additional analyses. The example shown here is of Springdale, a residential area with newly planted trees and an existing park with larger trees. The 16-acre site has a 9% tree canopy, 41% impervious surfaces (buildings and roads), and 57% open space. Benefits are listed in the table (on page 8).

Calculating the Benefits of Urban Trees

Identifying and working with the green data layer within the community's infrastructure pays big dividends. The greater the canopy coverage and the less impervious surface, the more environmental benefits. The City of Fayetteville can then devise strategies to increase tree cover and recognize their environmental benefits and management cost savings.

CITYgreen

Though the idea that trees are good for the environment isn't a new one, until recently it was difficult to place a value on the actual work that trees do. CITYgreen software has changed that. As a synthesis of decades of research formulas and engineering models, CITYgreen is used to calculate the value of trees to urban ecosystems. CITYgreen analyzes the land cover information provided in a green data layer and determines the benefits in dollar values that the trees on that site provide. Here's how trees provide environmental benefits and how CITYgreen software measures them.

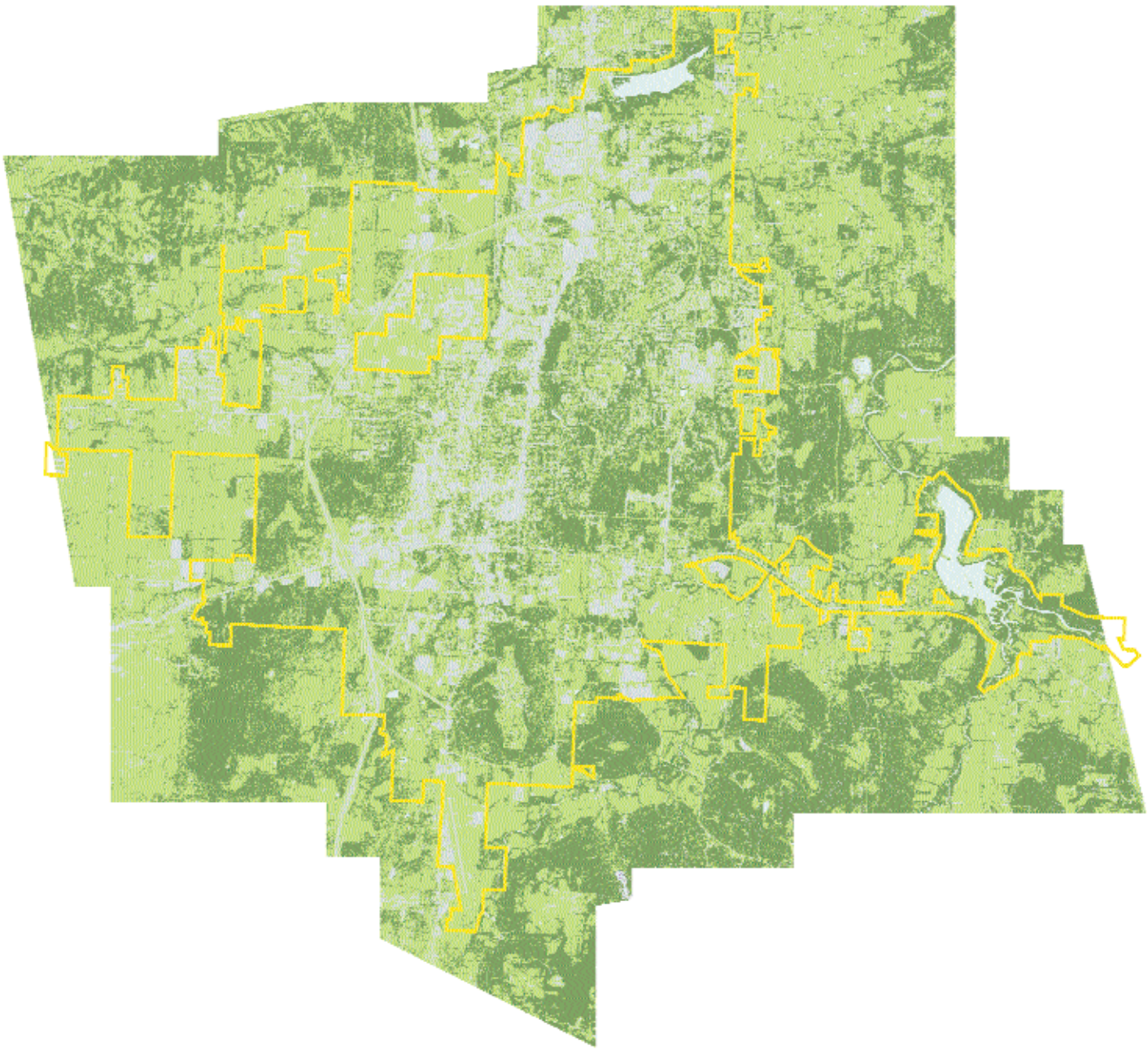
Stormwater

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.

Communities that use increased tree cover to help manage stormwater 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 stormwater retainment facility construction costs are multiplied by the total volume of avoided storage of water to determine dollars saved by trees.

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 according to USDA Forest Service research findings. To calculate the value of mitigating these pollutants, 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 paid in areas such as health care, if trees did not remove these pollutants.



A green data layer of the City of Fayetteville provides data to conduct Urban Ecosystem Analyses by site, neighborhood, watershed or other political or ecological areas of interest. This green data layer was created from a classification of a multispectral 4-meter resolution satellite image. Dark green represents tree cover, light green represents grass and open space, and gray designates impervious surface.

Stored and Sequestered Carbon

This study also analyzed the amount of carbon stored and sequestered per year in the region's trees. Carbon accounts for about half the dry weight of most trees. The carbon-related function of trees is measured in two ways: storage, or the amount currently stored in tree biomass, and sequestration, the rate of absorption per year.

Energy Use

Cities can use vector data from existing high-resolution aerial imagery (1 meter resolution) and site-surveyed information from sample sites to estimate the energy savings that trees provide. This savings not only conserves residential energy use, it also cools the urban heat island and improves air quality since air pollutants increase as temperature rises.

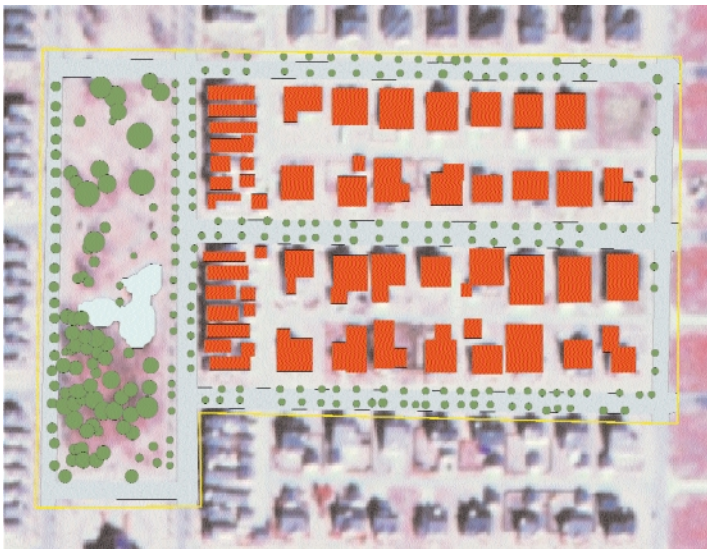
To estimate the city-wide energy conservation savings of trees, the average, annual savings of per home (calculated using CITYgreen from sample sites) is projected across the city's estimated number of single-family detached residences (obtained from U.S. Census Bureau).

Avoided Carbon

Reducing energy use also reduces the amount of carbon pollution produced by utility companies. CITYgreen calculates the amount of kilowatt-hours of electricity conserved as a result of direct shading of trees. This number is multiplied by the fuel mix profile of Arkansas's electricity production.

City of Fayetteville and Site Specific Benefits Calculated With CITYgreen

Study Area	Acres	% Trees	% Impervious	% Open Space	Air Quality (Annual benefits)		Carbon Benefits		Stormwater (Capital improvement benefits)	
					Pollutants Removed (lbs)	$ Value	Carbon Stored (tons)	Carbon Sequestered (tons/year)	Cubic ft. avoided	$ Saved
City of Fayetteville benefits	28,857	27	18	53	731,000	$1.6 million	330,000	2,600	46 million	$92 million
Springdale study site Har-Ber Meadows Neighborhood	16.36	9	41	57	136	$306	46	1	17,000	34,000



Springdale Study Site

This is an example of one meter, infrared aerial imagery available for use to conduct site-level analyses using CITYgreen. Go to www.gis.state.ar.us to download this imagery.

Modeling Development Scenarios

As the region's community leaders prepare for future development, they can use the green data layer and aerial imagery with CITYgreen to understand the impacts tree canopy and impervious surface changes would have on the ecology of the area. AMERICAN FORESTS has studied urban tree cover for almost 20 years, and along with federal, state and local urban forestry experts has developed a recommended 40% urban tree cover goal for most communities to achieve. What would this look like in the City of Fayetteville? The table below demonstrates the environmental and economic benefits the city could achieve with this increased canopy as compared with the City's existing 27% canopy.

Another type of modeling allows the user to create alternative development scenarios, using either the green data layer (raster data) or aerial imagery (vector data). The user alters an existing condition and then runs a CITYgreen analysis on the new scenario to compare the benefits.

For example, the new I-540 Freeway is a hotspot of tree canopy decline, as identified in the Landsat analysis and a potential area of new development. AMERICAN FORESTS created a future development scenario of this important transportation artery. In this 539 sq. acre scenario, existing tree cover on either side of the road is replaced with urban development.

Using the green data layer (high-resolution, multispectral imagery), land cover percentages for buildings, roads, trees and grass were assigned. The existing tree canopy is reduced from 32% to 10% and the impervious surface is increased from 8% to 30%. CITYgreen was used to calculate the scenario's environmental benefits. The table below compares the development scenario with the current condition. Numerous development scenarios can be compared using this technique. Using a more detailed, spatial modeling approach, this same development scenario can be "designed" by drawing (digitizing) buildings, impervious surfaces, grass and trees on top of an aerial image of this area and running a CITYgreen analysis.

With a third type of modeling, CITYgreen can model future tree growth, demonstrating the long-term benefits of an immediate financial investment in tree planting or to help evaluate the effectiveness of a new tree ordinance. The tree growth model predicts the size and benefits of trees if allowed to grow over time. Growth modeling can be selected for 1-50 years and uses information collected in the field on each tree—species, size, health, as well as other environmental factors such as soil type and growing condition.

Modeling Economic Benefits of Tree Canopy at Fayetteville's Current and Recommended Canopy Percentages.

Study Area	% Trees	% Impervious	% Open Space	Air Quality (Annual benefits)		Carbon Benefits		Stormwater (Capital improvement benefits)	
				Pollutants Removed (lbs)	$ Value	Carbon Stored (tons)	Carbon Sequestered (tons/year)	Cubic ft. avoided	$ Saved
Current Citywide benefits	27	22	53	731,000	1.6 million	330,000	2,568	46 million	$92 million
Modeled at 40% canopy cover	40	18	40	1.1 million	2.5 million	497,000	3,867	67million	$135 million

Modeling the Impact of I-540 Freeway Corridor Development.

Study Area	% Trees	% Impervious	% Open Space	Air Quality (Annual benefits)		Carbon Benefits		Stormwater (Capital improvement benefits)	
				Pollutants Removed (lbs)	$ Value	Carbon Stored (tons)	Carbon Sequestered (tons/year)	Cubic ft. avoided	$ Saved
Current I-540 Freeway	32	8	59	16,587	$37,000	7,485	58	804,000	1.6 million
Modeled with Urban Development	10	30	59	5,141	$12,000	2,230	18	622,000	1.2 million

Recommendations

The Regional Ecosystem Analysis from Landsat satellite imagery gave us our first look at tree canopy trends over the last 15 years in the region. This analysis forms a baseline of the region's urban forest resources in anticipation of major urban development being planned around the new airport.

From this study, AMERICAN FORESTS also learned that Fayetteville needs more detailed information in order to incorporate a green data layer into their decision-making. The high resolution multispectral imagery that covers the City of Fayetteville does just that. This study provides a detailed assessment of the tree cover and quantifies ecological benefits. 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.

A Beginning

Though this report provides valuable information regarding the tree cover and its benefits, the true strength of this project is in the data it provides for the cities' planners, engineers, environmentalists, and elected officials who use it for additional analyses as needed for regional and local planning. With the land cover data set (pictured on page 7) provided to the City of Fayetteville, staff now has the tools they need to put trees into 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 project-by-project basis.

The Northwest Arkansas region should adopt specific tree cover targets for various land use areas.

■ Establish these goals with an understanding of current and future ecological and land use objectives.

■ Establish goals for individual communities along with future growth and development of the entire region. Currently, the region has a 35% canopy and the City of Fayetteville has a 27% tree canopy.

■ Work toward a balance between the natural and the built landscape to take full advantage of the ecological benefits of urban tree cover.

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

Expand the green data layer to other areas within the region planned for future growth.

■ Use classified high resolution multispectral and pan imagery (now available at 2.8 meter multispectral and .7meter pan) in other areas within the region to conduct urban ecosystem analyses by political and ecological jurisdictions.

■ Use the green data layer to assist with watershed protection planning to promote the use of trees and other vegetation as a strategy for meeting water quality standards

■ Coordinate planning between communities using the green data layer to maintain green connections along watersheds, trail systems, wildlife corridors and other regional natural resources

■ Continue to use Landsat data to identify areas of change and then conduct urban ecosystem analyses using the green data layer to obtain best results.

Use CITYgreen software to conduct analyses when considering how a proposed development will impact the ecological and economic health of the area.

■ Use modeling capabilities of CITYgreen when looking at future growth of trees, alternate design scenarios and the impacts of adding or removing tree canopy, imperious surfaces and other land covers.

■ Compare development scenarios with clean air and water regulations in mind to choose the best development alternatives.

About the Urban Ecosystem Analysis

AMERICAN FORESTS' Regional Ecosystem Analysis is based on the assessment of ecological structures—unique combinations of land use and land cover patterns. Each structure performs ecological functions differently and thus provides different values. For example, a site with a heavy tree canopy and few impervious surfaces provides more stormwater reduction benefits than one with low tree canopy.

In this study, the regional analysis provided tree cover change trends in the Northwest Arkansas region. Landcover classifications of the study area were conducted from satellite imagery spanning the last 15 years. These areas were then modeled to assess the current and future benefits of tree cover at its current rate of decline. AMERICAN FORESTS used high-resolution satellite data to create a "green data layer" of the City of Fayetteville for refined analysis. Aerial imagery is available to conduct CITYgreen analyses on a site basis.

Data Used in this Study

For the regional analysis, Landsat satellite TM (30 meter pixel) images were used as the source of land cover data. AMERICAN FORESTS used a full pixel classification technique and divided land cover into nine vegetation categories. A change detection technique (NDVI) was also employed to show areas of forest decline between 1985 and 2000. Tree benefits of the region were calculated using CITYgreen® software on the satellite images.

For the green data layer, AMERICAN FORESTS acquired, multispectral, 4-meter resolution satellite imagery and used a subpixel classification technique. Tree benefits of the City of Fayetteville were calculated using CITYgreen software on the satellite images.

An example of available 1-meter resolution, color infrared aerial imagery available to use is shown on page 8. Tree benefits of a sample site were calculated using CITYgreen software on the aerial image.

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 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.

Acknowledgements for this Study

We gratefully acknowledge the support of the following agencies, and companies in conducting this study:
Arkansas Forestry Commission
Arkansas Geographic Information Office
City of Fayetteville
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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