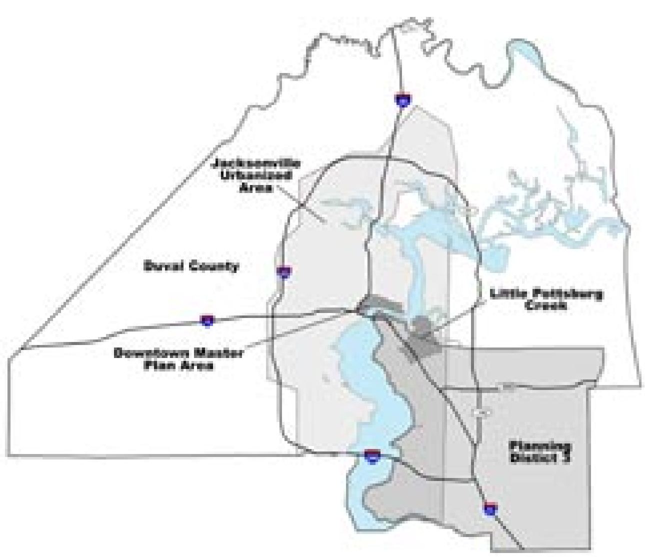
March 2005

Urban Ecosystem Analysis City of Jacksonville, Florida

Calculating the Value of Nature

Report Contents



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Project Overview

American Forests, in conjunction with the state of Florida and City of Jacksonville partners, analyzed the effects of 10 years of changing landcover in the City of Jacksonville, Duval County, Florida. The results demonstrate the ecosystem services that tree canopy provides for improving the City's air and water resources. More importantly, this project provides Jacksonville's decision makers with the capacity to calculate the value of their green infrastructure and apply the findings to their daily management and decision making. By investing in Jacksonville's urban tree cover—this *natural capital* saves money managing air and water, helps meet environmental regulations, and fulfills the City's goals for environmental protection.

The Urban Ecosystem Analysis (UEA) is a process that analyzes the ecology of landcover in two ways. The first assessment measures a decade of landcover change using Landsat satellite imagery. At this moderate resolution, the analysis provided a graphic and measurable snapshot of how growth and development have changed the landscape and its impact on air and water quality and stormwater runoff. This *trend analysis* provides a framework for the City to adopt ecosystem-based public policies and set tree canopy goals to help fulfill their environmental mandates.

The second part of the UEA creates a high resolution digital version of the City's green infrastructure, called a *green data layer*. This data fits seamlessly into the City's Geographic Information System (GIS) and gives the City the ability to use green infrastructure to fulfill the City's environmental goals articulated in the 2010 Comprehensive Plan, Downtown Master Plan, and other planning strategies. This report offers some examples and recommendations of how the City can use the UEA to protect its natural capital and maximize the ecosystem services that their green infrastructure provides.

The Jacksonville UEA covered more than 544,000 acres (849 square miles). Known as the shoreline city, Jacksonville has the largest estuarine system in the state which feeds the St. Johns and Nassau Rivers. The original forest cover has changed with multiple cuttings over hundreds of years. Today the upland forests are predominantly pine plantations with 2% planted in hardwoods. Fifteen percent of the wetlands are mixed forest, which are critical to wildlife habitat. The City's population is projected to increase by 35% between 1990 and 2020, with the majority of growth located south of the St. Johns River.

Along with this growth the City faces many environmental challenges. Prior to city and county consolidation, many homes were built in the floodplain. Urbanization in flat topography and poorly drained soils exacerbates the City's ability to control stormwater runoff and flooding. With increased impervious surfaces, a growing demand for water and a long-term shortage of rainfall, there is a net loss of the Floridian Aquifer available for drinking water. In addition to quantity, the City recognizes stormwater runoff as its most significant surface water quality problem.

In its 2010 Comprehensive Plan (August 2003), the City of Jacksonville has detailed many strategies for improving its air and water. Everything from retrofitting antiquated stormwater systems, acquiring land, regulating buffer zones and setbacks, restoring wetlands, and storing stormwater in developed upland areas. This project brings another best management practice to the mix of structural and environmental strategies—its urban forest.

Conserving and fostering a healthy green infrastructure is far more than an aesthetic choice, it's an environmental and economic one. The 2010 Comprehensive Plan also recognizes the limitations of land acquisition and structural improvements for stormwater detention and flood plain protection in areas that are impractical or too costly. It is also important to maintain green infrastructure for air quality. While the City's air quality currently meets attainment status for ozone under the federal Clean Air Act, it is unclassified for sulphur dioxide. This could be a problem under particular meteorological conditions. Cities that fall into non-attainment status could lose federal funds for roads and highways.

Background

Urban forests provide enormous environmental benefits—among them improving air and water quality and slowing stormwater runoff. Yet, tree canopy in many U.S. metropolitan areas has declined significantly over the last few decades. American Forests has analyzed the tree cover in more than a dozen metropolitan areas and documented changes. Over the last 15 years, naturally forested areas of the country located east of the Mississippi River and in the Pacific Northwest have lost 25% canopy cover while impervious surfaces increased about 20%. All metropolitan areas analyzed needed to increase tree cover. Communities can offset the ecological impact of land development by planting trees—using their natural capacity to clean air and water and slow stormwater runoff.

American Forests developed the Urban Ecosystem Analysis process to:

- Measure tree canopy and quantify changes over time.
- Quantify their ecological benefits.
- Calculate their dollar value.
- Communicate the positive impacts urban ecosystems have on reducing built infrastructure costs, while increasing environmental quality.
- Provide city staff with the tools and technology to incorporate trees and other vegetation— the *green*

infrastructure into land use planning
- Build the capacity of policy makers to plan and manage their cities with green infrastructure to maximize their *natural* capital.

Trees: The Green Infrastructure

The physical framework of a community is called its infrastructure. These utilitarian workhorses of a city can be divided into *green and gray*. Green infrastructure are areas covered with trees, shrubs, and grass; gray infrastructure are areas of buildings, roads, utilities, and parking lots. Green infrastructure is porous, allowing water to soak into soil which naturally filters pollutants before entering rivers. Gray infrastructure is impervious, forcing water to runoff and which must be managed and cleaned before entering rivers.

Unlike gray infrastructure, the functional role of trees as green infrastructure in cities is not adequately documented. Without quantifying its value, trees are not factored into the budget process. The size, shape, and location of a city's green infrastructure can be measured and the public utility functions they perform can be accurately calculated.While both gray and green infrastructure are important in a city, communities that foster green infrastructure wherever possible are more livable, produce fewer pollutants, and are more cost effective to operate. However, balancing the gray with the green can be a serious challenge for a local government manager.

To establish a healthy balance of gray and green infrastructure, communities can now:
- Quantify the presence of green infrastructure and its function for air and water improvement.
- Once quantified, designate green infrastructure as a public utility (just as gray infrastructure is) in the budget process.
- Establish a tree canopy goal or target (see page 9) as part of every development and management project to utilize its functional potential.
- Adopt public policies, regulations, and incentives to increase and protect green infrastructure.

With the advent of geographic information systems (GIS) that most cities currently use, staff can integrate the value of green infrastructure, as well as model the impacts of development scenarios into daily planning and management.

Using Satellite Imagery and GIS to Measure Infrastructure

While municipalities commonly use geographic information systems (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, and 2) the absence of a means to readily use this information in commonly-used GIS systems.

This project addresses both of these impediments. Data documenting the environmental characteristics of trees are now available thanks to data provided by researchers from the U.S. Forest Service, the Natural Resources Conservation Service, the Environmental Protection Agency and Purdue University. This project creates and uses an accurate digital data layer—a *green data layer* that will fit easily within the city's GIS. Those working in planning, urban forestry and on related natural resource issues can now readily utilize this data to integrate green infrastructure into land use planning.

Two types of satellite imagery are useful for determining tree cover in cities. Landsat satellites have been circling the earth since 1972 and therefore can provide a good view of the historic changes that have occurred. In the last few years, new satellites are in orbit and provide high resolution imagery, that show individual trees with 6 foot crowns. Landsat data is best used to understand change trends and to support general public policies. In contrast, high resolution satellite data is used to create a digital representation of a city's green infrastructure. This *green data layer* integrates well with other GIS data layers and is most useful for daily land use planning and management.

This report documents Jacksonville's green infrastructure and its value. More importantly, this project provides the city with the digital data, CITYgreen software and training in its use, and examples of how local leaders can conduct their own Urban Ecosystem Analyses to protect and enhance their natural capital.

Major Findings for Jacksonville

An Urban Ecosystem Analysis of the City of Jacksonville, using Landsat Satellite imagery shows a decline in tree canopy and an increase in developed land over the last 10 years.

- As of 2002, Jacksonville is comprised of 175,686 acres (32.3%) of developed areas (defined by at least 30% impervious surface); 205,320 acres (37.7%) of forested and woody wetlands (trees in standing water 14 more days per year); 59,825 acres (11%) of open space (defined as vegetated areas such as grass, shrub, and cropland, golf courses and playing fields); 55,787 acres (10.3%) of water; 45,817 acres (8.4%) of open wetlands (non-tree vegetation in standing water 14 days or more per year); and 1,210 acres (.2%) of bare soil (non-vegetative land such as fallow fields).

- Between 1992 and 2002, Jacksonville lost 12.4% of its forest and woody wetlands, along with small amounts of wetlands, water, and bare soil acreage. Over that same time period, the City gained 16.4% in its developed urban area and 2% in its open space.

  Developed areas are defined as residential, commercial, industrial, and transportation with 30-100% impervious surface and 0-70% vegetation.

Major Findings (continued)

- Given the development trends, it is estimated that the gain in open space could be attributed to more urban uses such as golf courses, planted grass, and playing fields.

The decline in tree canopy and increase in impervious surfaces in urbanized areas has ecological consequences, particularly in stormwater runoff, air quality and carbon.

- Trees slow stormwater runoff, reducing peak flows and decreasing the amount of stormwater storage needed. Fifty-six million cubic feet of stormwater retention capacity, valued at $113 million was lost over this time period due to tree canopy decline. The total stormwater retention capacity of this urban forest as of 2002 is 928 million cubic feet. Without these trees, the cost of building stormwater retention ponds and other engineered systems to handle the increase in stormwater runoff would be valued at $1.86 billion. Stormwater costs were calculated for a typical 2-year peak storm event and a $2 per cubic foot construction cost for stormwater retention ponds.

Table 1. Landcover Changes Between 1992 and 2002.
30 meter resolution Landsat Imagery

City of Jacksonville Land Cover***	1992 Acres	2002 Acres	% Change of landcover type
Forest/woody wetlands	234,262.4	205,320.0	-12.4%
Open Space	48,692.9	59,825.0	22.9%
Developed Area	150,869.8	175,685.3	16.4%
Open Wetlands	49,745.5	45,816.7	-7.9%
Water	56,772.9	55,787.0	-1.7%

*Landcover was derived from 1992 USGS National Landcover Dataset
**Lancover was derived from 2002 Landsat image
***Total acreage is 544,000. Bare soil landcover is omitted in Table 1.

- In rapidly developing sections of the City, such as in Planning District 3, there are more dramatic changes. An analysis of the land area (St. John's River is removed for this analysis) showed an 18.2% decline in forest and woody wetlands and a 22% increase in developed area. This change resulted in a need to increase stormwater retention by 41 million cubic feet at an estimated construction cost of $ 82 Million (page 6).

- 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) in size. During the ten year time frame of this study, Jacksonville's tree cover lost its ability to remove approximately 2.8 million pounds of air pollutants annually, at a value of $6.8 million per year.

- Trees help clean the air by storing and sequestering carbon in their wood. Total storage and the rate at which carbon is stored (sequestration) can be measured. If the City's trees had not declined since 1992, they would have stored an additional 1.2 million tons of carbon and sequestered an additional 9,696 tons annually.

- In 2002, nine out of ten water quality contaminants would worsen by 4-15% if trees were removed from the land. These percentages are calculated from the stormwater runoff changes.

Table 2. Loss of Ecosystem Services Between 1992 and 2002.
30 meter resolution Landsat Imagery

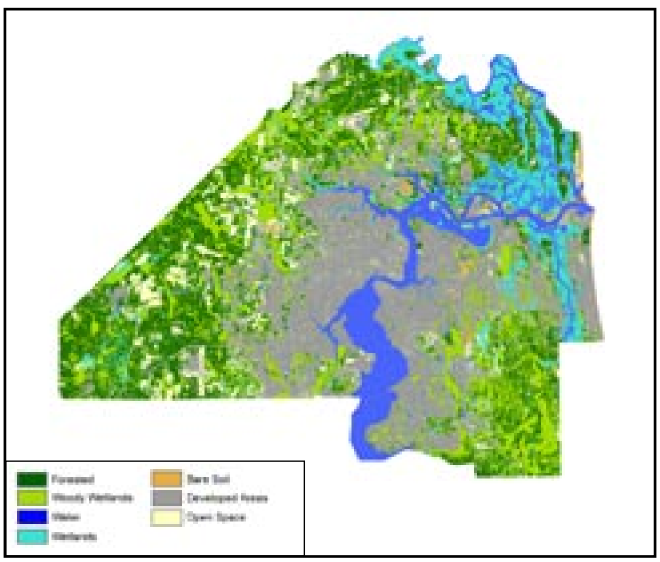
	Forest/ Woody Wetlands (acres)	Stormwater Management Value (cu.ft.)	Stormwater Management Value** ($)	Air Pollution Annual Removal Value (lbs.)	Air Pollution Annual Removal Value ($)	Carbon Stored (tons)	Carbon Sequestered Annually (lbs.)
City of Jacksonville 1992	234,262	984 million	$1.97 billion	22.3 million	$55.4 million	10 million	78,481
City of Jacksonville 2002	205,320	928 million	$1.86 billion	19.6 million	$48.5 million	8.8 million	68,785
Change	-12.4%	-56 million	-113 million	-2.76 million	-6.84 million	-1.2 million	-9,696

* Ecologically, woody wetlands were classified as *water* when calculating stormwater runoff and water quality. Woody wetlands were classified as *trees* when calculating air quality and carbon benefits using CITYgreen software. ** Based on $2/cu. ft. construction costs to mitigate the change in peak flow.

Landcover Change Analysis using Landsat Data

American Forests classified Landsat TM 30 meter pixel satellite images to show the change in landcover in Jacksonville over a 10 year period. Visually, the images show a noticeable decrease in tree canopy in the quickly developing southeast part of the City. Development has increased. Open space has replaced tree canopy in the western side of the county.

Landsat satellite imagery, taken in 1992 and 2002 is classified into different types of landcover such as trees and woody wetlands, open space, urban development, wetlands etc. A comparison of the two years documents how landcover has changed from a greener to a grayer landscape as the City continues to develop. This stratified data is then used to measure the environmental impacts that green infrastructure has on air quality, carbon storage and sequestration, water quality and stormwater runoff.

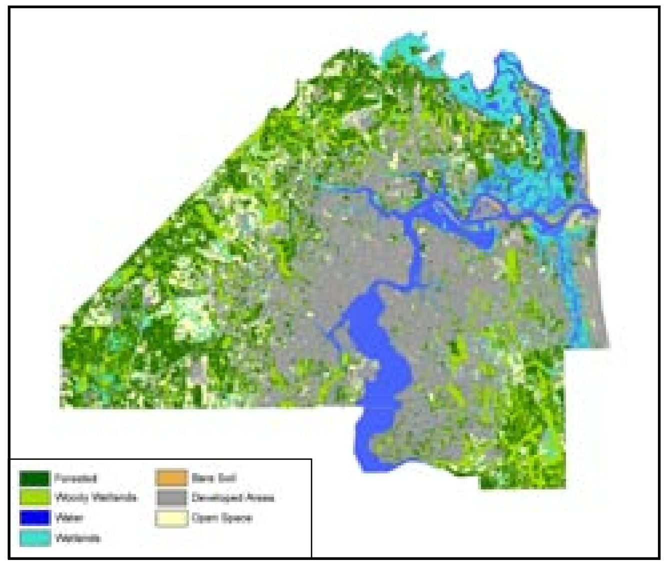


Jacksonville 1992 classified Landsat image

The Landsat images provide valuable public policy information showing general trends in tree loss and increase in impervious surfaces, but do not provide enough detail for local planning and management. High-resolution data, as shown on pages 6-8, produces a close-up view, in which individual trees with a 6 ft. canopy spread can be seen.

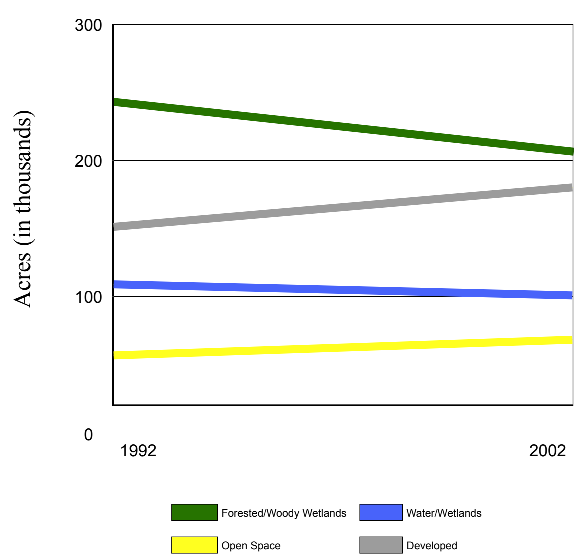
Graphing Change

The change in landcover depicted in the satellite images above is represented in a line graph below. The graph shows the change in landcover over a 10 year period for four categories: forest and woody wetlands, open space, water/wetlands, and developed areas (see definitions on page 2). The woody wetlands category includes trees that are in standing water at least 14 days annually. Ecologically, woody wetlands do not provide stormwater runoff mitigation. However, for purposes of determining air quality and carbon benefit, these woody wetlands areas are reclassified as "trees" when running the air quality module in CITYgreen, since they function ecologically for mitigating air pollutants.



Jacksonville 2002 classified Landsat image

Landcover Change 1992-2002



Jacksonville Urbanized Area Green Data Layer

A 125,000-acre portion of the City inside the beltway was classified using high resolution satellite data and a similar classification process as described for Landsat data. The result is a digital representation of the green infrastructure—called a *green data layer* that fits seamlessly into the City's existing Geographic Information Systems (GIS). Having the ability to use a working model of the City's green infrastructure introduces a new dimension to planning and development discussions, one that considers how to work with the natural environment to minimize building costly infrastructure to manage air and water systems.

The green data layer was created from 2.4 meter Quickbird multi-spectral satellite imagery taken in 2004. This data has a higher resolution than the Landsat and thus provides more detailed information of landcover that can be used in site planning. The image, taken from the urbanized center of the City was classified into six land cover categories. Trees comprise 26% and woody wetlands 6% together make up a 32% tree canopy. Impervious surfaces comprise 27%, Open space 26%, wetlands 4% and water 12%.

Jacksonville's urbanized area contains more canopy cover than most U.S. urban centers. The presence of woody wetlands has helped to protect the overall canopy cover in the City. The percentage of green infrastructure in this older part of the City provides an excellent example with which to mirror in the newer, developing parts of the City.

The green data layer of the Master Plan Districts in Downtown Jacksonville, however tell a different story. The average tree cover in these 10 districts is just 6%; with a high 14% in the South Bank District and a low 1.5% in the Institutional District. Likewise impervious surfaces are quite high averaging 73%. According to the Center for Watershed Protection, at 20% impervious surface, stormwater runoff rate begins to increase significantly.
Even though this area is in the urban core, areas closest to the

Downtown Jacksonville Master Plan District 2004 classified data using high resolution multispectral image.

Table 3. 2004 Ecosystem Services of Trees within the Jacksonville Urbanized Area
High Resolution, Multispectral Imagery

	Acres	Tree and Woody Wetlands 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 (lbs.)
Jacksonville AOI	125,347	32	286,426,744	572,853,488	3,812,407	9,448,337	1,719,983	13,391

* Ecologically, woody wetlands were classified as *water* when calculating stormwater runoff and water quality. Woody wetlands were classified as *trees* when calculating air quality and carbon benefits using CITYgreen software.

**based on $2/cu.ft construction costs to mitigate the change in peak flow

2004 High resolution classified data of urbanized area.

water are the most critical for conveying stormwater runoff and pollutants into waterways. Boosting tree canopy in these critical areas can have an even bigger impact than in other areas of the City.

Though this report provides valuable information regarding the tree cover and its benefits throughout the City, the most important part of this project is the digital data provided to the City for additional analyses as needed for local planning. With the green data layer and CITYgreen software, the City of Jacksonville now has the tools to put green infrastructure in the decision making process. The data produced for this study are flexible enough to be used in almost any way imaginable, along any boundaries—be they political, such as the Master Plan Districts or natural, like Little Pottsburg Creek watershed (see page 6). The results from conducting analyses of these areas are useful to those who work on planning, stormwater management, water quality, wetlands protection, and urban forestry.

Table 4. 2004 Ecosystem Services of Trees by Master Plan District

High Resolution, Multispectral Imagery

Name of District	Acres	Tree and Woody Wetlands 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 (lbs.)
Brooklyn	269	13.3	211,324	422,649	3,410	8,452	1,539	12
Cathedral	127	8.5	51,752	103,504	1,025	2,539	462	4
Church	72	4	29,335	58,670	277	687	125	1
Civil Central Core	157	3.3	64,667	129,335	491	1,217	222	2
Institutional	27.7	1.5	0	0	40	99	18	0
La Villa	173	5.5	68,441	136,882	902	2,236	407	3
River Park	48	6.4	18,307	36,613	297	736	134	1
Riverfront	100	2.4	0	0	216	536	98	1
South Bank	294	14.8	230,414	460,828	4,124	10,220	1,861	14
Stadium	201	3.8	80,767	161,534	731	1,811	330	3

* Ecologically, woody wetlands were classified as *water* when calculating stormwater runoff and water quality. Woody wetlands were classified as *trees* when calculating air quality and carbon benefits using CITYgreen software.

** based on $2/cu.ft construction costs to mitigate the change in peak flow

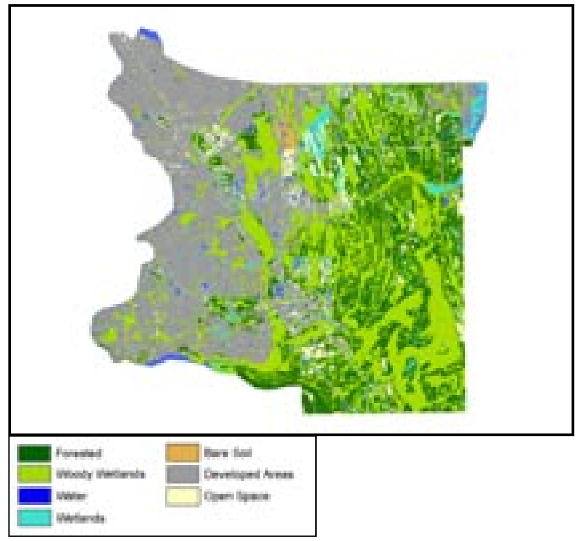
Using a Green Data Layer for Planning

The 2010 Comprehensive Plan details many strategies to improve air and water quality and protect sensitive habitat. The Little Pottsburg Creek Watershed is a good example of using vegetation to restore the ecology of an urban area. Vegetation has been used to stabilize side banks and minimize erosion. The City is also restoring wetlands by buying homes in the 100 yr. floodplain. An Urban Ecosystem Analysis conducted of Little Pottsburg Creek Watershed using the green data layer shows a 36% tree canopy cover and 31% impervious surface. The tree canopy provides ecosystem services valued at $20 million in stormwater management and $229,000 in annual air quality. This area demonstrates a desirable and attainable tree canopy goal (with its associated ecosystem benefits for air and water) that can be modeled in rapidly growing parts of the City to retain ecosystem benefits.

For example, one of the fastest growing parts of the City is in the southeast, along SR 202, between I-95 and the beach. An Urban Ecosystem Analysis, of Southeast Planning District 3 from Landsat data reveals the loss in tree canopy and resulting loss in environmental benefits. For this analysis of land cover, the St. John's River within District 3 was not included.

Even though an analysis using Landsat is too low a resolution for detailed planning, this provides a general change trend of this area. The City can acquire and conduct an Urban Ecosystem Analysis using high resolution data to test development scenarios against achieving the City's ecological goals and pre-determined tree canopy targets for this area.

Southeast Planning District 3 - 1992 Landsat



Southeast Planning District 3 - 2002 Landsat

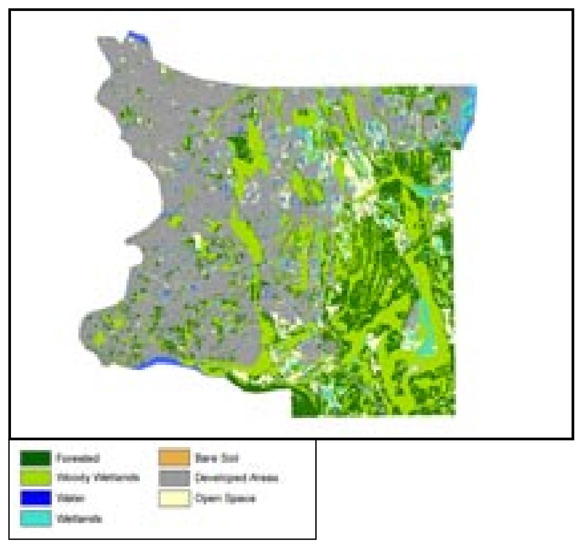


Table 5. Southeast Planning District 3
Loss of Forest Cover and Ecosystem Benefits
30 meter resolution Landsat Imagery

Year of Imagery	Forest and Woody Wet-lands*** (acres)	Forest and Woody Wetlands* % of Total Landcover	Developed Area	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 (lbs.)
Landsat 1992	52,616	53%	34%	159,666,304	319,332,609	5,018,519	12,437,466	2,264,127	17,627
Landsat 2002	43,019	43%	41%	118,955,236	237,910,473	4,103,144	10,168,878	1,851,151	14,412
Change in landcover and ecosystem services	-9,597	-18.2%	22%	-40,786,710	-81,573,420	-923,876	-2,289,657	-416,811	-3,245

* Ecologically, woody wetlands were classified as *water* when calculating stormwater runoff and water quality. Woody wetlands were classified as *trees* when calculating air quality and carbon benefits using CITYgreen software.

** based on $2/cu.ft construction costs to mitigate the change in peak flow

***St. John's River removed for this analysis

Process and Tools for Integrating Green Infrastructure into Jacksonville

Tree canopy is directly related to environmental quality. The economic value of the City's green infrastructure can be measured and quantified. American Forests recommends that the City of Jacksonville use the green data layer and CITYgreen software tools provided with this project to integrate the gray and green infrastructure.

Establish Tree Cover Goals

- Establish an overall tree canopy goal for the City. Establish goals for specific land use categories. Incorporate these goals into planning policies and test achieving them with the Urban Ecosystem Analysis process. Maintain those targets as the City grows and develops over time.

- The City of Jacksonville should use American Forests' canopy goals as a guide, but the City should develop its own goals to meet the needs of their unique community.

    - 40% tree canopy citywide
    - 50% tree canopy in suburban residential
    - 25% tree canopy in urban residential
    - 10-15% tree canopy in the urban core; greater in areas adjacent to rivers.

Process for Setting Tree Canopy Goals

- Designate a planning review committee to set goals. Start with predevelopment canopy cover percentages throughout the City. Determine its current percentage. Test that against what is proposed.

- Stratify tree canopy goals by land use; if canopy is lower in one area, then set standards in other areas to reach the overall citywide canopy goal.

Use the green data layer and CITYgreen to document the ecosystem services in fulfilling Jacksonville's goals to protect environmental quality.

- Obtain high resolution aerial or satellite imagery in other areas of interest in the city and have it classified into land cover categories—creating a green data layer. Conduct an Urban Ecosystem Analysis using CITYgreen software to assess development options.

- Overlay master plan designs onto a green data layer to test whether the designs fulfill Jacksonville's goals to contain stormwater runoff on site and protect natural resources such as wetlands, floodplains, the Floridian Aquifer, and other sensitive land areas.

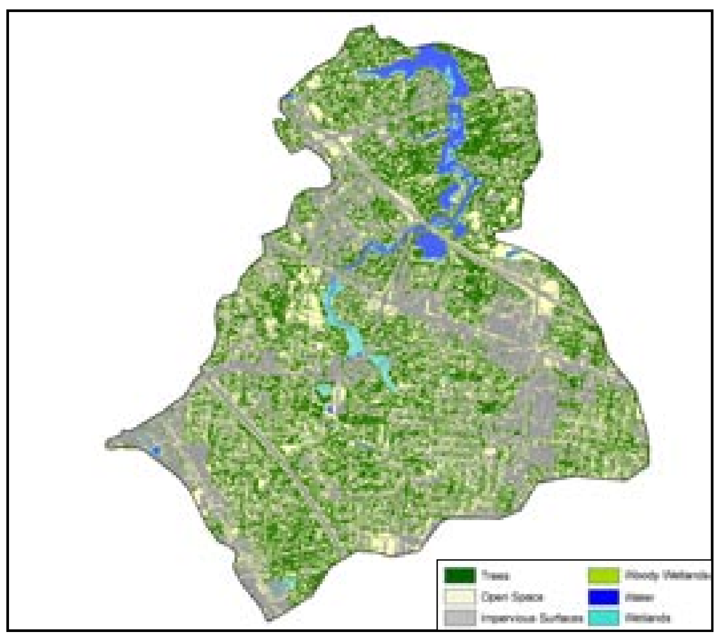
- Use the modeling capabilities of CITYgreen software when looking at future growth, such Jacksonville's rapidly growing southeast section. Test the impacts of changing tree canopy, impervious surfaces, and other land covers under different development scenarios.

- To adhere to the ecological functions of landcover when using CITYgreen software, designate woody wetlands as *water* when calculating stormwater runoff and water quality. Designate woody wetlands as *trees* when calculating air quality and carbon benefits.

Increase public awareness of the direct relationship between environmental quality and tree canopy.

- Use analysis findings in popular media to demonstrate and educate the public about the importance of conserving and enhancing the urban forest.

- Incorporate CITYgreen schools program into Jacksonville's public schools to increase awareness of environmental issues, by teaching practical applications of GIS, math, science and geography. Curriculum is available through American Forests.



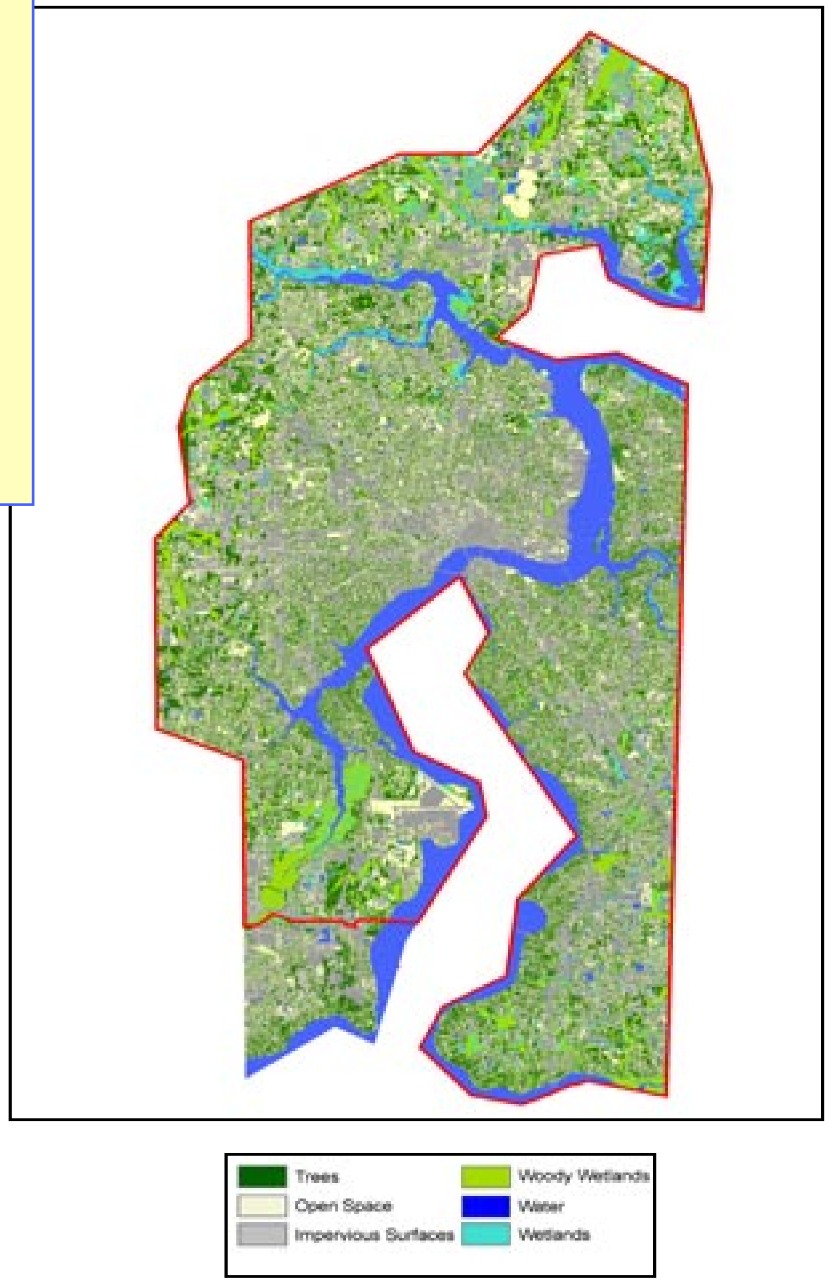
Little Pottsburg Creek Watershed
High resolution classfied imagery

More Than What Meets The Eye

At first glance the images throughout this report appear to be aerial photographs of Jacksonville. They really aren't. These images have been gathered from satellites which have been digitally assembled from large amounts of spatial and spectral data tied to various land characteristics. The images represent far more than the colors seen here; they contain a wealth of data from which tree cover and other land covers discussed in this report and their benefits can be analyzed.

This 125,000-acre area of the City was taken from 2004 high-resolution multispectral imagery, and then classified into different landcovers. The city can use this green data layer, (supplied digitally) along with CITYgreen software, to evaluate the environmental benefits and impacts of various development scenarios and management strategies.

Jacksonville Urbanized Area
High resolution classified imagery



Jacksonville Program Initiatives

The green data layer is a tool City leaders can use to establish tree canopy goals and periodically evaluate how those goals are being met. Reaching those goals is achieved through city initiatives for land conservation and tree planting. Several initiatives to increase tree canopy and improve water quality are already underway:

In May 2001, former Mayor John Delaney announced achieving a five-year community tree challenge of distributing and planting 1,022,199 trees through the Clean It Up, Green It Up flowering tree program. Trees are given to non-profit organizations through the Communi-Tree Program, through a grant for up to twenty-five, 30-gallon container-grown trees for a community project.

The City of Jacksonville's Tree Ordinance, regarded as 'cutting edge' in the state for replacing tree canopy lost to construction. Removal of protected tree species requires that trees be replaced on the site, or if not possible, compensation to the Tree Protection Trust Fund is required. Funds are used to plant trees in public spaces. Non-protected trees saved on site are rewarded mitigation credit.

Begun by former Mayor John Delaney in 1999, the Preservation Project Jacksonville is designed to manage growth, protect environmentally sensitive lands, improve water quality, and provide public access to the City of Jacksonville's vast natural areas. Today the program partners have acquired more than 50,000 acres of preservation parkland and open space that will play a crucial role in diversified urban planning in Duval County and throughout northeast Florida. Now under the guidance of current Mayor John Peyton, the Preservation Project will provide public access to the city's vast natural areas, while continuing to protect the environmentally sensitive lands.

About the Urban Ecosystem Analysis

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 temporal change analysis (page 3), landcover was derived from the 1992 National Land Cover Data. The more recent landcover was derived from three Landsat Images (March 2002, June 2002, and February 2003—referred to as 2002 throughout report) with a 30 meter pixel resolution. American Forests used a knowledge-based classification technique to divide the landcover into eight categories (water, wetlands, trees, woody wetlands, high developed and low developed urban, open space, and bare soil).

To create the green data layer (pages 4-6), 2004 Quickbird, high-resolution (2.4 meter pixel) multispectral imagery was obtained. American Forests used a knowledge-based classification technique to categorize different the land covers as above. The National Wetlands Inventory (NWI) 1992, prepared by the US Fish and Wildlife Service, was used to aid in the classification of wetlands and woody wetland areas.

Analysis Formulas
Urban Ecosystem Analyses using CITYgreen software were conducted for City of Jacksonville in Duval County, urbanized area of City of Jacksonville, downtown Jacksonville master plan districts, Little Pottsburg Creek Watershed, and Planning District 3 (without the St. John's River).

CITYgreen for ArcGIS used the raster data land cover classification from the high-resolution imagery for the analysis. To comply with the ecology of their landcover characteristics, woody wetlands were classified as *water* when calculating stormwater runoff and were classified as *trees* when calculating air quality and carbon benefits.

The following formulas are incorporated into CITYgreen software:

TR-55 for Stormwater Runoff: The stormwater runoff calculations incorporate volume of runoff 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. For greater accuracy, a stormwater analysis was conducted for each Planning District and then values were added together to provide stormwater runoff for the entire city.

L-THIA *for Water Quality:* Using values from the U.S. Environmental Protection Agency (EPA) and Purdue University's Long-Term Hydrological Impact Assessment (L-THIA) spreadsheet water quality model, The Natural Resources Conservation Service (NRCS) developed the CITYgreen water quality model. This model estimates the change in the concentration of the pollutants in runoff during a typical storm event given the change in the land cover from existing trees to a no tree condition. This model estimates the event mean concentrations of nitrogen, phosphorus, suspended solids, zinc, lead, copper, cadmium, chromium, chemical oxygen demand (COD), and biological oxygen demand (BOD). Pollutant values are shown as a percentage of change.

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 55 U.S. 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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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, teacher workshops and technical support for CITYgreen and is a certified ESRI developer and reseller of ArcView and ArcGIS products. For further information contact:

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