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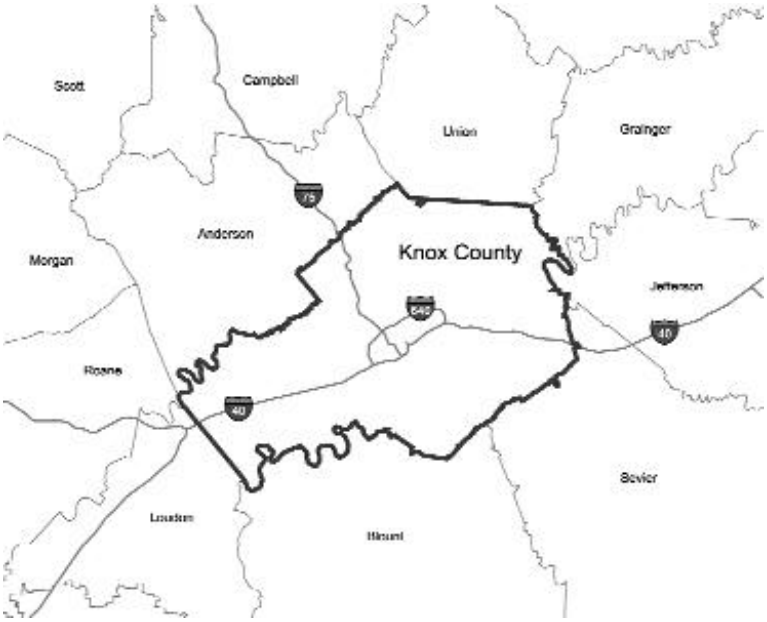
Urban Ecosystem Analysis Knox County, Tennessee

Calculating the Value of Nature

Report Contents



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Project Overview

AMERICAN FORESTS and Knox County have conducted a detailed assessment of the tree cover throughout the county. Covering over 337,000 acres (526 square miles), the study area covered all of Knox County including its 40 subwatersheds. The analysis used Geographic Information Systems (GIS) technology to measure the structure of the landscape with emphasis on tree cover. Landsat Satellite imagery was used to measure how the landscape of Knox County has changed over time. The analysis assessed the loss of tree canopy over a ten-year period between 1989 and 1999. AMERICAN FORESTS also utilized high-resolution satellite imagery to produce a land cover classification data layer for the entire study area, while CITYgreen software was used to calculate the environmental and economic values of Knox County'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 Knoxville-Knox County - Knoxville Utilities Board Geographical Information System. 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.

Findings for Knox County

In Knox County, 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 the city of Knoxville, each of the county's 40 subwatersheds, and the county as a whole. The analysis revealed that the tree cover varies from a high of 78% in the Toll Creek subwatershed (among watersheds falling completely within Knox County) to a low of 28% in the Second Creek subwatershed. 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.

Knox County's urban forest provides ecological benefits for managing stormwater, and mitigating air pollution.

- Between 1989 and 1999, heavy tree cover (areas with greater than 50% canopy) in Knox County declined by 2.2% (a loss of 3,262 acres). Area with less than 20% tree canopy (urban and agricultural areas) increased by 9.8% (up 14,883 acres). The greatest loss of tree cover was in areas with moderate tree cover (20-49% tree canopy)—areas that often represent a mixture of development and natural tree cover. These areas decline by nearly 42% (a loss of 11,621 acres).

- Knox County is comprised of 174,327 acres of tree canopy (52%), 91,380 acres of open space (27%), 44,019 acres of impervious surfaces (13%), 15,847 acres of bare ground (5%), and 10,619 acres of water (3%).

- The total stormwater retention capacity of this urban forest is 744 million cubic feet. Without these trees, the cost of building the infrastructure to handle the increase in stormwater runoff would be approximately $1.48 billion (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. Knox County's urban forest removes 16.5 million pounds of pollutants from the air each year—a benefit worth $41.2 million annually.

The City of Knoxville currently meets AMERICAN FORESTS' minimum tree cover recommendations, but as development continues this tree cover will be in jeopardy.

- Covering 25,151 acres (40%), the dominant landcover features in Knoxville are trees. Impervious urban surfaces comprise 16,981 acres (27%). Open space accounts for 21% of the city (13,105 acres), bare land for 4,276 acres (7%), while water covers 3,360 acres (5%).

- The total stormwater retention capacity of Knoxville's existing urban forest is more than 140 million cubic feet. This translates into a value of approximately $280 million (based on construction costs estimated at $2 per cubic foot to build equivalent retention facilities).

- Every year, the tree cover in Knoxville sequesters more than 2.3 million pounds of pollutants from the air, with a value of more than $5.9 million.

2002 Forest Cover Benefits of Knox County, Knoxville, and 40 Subwatersheds

ID		Acres	Tree Canopy	Stormwater Management Value (cu.ft.)	Stormwater Management Value ($)	Air Pollution Annual Removal Value (lbs)	Air Pollution Annual Removal Value ($)	Carbon Stored (tons)	Carbon Sequestered Annually (tons)
	Knox County	337,144	52%	744,011,728	$1,488,023,456	16,575,016	$41,249,267	7,501,293	58,399
	Knoxville	62,894	40%	140,088,728	$280,177,456	2,391,395	$5,951,324	1,082,264	8,425
1	Baker Creek	1,663	59%	3,737,808	$7,475,616	93,046	$231,559	42,109	327
2	Beaver Creek	49,592	45%	95,455,913	$190,911,826	2,137,344	$5,319,082	967,289	7,530
3	Bull Run Creek	25815	72%	67,661,006	$135,322,012	1,762,180	$4,385,434	797,503	6,208
4	Burnett	2,297	58%	5,318,673	$10,637,346	155,379	$386,683	70,319	547
5	Cement Hill	1,326	71%	3,432,330	$6,864,660	88,999	$221,487	40,278	313
6	Clift Creek	1,939	69%	4,477,516	$8,955,032	126,674	$315,246	57,328	446
7	Clinch River	6,268	55%	15,651,434	$31,302,868	328,106	$816,538	148,489	1,156
8	Conner	4,278	52%	7,459,212	$14,918,424	210,927	$524,923	95,458	743
9	Fawver	759	50%	1,336,374	$2,672,748	35,984	$89,553	16,285	126
10	First Creek	7,758	39%	14,009,498	$28,018,996	290,829	$723,770	131,619	1,024
11	Flat Creek	20,252	49%	37,071,181	$74,142,362	939,507	$2,338,096	425,189	3,310
12	Fourth Creek	6,835	46%	16,181,772	$32,363,544	300,185	$747,053	135,853	1,057
13	Gap Creek	512	85%	1,825,132	$3,650,264	41,235	$102,620	18,661	145
14	Goose Creek	2,369	62%	5,355,062	$10,710,124	140,117	$348,702	63,412	493
15	Grassy Creek	4,305	53%	8,338,777	$16,677,554	215,968	$537,467	97,740	760
16	Hickory	5,492	65%	13,327,748	$26,655,496	339,924	$845,949	153,838	1,197
17	Hinds	5,379	69%	12,619,924	$25,239,848	352,041	$876,106	159,322	1,240
18	Holston R./French Br.	36,029	51%	74,070,834	$148,141,668	1,741,140	$4,333,074	787,981	6,134
19	Knob Creek	3,970	72%	12,934,750	$25,869,500	272,545	$678,269	123,345	960
20	Knob Fork	3,754	53%	7,187,592	$14,375,184	187,792	$467,347	84,988	661
21	Legg Creek	2,043	53%	3,521,848	$7,043,696	103,410	$257,351	46,800	364
22	Loves Creek	6,392	45%	13,750,168	$27,500,336	276,121	$687,166	124,963	972
23	Lyon	4,006	64%	8,826,632	$17,653,264	242,121	$602,552	109,575	853
24	Roseberry Creek	8,418	47%	14,353,114	$28,706,228	376,425	$936,788	170,357	1,326
25	Second Creek	4,496	28%	7,586,278	$15,172,556	120,236	$299,225	54,414	423
26	Sinking Creek	5,634	50%	13,218,572	$26,437,144	268,451	$668,078	121,491	945
27	Sinking East	2,086	58%	4,400,604	$8,801,208	115,107	$286,462	52,093	405
28	Stock Creek	15,855	65%	34,382,979	$68,765,958	973,401	$2,422,446	440,528	3,429
29	Strong Creek	1,636	49%	2,723,868	$5,447,736	76,348	$190,003	34,552	269
30	Swan Pond Creek	7,364	56%	14,860,770	$29,721,540	393,825	$980,091	178,232	1,387
31	Ten Mile Creek	9,610	45%	20,857,679	$41,715,358	410,986	$1,022,797	185,998	1,448
32	Tennessee River	29,754	47%	69,393,380	$138,786,760	1,335,250	$3,322,960	604,289	4,704
33	Third Creek	11,337	38%	21,153,822	$42,307,644	405,781	$1,009,844	183,642	1,429
34	Thompson	611	63%	1,501,954	$3,003,908	36,364	$90,497	16,457	128
35	Toll Creek	1,216	78%	3,434,714	$6,869,428	90,193	$224,459	40,818	317
36	Tuckahoe	6,593	64%	15,157,220	$30,314,440	398,869	$992,642	180,514	1,404
37	Turkey Creek	18,135	39%	33,210,955	$66,421,910	674,128	$1,677,663	305,087	2,375
38	Whites Creek	7,059	48%	12,424,779	$24,849,558	321,718	$800,642	145,598	1,133
39	Williams Creek	1,677	46%	3,681,318	$7,362,636	73,095	$181,909	33,080	257
40	Woods Creek	2,611	50%	4,853,829	$9,707,658	123,247	$306,718	55,777	434

Knox County Green Data Layer

Creating A Green Infrastructure

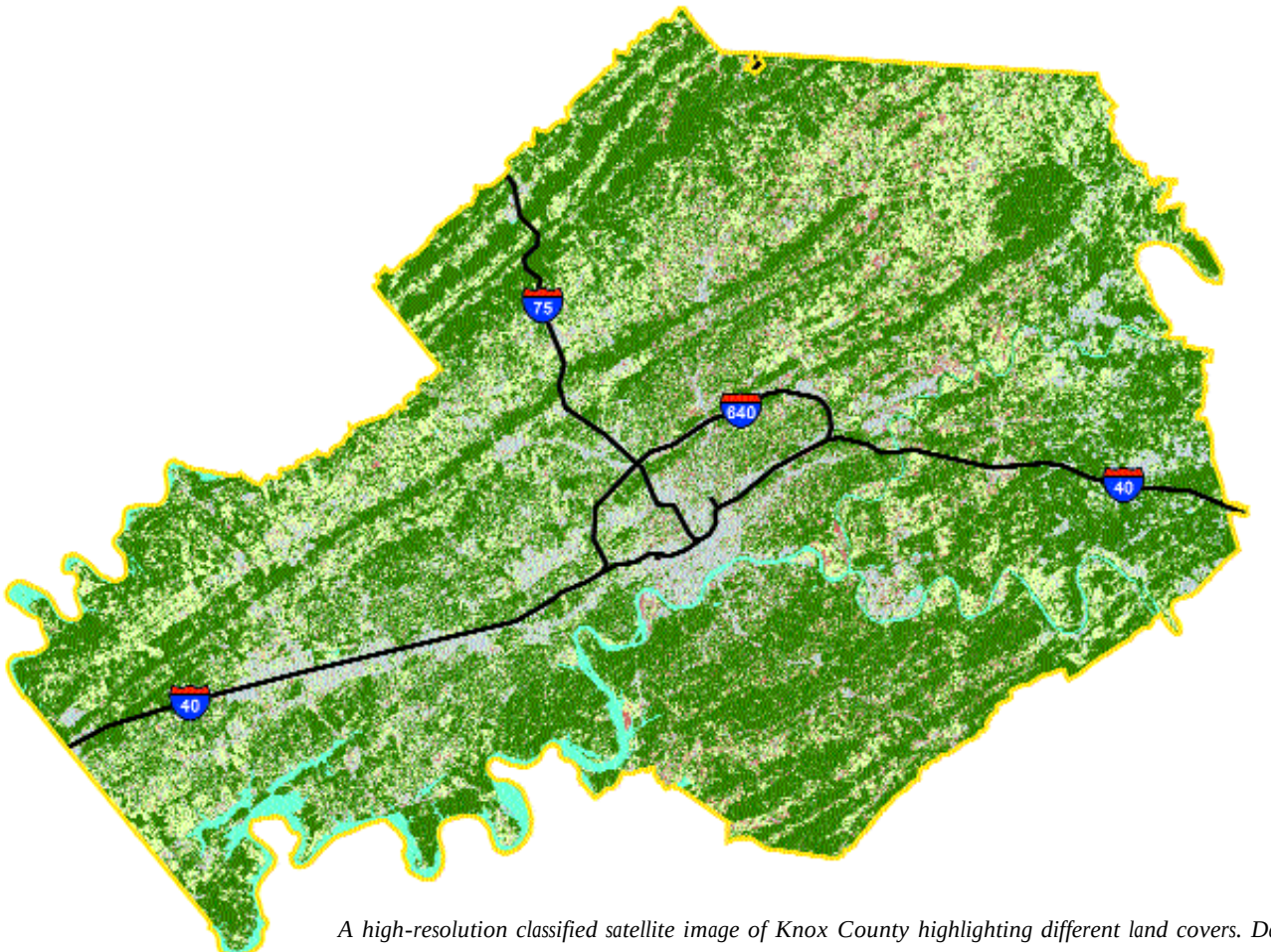
Adding a green infrastructure data layer to the decision making process introduces a new dimension to planning and development discussions, one that considers how to work with the natural environment instead of building costly infrastructure to manage air, water and energy systems. By developing and 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. 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 that 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 Beginning

Though this report provides valuable information regarding the tree cover and its benefits throughout the Knox County, 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 right), communities in Knox County 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.



A high-resolution classified satellite image of Knox County highlighting different land covers. Dark green represents t cover, light green represent grass and open space, and gray designates impervious surface. Clips of this data set are availab to communities within Knox County to use in conjunction with CITYgreen software and on a daily decision-making ba

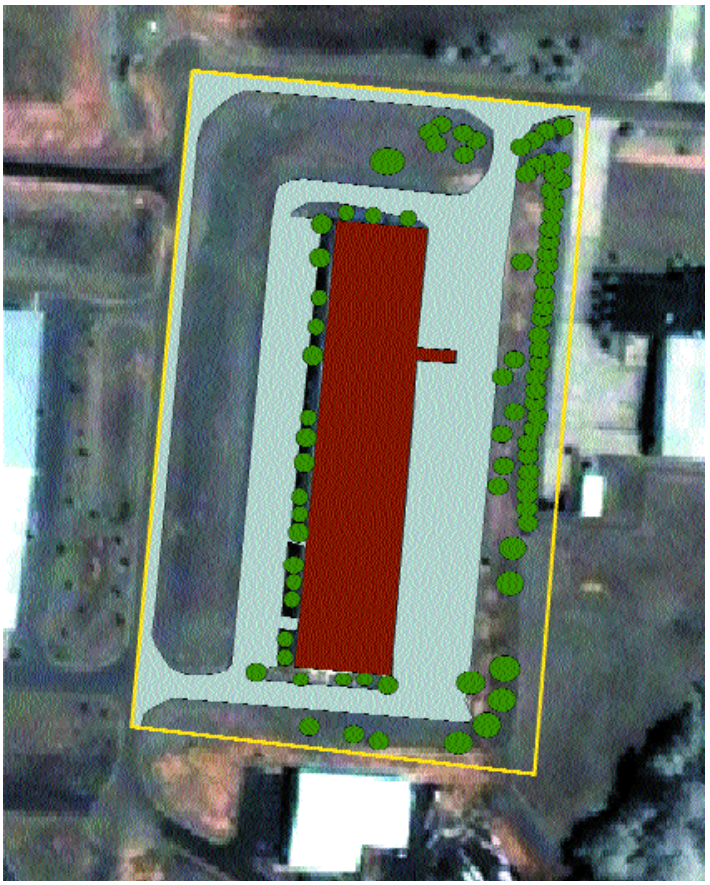
Small Site Analysis

As part of this project, nine study sites were chosen for in-depth analysis in order to demonstrate the utility of the process to smaller projects. The study sites ranged in size from 1 to 8 acres and have canopy coverage from a low of 2% to a high of 31%.

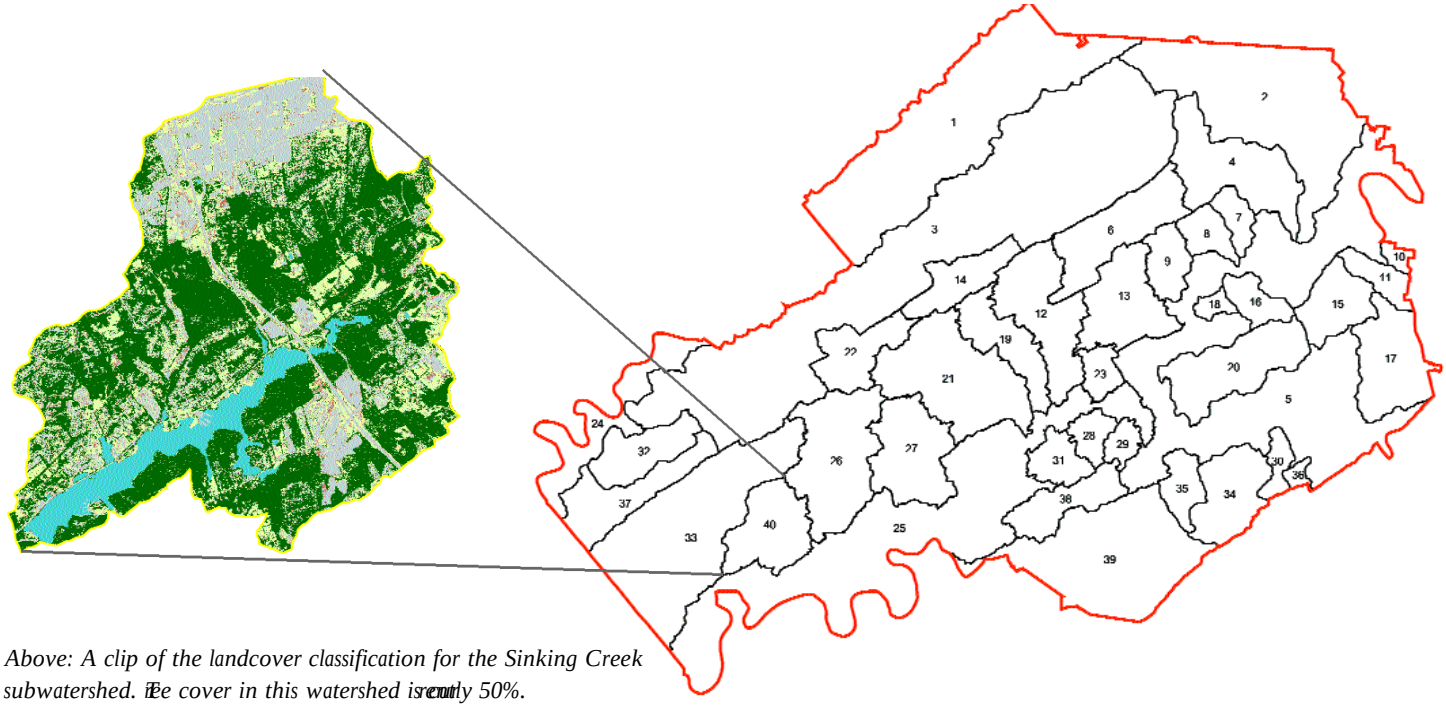
The local level analysis is a detailed assessment of a selected number of sample study points where high resolution aerial photographs, a site survey, and CITYgreen software are used to calculate the effect of tree cover on air, water and energy. Aerial photographs of each sample site provided data about trees, grass, and impervious surfaces. Additional information was collected in the field, including tree species, size and, health. Other data is added to the calculations using national data sets for soil types, and rainfall. CITYgreen software is used to calculate ecosystem benefits for each sample site.

Subwatershed Analyses

One the strengths of the data generated from this study is the ability to clip it to any boundary—political or natural. Knox County is made up of 40 subwatersheds of the Tennessee, Clinch, Holston, and French Broad Rivers. AMERICAN FORESTS analyzed the tree cover in these 40 subwatersheds and the results are reported below. The analysis revealed that the tree cover varies from a high of 78% in the Toll Creek subwatershed (among watersheds falling completely within Knox County) to a low of 28% in the Second Creek subwatershed. The trees in the Baker Creek subwatershed (49,592 acres) are worth over $190 million, while the trees in the small Fawver subwatershed (759 acres) are worth approximately $2.6 million in stormwater benefits.

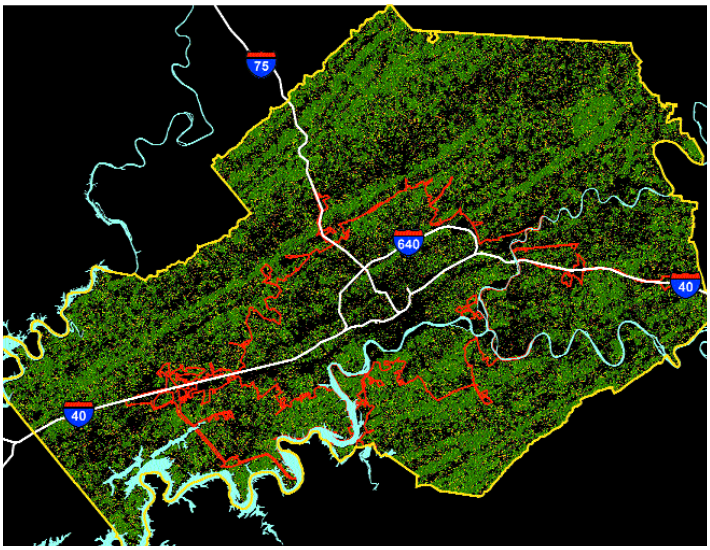


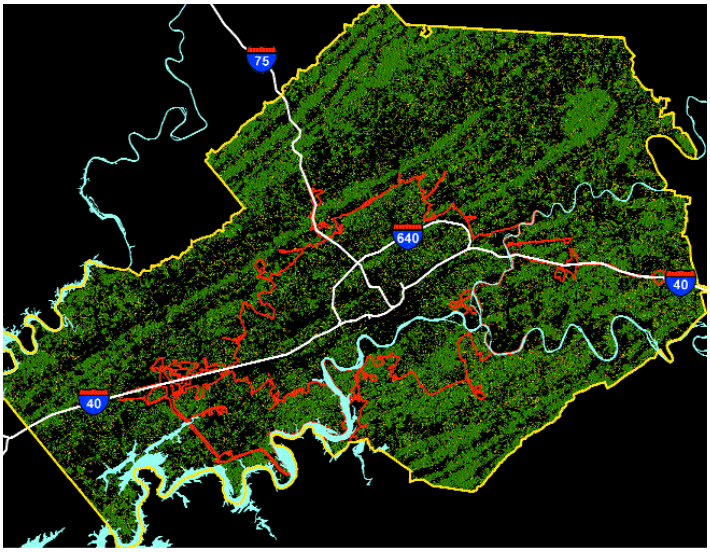
One of the nine sites chosen for local level CITYgreen Analysis. Tree canopy on this 8 acres site is currently 9%. The trees provide over $13,000 in stormwater management benefits and $165 per year in air quality benefits to the site.



Above: A clip of the landcover classification for the Sinking Creek subwatershed. Tree cover in this watershed is currently 50%.
Right: A map of Knox County's 40 subwatersheds (see page 6).

Lessons from Landsat





The classified Landsat images above illustrate tree density Knox County in 1989 (left) and 1999 (right). The City of Knoxville is outlined in red.

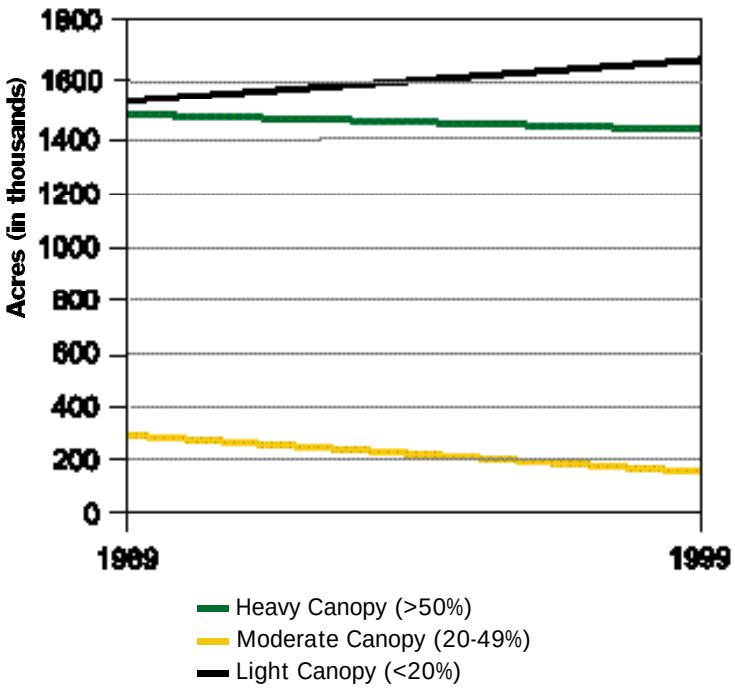
Landsat satellites have been in orbit around the Earth since 1972 and data from them allow us to look at changes in landcover over time. AMERICAN FORESTS classified Landsat TM satellite images to show the change in tree cover for Knox County over a ten-year period. The analysis assessed the loss of tree canopy between 1989 and 1999.

The Landsat images (above) provide valuable public policy information showing general trends in tree loss, but do not provide high-resolution data for local planning and management activities. High-resolution imagery (like that which is used in this study) produces a 4-meter or better resolution (compared to 30 meter with Landsat) and can be used to accurately inventory the tree cover in Knox County (see pages 4-5).

Graphing Change

The change in vegetation depicted in the satellite images above is represented in a line graph on the right. The chart shows the change in vegetative cover over a 10-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 and agricultural 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%.

Vegetation Change
Knox County, TN, 1989-1999



Recommendations

From the Landsat satellite analysis (page 3), it is clear that Knox County has lost trees over the last decade (a 2.2% decline). While this reveals a negative trend, communities need more detailed information in order to incorporate a green data layer into their decision-making. AMERICAN FORESTS' analysis uses high-resolution imagery to do just that. This study provides a detailed assessment of the tree cover and quantifies ecological benefits for Knox County, Knoxville, and the county's 40 subwatersheds. 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.

1. Integrate the green data layer into municipal GIS systems.
- Distribute to local agencies for use in management and development decisions.

2. Use the findings of this study to address public policy issues for land-use planning and growth management.
- Consider the financial value of natural resources during the public policy decision-making process. Urban ecosystems provide concrete financial benefits to municipalities.

- Investment in resource management should capture these benefits.

3. Consider the dollar values associated with trees when making land-use decisions.
- Implement innovative land-use planning techniques and engineering guidelines to save existing trees and plant new ones.

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

4. Use CITYgreen to conduct additional local analyses.
- Use CITYgreen software as a decision support tool to increase community participation.

- Update the local analysis every five years to track future trends in forest canopy and associated benefits.

5. Setting Tree Canopy Goals
- Local communities should set specific tree cover targets for various land use areas. Goals should be established with an understanding of current and future ecological and land use objectives. This stratification of goals is an important part of building a green infrastructure. Though development will continue in Knox County, a balance can be achieved between the natural and the built landscape.

6. Tree Canopy Conservation
- Recognize that tree canopy conservation is a more cost effective method of managing Knox County's green infrastructure than tree canopy replacement. Ten or more newly planted trees may be required to equal a single large mature tree's ecological value.

- Utilize CITYgreen software in conjunction with the data from this study to inform decisions on Knox County's land development process.

- Recognize that trees in urban areas have a more noticeable effect on the ecology of their surroundings than do trees in dense forests. Though both provide valuable ecological benefits, a tree with an impervious understory (i.e. a street tree) will have a greater impact on the total stormwater runoff from a site than will a tree with a dense forest litter understory.

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

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 time sequence analysis, Landsat Satellite TM (30 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. Knox County also has aerial imagery available for use with CITYgreen for site-level analsysis.

Analysis Formulas
A CITYgreen analysis was conducted for each of the 40 subwatersheds within Knox Coutny as well as for the area as whole and for the City of Knoxville. 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.

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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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