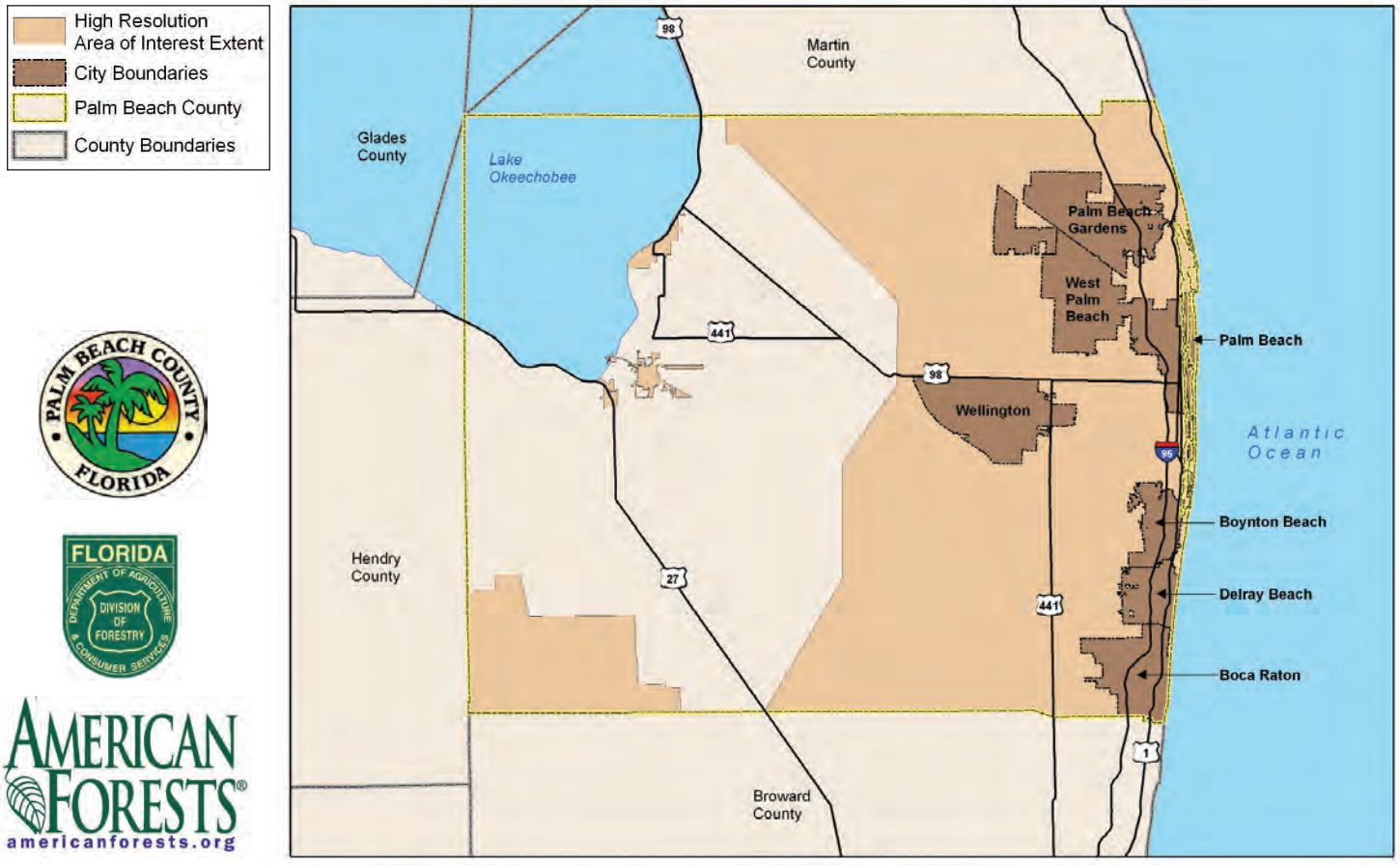
July 2007

Urban Ecosystem Analysis Palm Beach County, Florida

Calculating the Value of Nature

Report Contents



Project Overview

Prompted by a concern over significant tree canopy loss from several hurricanes in recent years, Palm Beach County commissioned a study to determine the extent of the loss and the impacts the loss had on environmental quality. American Forests, in conjunction with Palm Beach County Department of Environmental Resources Management (ERM), and funding from the Federal Emergency Management Agency (FEMA) and the State of Florida Division of Forestry conducted an Urban Ecosystem Analysis of an 1,213 square mile ERM-designated area within Palm Beach County (called the Area of Interest or AOI). The AOI is comprised of Palm Beach County without the Everglades Agricultural Area, which was omitted since this area is void of trees.

The findings show that the loss of vegetative landcover also decreased the air and water benefits the landcover provided. The loss of tree cover from Hurricanes exacerbated the trend of canopy loss due to development as shown in the ten year analysis findings. The findings also show how much more resilient native trees growing in natural areas were compared to non-native species growing in urban areas. This study quantified the landcover changes due to these two events and their ecological impacts. The evidence presented along with the data and tools included in this project will provide Palm Beach County's leaders with the rational and the capacity to better integrate natural systems into future development decisions.

Building resiliency into urban landscape will lessen the devastation in property and in peoples' lives and reduce the costs of cleaning and rebuilding hurricane prone areas. By investing in Palm Beach County's urban tree cover—this *natural capital* also saves money managing air and water, helps meet environmental regulations, and fulfills the County's goals for environmental protection.

The Urban Ecosystem Analysis (UEA) process analyzed the ecology of landcover at two scales, spanning two time periods. The hurricane assessment used high resolution (2.5 meter pixel resolution), digital data to measure changes in landcover between 2004 and 2006, when Hurricanes Jeanne, Frances, and Wilma battered the region. The data resolution was sufficient to visually distinguish between tree canopy loss due to hurricane damage and development.

The second assessment measured landcover changes using moderate resolution (30 meter pixel resolution) from Landsat satellite imagery taken in 1996 and 2006. This analysis provided a ten year trend of tree loss and urban gain, primarily due to development and the impact the landcover changes have had on air and water quality and stormwater runoff. While the resolution of Landsat data is too coarse for analyzing small scale site or neighborhood scale areas, this *temporal analysis* can also be a good predictor of future development trends if current development policies continue.

Palm Beach County Convention and Visitors Bureau.

West Palm Beach, Florida

Data from this project fits seamlessly into the County's Geographic Information System (GIS) and gives Palm Beach County and municipal staff the ability to conduct their own assessments. This will assist with County-wide conservation and restoration programs currently underway. From a broader perspective, the urban ecosystem analysis offers county leaders a way to strengthen the connections between urban and natural systems.

Background

Palm Beach County is part of the Everglades ecosystem which stretches from the numerous lakes in Central Florida south to the Florida Keys. This unique U.S. Ecoregion is characterized by its flooded grasslands and rich wildlife that resides within the county's one-half million acre natural areas. These natural areas are critical for protecting the county's drinking water as well as providing thriving agriculture and tourism industries. The City of West Palm Beach, for example, depends on natural water catchment areas to filter surface water used for drinking.

The County is also subject to annual tropical storms and hurricanes, destroying property and the very green infrastructure that protects its shorelines. Humans have further changed the land with drainage projects, waterway channels, and agriculture practices that have exacerbated flooding to the detriment of people and property.

Urban forests provide enormous environmental benefits—among them improving air and water quality and slowing stormwater runoff. Palm Beach County is indicative of tree canopy decline trends seen in many U.S. metropolitan areas 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 about 25% canopy cover while impervious surfaces increased about 20%. American Forests recommended that all metropolitan areas analyzed increase tree cover. Communities can offset the ecological impact of land development by planting trees and utilize their natural capacity to clean air and water and slow stormwater runoff.

American Forests developed the Urban Ecosystem Analysis so that communities could:

- 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
- Use the GIS-based tools and data provided with this project to incorporate trees and other vegetative landcover— the *green infrastructure* into conservation and land use planning
- Adopt policies that maximize the use of natural systems into urban development, thereby building resiliency into development and natural disasters.

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 types* of landcover. Green infrastructure includes vegetation and their complex interactions with soil, air and water systems. As defined in this project, green infrastructure categories are tree canopy, open space/grass, bare soil, and water. Green infrastructure is porous, allowing water to soak into soil which naturally filters pollutants before entering rivers. Green infrastructure is a natural system that provides many environmental benefits to a community including slowing stormwater runoff, improving water quality, protecting soil from erosion, improving air quality, and storing atmospheric carbon.

Gray infrastructure is impervious, forcing water to runoff and which must be managed and cleaned before entering rivers. Examples of gray infrastructure typically found in urban areas include buildings, roads, utilities, and parking lots. While both gray and green infrastructure are important in a city, communities that foster green infrastructure and integrate natural systems wherever possible are not only more attractive, they produce fewer pollutants and are more cost effective to operate (Building Greener Neighborhoods: Trees as Part of the Plan, HomeBuilder Press; 1995).

Using Satellite Imagery and GIS to Measure Green and Gray Infrastructure

While local governments commonly use geographic information systems (GIS) to map and analyze their gray infrastructure, they typically have not integrated trees and other elements of the green infrastructure. Reasons for this include 1) the lack of means to calculate the ecological and economic value of trees and other environmental features, and 2) the lack of a data set to readily use this information in existing GIS.

This project addresses both of these impediments. Calculating the ecosystem services provided by tree canopy cover is available from data provided by researchers with the U.S. Forest Service, the Natural Resources Conservation Service, the Environmental Protection Agency and Purdue University.

Different types of satellite imagery are useful for determining urban landcover and ecosystem benefits. The hurricane analysis used high resolution, 2.5 meter pixel resolution satellite imagery taken in two years. The 2004 Digital Orthoquad (DOQ) data was provided by the County; the 2006 data was collected from the SPOT 5 satellite. The DOQ data was resampled at a 2.5 meter resolution to match the SPOT data. The imagery at this resolution is used to create a digital representation of a County's green infrastructure. This *green data layer* integrates well with other County GIS data layers and the 2006 data can be used for daily land use planning and management.

The Landsat satellite (30 meter pixel resolution) provided a ten year historic temporal change trend. The imagery collected in 1996 and 2006 was classified into digital data sets with five landcovers for comparison: tree canopy, open space/grass, urban, bare soil, and water.

The data, software tools, and training provided with this project allow the County staff to conduct their own analyses and connect landcover with the environmental benefits they provide.

Major Findings

Dramatic tree canopy loss between 2004 and 2006 indicate Hurricane-related damage

- The analysis compared landcover changes from 2004 and 2006. Tree canopy loss, mostly due to Hurricanes Jeanne, Francis, and Wilma was most dramatic within the non-natural areas. Excluding natural areas, tree canopy in Palm Beach County declined by 38% and while open space/grass and impervious surfaces (from urban growth) increased 20% and 6% respectively. Countywide (including natural areas), there was a 17% decline in tree cover and a 9% and 13% increase in open space/grass and impervious areas respectively.

- The greatest loss of tree canopy was in the southern part of the County. Anecdotally, in the southern part of the County, most of the tree canopy consists of non-native species which, in many situations, were ill-adapted to hurricanes.

- The County-designated natural areas had very little tree canopy decline, especially in the northern part of the County, where much of the canopy is comprised of native slash pines, especially in the natural areas and in the ranchette communities (1-acre and greater residential areas) In contrast these same species, when grown in urban environments, either succumb to hurricanes, or were more likely weakened and became susceptible to pine bark beetle infestation. Because of this, additional tree loss is anticipated in the future.

Vegetation change between 2004 and 2006 has ecological consequences, as measured in stormwater runoff; air and water quality; and carbon storage and sequestration

- There was a loss in the stormwater retention capacity of vegetative landcover, as measured in an additional 146.2 million cubic feet of stormwater that needed to be managed. Without these trees, the cost to manage this increased stormwater runoff is valued at $292.4 million.

- Palm Beach County's vegetative landcover lost its ability to remove approximately 4.7 million pounds of air pollutants annually, valued at $12 million per year.

- The loss in tree canopy equated to a loss in 1.8 million tons of carbon stored in trees' wood and a loss of 14,000 pounds of carbon sequestered annually.

Temporal landcover changes between 1996 and 2006 indicate tree canopy loss due to development

- The analysis using Landsat satellite data revealed a 10% decline in tree canopy and a 21% increase in urban areas during this time period, indicating that these changes were primarily due to development.

- During this time, the County lost 20,452 acres of forested land and gained 23,351 acres of urban land.

In the natural areas managed by ERM, the landcover changes between 1996 and 2006 were much less than in the County overall

- Of the 30,000 acres of natural areas managed by ERM, the analysis revealed changes in two land cover classes: a 3% decline in tree canopy (430 acres lost) and a 9% increase in urban areas (33 acres gained) during this time period.

- The loss of tree canopy in ERM managed natural areas could reflect the County's aggressive removal of invasive non-native tree species in areas that changed from tree canopy to either open space/grass or bare soil.

- Landcover changes from forested to urban were most apparent just outside of the natural areas' boundaries.

Between 1996 and 2006, the decline trend of Palm Beach County's vegetative cover and increase in urban areas has ecological consequences for today and by extension, for the future

- Trees slow stormwater runoff, reducing peak flows and decreasing the amount of stormwater storage needed. There was a loss of 157 million cubic feet of stormwater retention capacity, valued at $316 million during this time period due to tree canopy decline. Stormwater costs were calculated for a typical 2-year peak storm event and a $2 per cubic foot construction cost for stormwater retention ponds.

- Trees improve air quality by removing nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3) and particulate matter 10 microns or less (PM10) in size. During the ten year time frame of this study, Palm Beach County's tree cover lost its ability to remove approximately 2.3 million pounds of air pollutants annually, valued at $5.8 million per year.

- Trees have a direct impact on the carbon footprint. Trees help clean the air by storing and sequestering carbon in their wood. Total storage and the rate at which carbon is stored (known as sequestration) can be measured. The loss in tree canopy since 1996, equates to a loss in 880,000 tons of carbon stored in trees' wood and a loss of 6,852 pounds of carbon sequestered annually.

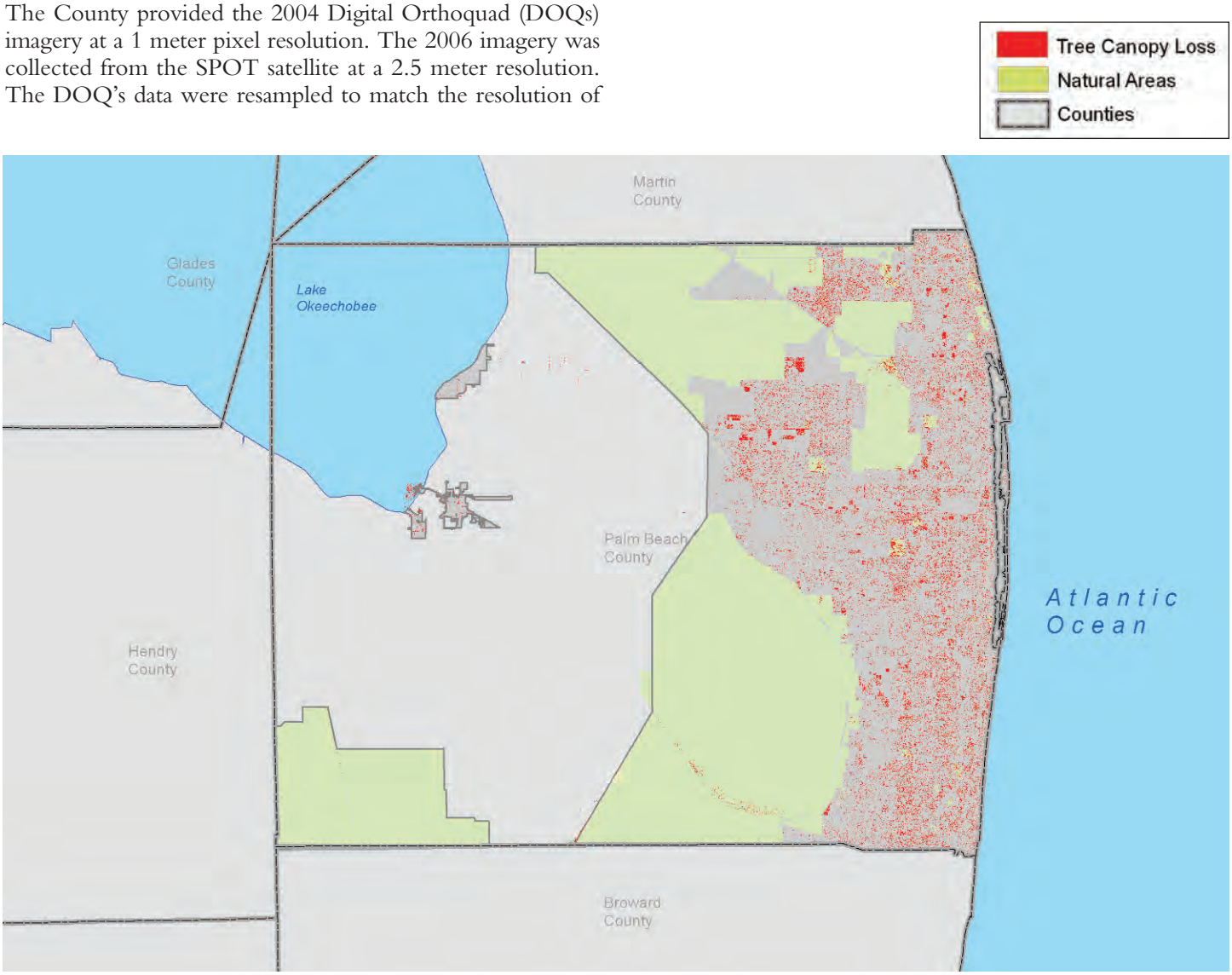
- Tree roots absorb water pollutants; eight of which can be measured: Biological Oxygen Demand, Cadmium, Copper, Lead, Nitrogen, Phosphorus, Suspended Solids, and Zinc. Of these, each would worsen by between 1-4% if trees were removed from the land (see contaminant loading bar graph on page 12). These percentages are calculated from the stormwater runoff changes.

Hurricane Landcover Analysis

After Hurricanes Francis and Jeanne battered the region in September 2004 and Hurricane Wilma in October 2005, Palm Beach County commissioned a study to determine the extent of the vegetation loss. In addition, the County wanted to quantify the environmental impacts the loss had on air and water quality. The County received funding from the Federal Emergency Management Agency (FEMA), administered through a Florida Division of Forestry grant, to conduct an Urban Ecosystem Analysis. This analysis revealed that tree loss during this time was primarily due to the hurricanes instead of urban development. The analysis also revealed the extent to which tree species and site conditions affected tree loss.

The County provided the 2004 Digital Orthoquad (DOQs) imagery at a 1 meter pixel resolution. The 2006 imagery was collected from the SPOT satellite at a 2.5 meter resolution. The DOQ's data were resampled to match the resolution of the SPOT for comparison. Both sets of imagery were then classified into five landcovers: tree canopy, impervious, open space/grass, bare soil, and water.

Wetlands comprise 44% of the total landcover in Palm Beach County. In order to determine the ecosystem services for mitigating stormwater runoff provided by other landcover, all landcover designated as "wetlands" or water were removed. The most recent wetlands data were provided by the South Florida Water Management District from 1999. The economic value used to calculate the ecosystem services of tree canopy to mitigate stormwater runoff is based on a $2/cu.ft construction cost to contain the additional stormwater runoff.



County designated "natural areas" are primarily comprised of native plant species growing in undisturbed or rehabilitated sites that are more resilient to hurricanes and other natural disasters. Tree canopy loss between 2004 and 2006 occurred primarily in urban areas where trees are subject to drought, over irrigation, fertilizer and compaction.

A visual inspection of the high resolution imagery, where changes in land use are apparent, can reveal the cause of tree canopy loss from either hurricane or development.

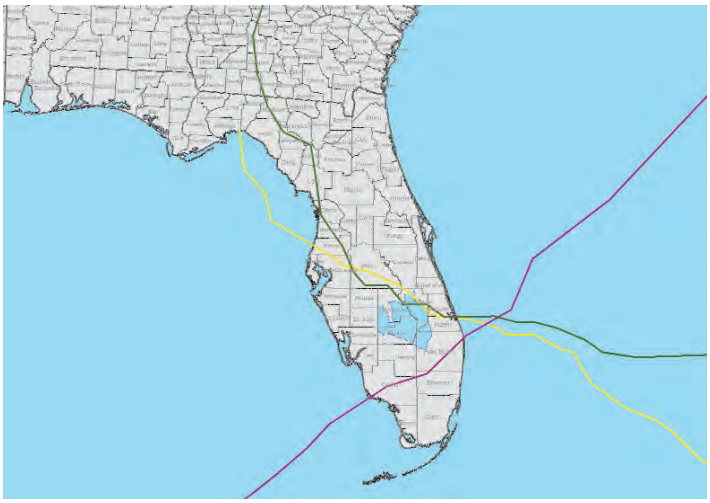
In the 2004 image (left), a stand of trees on a golf course is readily apparent. In the image taken in 2006 (right) the trees are gone.

In the 2004 image taken (left), there is a dense tree canopy in this neighborhood. In 2006 (right), the trees were replaced by homes.

Between 2004 and 2006, Palm Beach County experienced three major hurricanes and a 17% loss in tree canopy, a 9% increase in open space and a 6% increase in impervious surfaces.

Hurricane Paths

	Landfall Date	Windspeed
Frances	9/05/2004	120mph
Jeanne	9/26/2004	105mph
Wilma	10/24/2005	120mph



Tree Canopy Loss
Cities
Palm Beach County Area of Interest
Counties

Martin County
Glades County
Lake Okeechobee
Hendry County
Palm Beach County
Broward County
Atlantic Ocean
Hurricane Wilma Path
10/24/2005 11 AM
Wind Speed : 103 mph
10/24/2005 9 AM
Wind Speed : 110 mph
Tequesta
Jupiter Inlet Colony
Jupiter
Juno Beach
Palm Beach Gardens
North Palm Beach
Lake Park
Riviera Beach
Palm Beach Shores
Magonia Park
West Palm Beach
Royal Palm Beach
Loxahatchee Groves
Haverhill
Palm Beach
Glen Ridge
Lake Clarke Shores
Palm Springs
Wellington
Greenacres
Lake Worth
Atlantis
South Palm Beach
Lantana
Hypoluxo
Manalapan
Boynton Beach
Ocean Ridge
Golf
Briny Breezes
Gulf Stream
Delray Beach
Highland Beach
Boca Raton
Pahokee
Belle Glade
South Bay

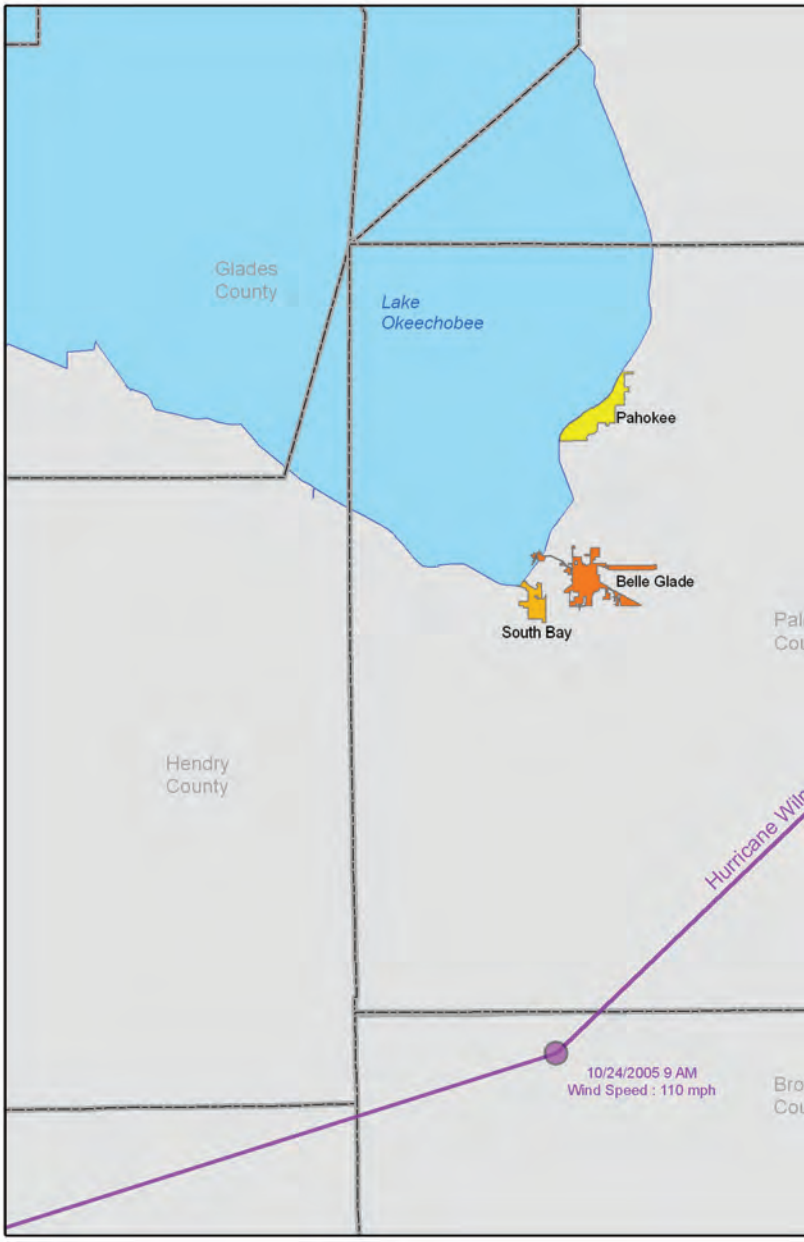
Landcover Change in Non-natural Areas

The most dramatic hurricane damage occurred in the Non-natural areas of the County. In these urban areas there was a 38% loss in tree canopy and a 20% and 6% increase in open space and impervious surface respectively. The loss means that 4.5 million pounds of air pollutants valued at 11.4 million annually were not removed. Also, there was a loss in carbon storage of 1.7 million tons and 13,000 fewer pounds of carbon are stored annually.

This digital GIS landcover map will help planners prioritize their reforestation efforts and tree give-away programs, and aid in determining best species selection for future planting. For example, Hurricane Jeanne affected the more northern part of the county, since it touched down in Martin County to the north. According to ERM staff, many sand pine trees toppled outright during the storm. Slash pines, for the most part, resisted the initial path of the damage. However, for most of the slash pines that grew outside of the natural areas, the hurricanes, along with other environmental conditions (drought, over irrigation, fertilizer, compaction, etc.), stressed them considerably. These stressed slash pines are now experiencing a massive die-off in the County due to subsequent bark beetle infestations which hasten the death of the pines.

In contrast, Hurricane Wilma went straight through Palm Beach County. This time the densely populated southern part of the County was most affected. Due to the larger number of non-native trees in the southern part of the County, many were ill-adapted to hurricane conditions. Researchers with the University of Florida Institute of Food & Agricultural Sciences have conducted surveys of trees damaged by hurricanes since 1992. Their recommendations show that for the most part native trees species, along with proper tree placement and proper tree care and maintenance, are better adapted at withstanding hurricane winds. Poor planting practices, soils conditions, and species selection contribute to urban tree failure. Their publication, "Assessing Damage and Restoring Trees After a Hurricane" contains a list of their recommended tree species. The publication can be downloaded at http://edis.ifas.ufl.edu/pdffiles/EP/EP29100.pdf.

The analysis findings substantiate observational conclusions that the southern part of the county sustained more hurricane damage than in the north, even though Hurricane Wilma passed through northern cities such as West Palm Beach. Native slash pine and oaks, growing mostly in the northern part of the County, withstood the hurricanes very well. In contrast, non-native species planted primarily in the south sustained more tree canopy loss. In addition, trees growing in County designated natural areas, which had better growing conditions, also fared much better than trees growing in urban conditions.



Hurricanes Frances, Jeanne, and Wilma demonstrated that most of the tree loss occurred in cities where the majority of trees are non-native. Trees growing in natural areas—with a combination of native species and undisturbed soils were more resilient to hurricanes.

Countywide Landcover Changes

A Countywide comparison of landcover within the Area of Interest (AOI) from 2004 and 2006 shows that tree canopy decreased by 42,000 acres (17%) while open space/grass increased by 33,000 acres (9%) as shown in Table 1. This change from tree canopy cover to open space/grass, suggests that hurricanes caused the change—knocking down trees and leaving the grassland understory. Impervious areas also increased by 6%, suggesting that these changes were most likely due to urban development. This can be seen in examples of landcover change that distinguish tree canopy loss due to hurricane damage from development on page 6.

The loss of tree canopy increased stormwater runoff. The County has an additional 146 million cubic feet of stormwater, valued at $292 million that must be managed. Air quality also declined with the loss of vegetative cover: without this landcover, the analysis calculated that there are 4.7 million more pollutants, valued at $11.9 million annually (Table 2). Water pollution, as measured in percent change in pollutant loading, increased as well (see Contaminant Loadings Bar Graph on page 10).

Table 1. Palm Beach County 2004-2006 Landcover Changes*

Landcover	2004 (Acres)	2006 (Acres)	2006 Percentage	Change
Trees	249,741	207,811	27%	-17%
Open space/grass	383,024	416,086	54%	9%
Bare Soil	7,922	6,890	1%	-13%
Urban	92,454	98,209	13%	6%
Water	37,910	42,046	5%	11%
Total Acres	771,048			

* Data from 2004 DOQ's imagery resampled to 2.5meter pixel resolution and 2006 SPOT imagery at 2.5 meter pixel resolution.

Table 2. Palm Beach County 2004-2006 Loss of Ecosystem Service*

Landcover Changes*	Acres	Stormwater Management add'l storage	Stormwater Management Value based on change**	Air Pollution Annual Removal ***	Air Pollution Annual Removal Value Change ($)	Carbon Stored Change	Carbon Sequestered Annually Change (lbs.)
Palm Beach Co.	771,082	146.2 million	$292.4 million	-4.7 million	-$12 million	-1.8 million	-14,047
Non-natural areas	389,476	123.5 million	$247 million	-4.5 million	-11.4 million	-1.7 million	-13,426
Natural areas	382,225	0	$0	-199,035	-$502,586	-75,654	-589
Natural areas managed by ERM	30,215	0	$0	-76,487	-$193,137	-29,073	-226

*Data from 2004 DOQ's imagery resampled to 2.5meter pixel resolution and 2006 SPOT imagery at 2.5 meter pixel resolution.

**Wetlands comprise 44% of the total landcover in Palm Beach County. For purposes of this stormwater analysis, all landcover designated as "wetlands" and open water were removed to demonstrate the ability of other landcovers to provide stormwater runoff management and water quality ecosystem services. The most recent wetlands data was provided by the South Florida Water Management District from 1999. The value is based on $2/cu.ft construction costs to contain the extra stormwater runoff.

Landcover in natural areas showed little change, demonstrating that native species growing in natural areas are better adapted to hurricane conditions.

***Wetlands were included when calculating air quality and carbon benefits using CITYgreen software.

ERM staff can use the digital green infrastructure data created for this analysis as a baseline for measuring their urban forestry restoration efforts. From a planning perspective, the 2006 green data layer provides the foundation for County and City Planners to make future development decisions utilizing green infrastructure (Table 3).

The County can also use these findings in public education programs to extol the tangible benefits of urban forests. Quantifiable data are especially important in disaster-prone areas. Citizens are often fearful of replanting trees, believing them to be more of a hazard than of benefit in hurricane zones. When benefit data is combined with information about the best species and planting locations for hurricane-prone areas, citizens are more apt to support reforestation efforts in their communities.

Percent Change in Pollutant Loading from 2004 to 2006 due to Landcover Change

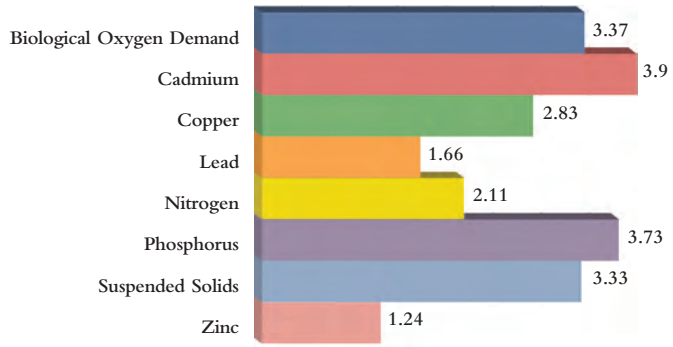


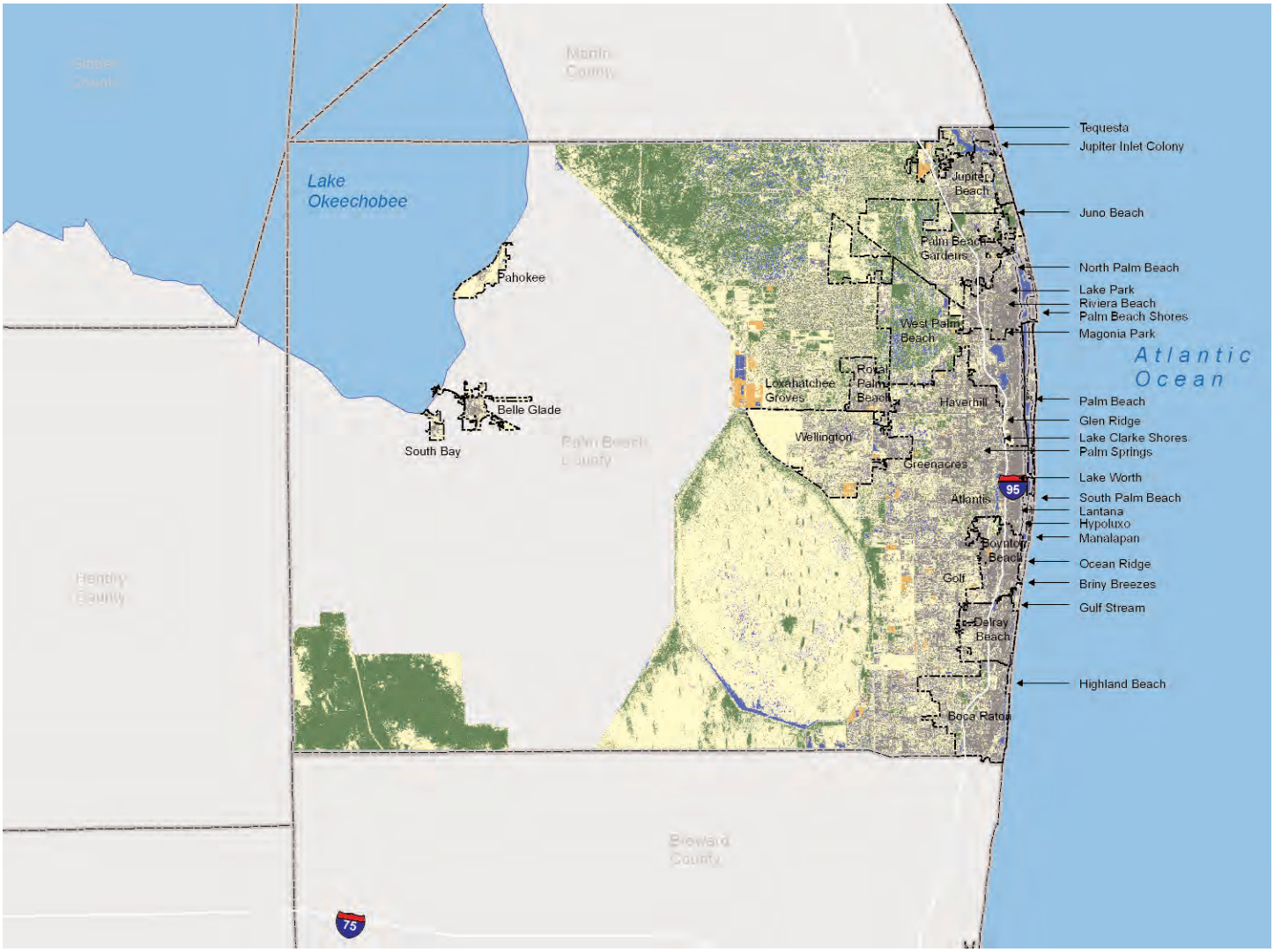
Table 3. Loss of Ecosystem Services Listed by City, 2004-2006

Name of City	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)
Atlantis, FL	894	95 (-59%)	54,987	$109,973	-15,535	-$39,227	-5,905	-46
Belle Glade, FL	3,495	211 (-31%)	31,265	$62,530	-10,552	-$26,644	-4,011	-31
Boca Raton, FL	19,019	2,267 (-56%)	3,509,261	$7,018,522	-322,095	-$813,326	-122,430	-953
Boynton Beach, FL	10,488	878 (-60%)	2,495,846	$4,991,692	-149,578	-$377,700	-56,855	-443
Briny Breezes, FL	46	1 (-76%)	97	$194	-213	-$539	-81	-1
Cloud Lake, FL	36	8 (-60%)	24,783	$49,566	-1,401	-$3,538	-533	-4
Delray Beach, FL	10,305	786 (-66%)	3,853,979	$7,707,959	-171,034	-$431,880	-65,011	-506
Glen Ridge, FL	100	24(-55%)	39,297	$78,593	-3,443	-$8,695	-1,309	-10
Golf, FL	511	92 (-54%)	193,221	$386,441	-12,479	-$31,511	-4,743	-37
Greenacres, FL	3,515	315 (-63%)	1,349,169	$2,698,338	-59,413	-$150,024	-22,583	-176
Gulf Stream, FL	527	87 (-56%)	38,891	$77,782	-12,808	-$32,341	-4,868	-38
Haverhill, FL	367	86 (-45%)	19,163	$38,326	-8,046	-$20,318	-3,058	-24
Highland Beach, FL	403	49 (-59%)	9,105	$18,211	-8,062	-$20,359	-3,065	-24
Hypoluxo, FL	514	44 (-60%)	149,590	$299,181	-7,463	-$18,845	-2,837	-22
Juno Beach, FL	1,310	566(-14%)	108,428	$216,857	-10,727	-$27,086	-4,077	-32
Jupiter Beach, FL	14,592	2,385 (-42%)	4,883,312	$9,766,623	-197,044	-$497,558	-74,898	-583
Jupiter Inlet Colony, FL	112	3 (-86%)	35,131	$70,263	-2,283	-$5,765	-868	-7
Lake Clarke Shores, FL	658	52 (-67%)	22,343	$44,686	-11,971	-$30,229	-4,550	-35
Lake Park, FL	1,600	83 (-69)	546,019	$1,092,038	-21,144	-$53,390	-8,037	-63
Lake Worth, FL	4,320	171 (-70%)	1,498,839	$2,997,678	-44,485	-$112,328	-16,909	-132
Lantana, FL	1,779	89 (-65%)	23,493	$460,986	-19,015	-$48,015	-7,228	-56
Loxahatchee Groves, FL	7,893	2,977 (-24%)	1,080,234	$2,160,467	-104,499	-$263,873	-39,721	-309
Manalapan, FL	660	32 (-57%)	20,552	$41,104	-4,915	-$12,412	-1,868	-15
Mangonia Park, FL	473	41 (-49%)	78,827	$157,654	-4,569	-$11,537	-1,737	-14
North Palm Beach, FL	3,340	341 (-51%)	781,975	$1,563,949	-40,424	-$102,074	-15,365	-120
Ocean Ridge, FL	614	84 (-44%)	23,809	$47,618	-7,589	-$19,164	2,885	-22
Pahokee, FL	3,122	400 (-9%)	-43,244	-$86,488	-4,475	$11,301	-1,701	-13
Palm Beach, FL	4,827	238 (-60%)	226,118	$452,236	-40,246	-$101,625	-15,298	-119
Palm Beach Gardens, FL	35,806	11,461 (-15%)	2,617,077	$5,234,153	-233,350	-$589,235	-88,698	-691
Palm Beach Shores, FL	265	5 (-73%)	3,666	$7,333	-1,518	-$3,832	-577	-4
Palm Springs, FL	1,926	147 (-64%)	465,067	$930,134	-29,844	-$75,360	-11,344	-88
Riviera Beach, FL	6,129	266 (-66%)	2,122,104	$4,244,207	-50,482	-$127,472	-19,188	-149
Royal Palm Beach, FL	7,091	1059 (-32%)	1,005,018	$2,010,036	-56,668	-$143,093	-21,540	-168
South Bay, Fl	1,228	200 (-29%)	434,739	$869,478	-9,095	-$22,966	-3,457	-27
South Palm Beach, FL	66	1 (-69%)	23,468	$46,935	-379	-$958	-144	-1
Tequesta, FL	1,387	109 (59%)	439,177	$878,355	-17,781	-$44,900	-6,759	-53
Wellington, FL	28,824	3097 (-32%)	9,567,967	$19,135,935	-165,286	-$417,366	-62,826	-489
West Palm Beach, FL	37,059	10427 (-17%)	3,285,185	$6,570,370	-237,950	-$600,850	-90,446	-704
Natural Areas	382,225	143,674 (-1%)	1,077,032	$2,154,065	-199,035	-$502,586	-75,654	-589
Natural Areas ERM	30,215	12,276 (-5%)	263,040	$526,080	-76,487	-$193,137	-29,073	-226

*The stormwater calculations are based on curve number index (ranging from 30-100) developed by the Natural Resources Conservation Service to represent the potential for stormwater runoff within a drainage area. The higher the curve number the more runoff will occur. The change in curve number reflects the increase in the volume of stormwater runoff.

**Wetlands comprise 44% of the total landcover in Palm Beach County. For purposes of this stormwater analysis, all landcover designated as "wetlands" and open water were removed to demonstrate the ability of other landcovers to provide stormwater runoff management and water quality ecosystem services. The most recent wetlands data was provided by the South Florida Water Management District from 1999. The value is based on $2/cu.ft construction costs to contain the extra stormwater runoff.

***Wetlands were included when calculating air quality and carbon benefits using CITYgreen software.



2006 Landsat (30 meter pixel resolution) image of Palm Beach County designated by landcover type. An analysis comparison to the 1996 Landsat image revealed a 10% loss in tree canopy and a 21% increase in urban areas. There was no change in open space during this time. Table 5 details the loss of ecosystem services as a result of these landcover changes.

Temporal Landcover Change Analysis using Landsat Data

American Forests classified Landsat TM 30 meter pixel satellite images from 1996 and 2006 to show the change in landcover in Palm Beach County over a 10 year period. At this scale, visual differences are hard to distinguish but changes in acreage can be measured (see Table 4).

Landsat satellite imagery was classified into five landcover types: trees, open space/grass, urban development, bare soil, and water. This stratified data was then used to measure the environmental impacts that green infrastructure has on air quality, carbon storage and sequestration, water quality and stormwater runoff.

The temporal analysis provides valuable public policy information showing general trends in vegetative loss and increase in urban areas. If land development policies and population increase trends remain unchanged, the trend could be extrapolated into the future.

Table 4. Palm Beach County Landcover Changes between 1996 and 2006*

Landcover	1996 (Acres)	2006 (Acres)	Change
Trees	204,366	183,914	-10%
Open space/grass	412,305	412,132	0%
Bare Soil	8,613	5,865	-32%
Urban	111,522	134,873	21%
Water	34,265	34,369	0%
Total Acres	771,082		

*Landcover data was calculated from 30 meter pixel resolution Landsat imagery, collected in March of 1996 and 2006.

Water Quality (Contaminant Loading)

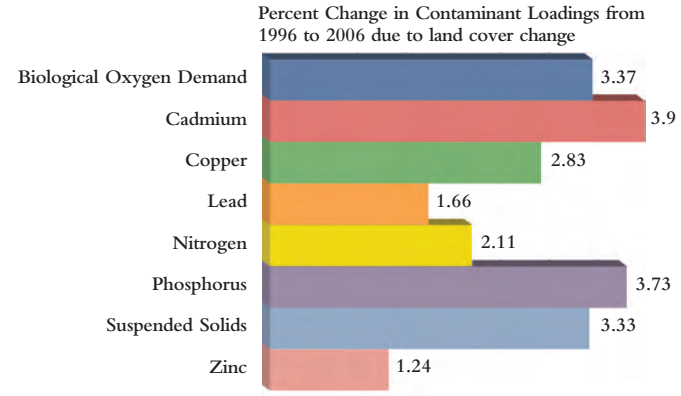


Table 5. Palm Beach County Loss of Ecosystem Services Between 1996 and 2006

Landcover Changes	Acres	Stormwater Management* curve number and add'l storage volume generated (cu.ft.)	Stormwater Management Value Change** ($)	Air Pollution Annual Removal Value Change (lbs.)***	Air Pollution Annual Removal Value Change ($)	Carbon Stored Change (tons)	Carbon Sequestered Annually Change (lbs.)
Palm Beach Co.	771,082	157,754,126	$315.5 million	-2,315,372	-$5.8 million	-880,000	-6,800
Natural areas	382,145	0	$0	-330,648	$-835,000	-125,681	-978
Natural areas managed by ERM	30,157	0	$0	-48,702	$-123,000	-18,500	-144

*The stormwater calculations are based on curve number index (ranging from 30-100) developed by the Natural Resources Conservation Service to represent the potential for stormwater runoff within a drainage area. The higher the curve number the more runoff will occur. The change in curve number reflects the increase in the volume of stormwater runoff.

**Wetlands comprise 44% of the total landcover in Palm Beach County. For purposes of this stormwater analysis, all landcover designated as "wetlands" and open water were removed to demonstrate the ability of other landcovers to provide stormwater runoff management and water quality ecosystem services. The most recent wetlands data was provided by the South Florida Water Management District from 1999. The value is based on $2/cu.ft construction costs to contain the extra stormwater runoff.

***Wetlands were included when calculating air quality and carbon benefits using CITYgreen software.

Taking a Natural Systems Approach for Future Planning

The environment is a seamless, interactive system that wraps the Earth embracing continents, regions, and local jurisdictions like Palm Beach County. This project has articulated Palm Beach County's green infrastructure--its landcover and corresponding ecosystem services-- into a GIS interactive data layer and digital map with which County leaders can make conservation and development decisions. But all too often it is very difficult to balance conservation with development.

Amazingly, even people who acknowledge the environment as a natural system have never truly integrated the environment as a system into other urban systems like transportation or commerce. Business has seen the environment as a resource. Government has tried to create legal frameworks to manage its use. The activist community has tried to protect it. Because of their conflicting goals—development versus conservation—businesses and activists have approached environmental problems from opposite directions. Governmental actions have ranged widely, depending on the political climate, from laissez-faire to inflexible regulation. The outcome is a piecemeal, ad hoc, and inconsistent policy.

The Palm Beach County community is in a position to bring these pieces together using a systems approach to enhance the value of the community—for both development and conservation. Recognizing the regional importance of its place in the Everglades Ecoregion, the County has preserved an extensive part of its natural environment. However, this desirable county also has growth pressures.

This project not only delivers information for developing future policies, but more importantly contains the data and tools that can be used by County staff already working on mandates set in the Comprehensive Plan for protecting and conserving natural resources of the County. The urban ecosystem analysis provides the tools to develop an innovative framework for connecting the natural systems to the urban infrastructure in the future. Weaving natural systems and

human infrastructure together into a healthy network ensures plans for a sustainable community for the future.

Palm Beach County's Comprehensive Plan addresses several conservation issues including: wetlands and conservation areas, air quality, water quality and quantity, estuarine systems, lakes, rivers, native vegetation, and wildlife habitat. There are three major areas where the County can use the urban ecosystem analysis process, green data layer and software tools in their existing policies and programs:

1. Planning for Development

Palm Beach County Department of Environmental Resources Management (ERM) is responsible for a majority of the codes and programs that protect and conserve natural resources of the county.

Through the County's Natural Areas Program more than 30,000 acres of natural areas have been purchased through County-issued bonds. Now that most of the large tracts have been acquired, the Palm Beach County staff has now shifted its task to link these areas together and augment them. Their priorities are now to reforest adjacent lands, plant riparian buffers, and create trails for wildlife and recreation.

As part of the County's invasive vegetation removal programs, the Board of County Commissioners also approved the creation of a Tree Canopy Replacement program, which is currently under development. The County takes a holistic approach with regard to preserving and replacing tree canopy and environmentally sensitive natural areas.

Through the County's role in development regulation and permitting, the County is able to mitigate the losses due to development activities. ERM has an active program in restoring and creating shoreline habitats, as well as mangrove systems. In unincorporated areas of the County, ERM mandates that lots cleared for development must revegetate and in some cases set aside areas as preserves. In addition, the County Planning, Zoning and Building Department regulates new development landscaping by requiring a specific number of trees be planted, including a percentage of which must be native.

2. Restoring Green Infrastructure for Water Quality

Improving and restoring water quality is critical to the region's vitality and economic well-being. Since trees slow down stormwater runoff and filter pollutants, they significantly contribute to water quality. The County has acquired large tracts of natural vegetation to safeguard this resource. County planners and managers have also targeted specific areas for restoration, increasing tree canopy cover as a best management practice. Examples include:

- Using vegetation to filter agricultural and equestrian-generated phosphorus out of the water in popular horse communities like the Town of Wellington.
- Adding trees to ranchettes, 1-1/4 acre residential lots that contribute to sprawl development.
- Restoring historic mangrove reef areas along the beaches (97% have been destroyed).
- Replanting hurricane-damaged slash pine trees. Due to the stress caused by the hurricanes along with poor landscaping practices typically found in urban, suburban and ranchette environments, the slash pines have come under a pine bark beetle infestation which is hastening the death of the pines. In contrast, slash pine trees growing in healthy, natural areas are well-adapted to their environment and have thrived. ERM will couple a tree giveaway program with an education program to teach homeowners how to make their properties habitable for slash pine.

In addition to the County's restoration efforts, the South Florida Water Management District (SFWMD) has designated hundreds of thousands of acres of land as Stormwater Treatment Areas (STA's). For example, the SFWMD constructed a several thousand acre STA north of the 147,000-acre Loxahatchee National Wildlife Refuge in order to filter pollutants before they enter the Refuge.

3. Addressing Regional Issues

While land planning is primarily done at the municipal level, regional-scale planning can best address ecosystem issues such as water and air quality, even when the coordination can be challenging, as it is in Palm Beach County which has 38 municipalities. Palm Beach County works with the South Florida Water Management District, the Florida Fish and Wildlife Commission, Florida Department of Environmental Protection, U.S. Army Corp of Engineers, the Treasure Coast Regional Planning Council, local municipalities and surrounding counties and numerous other local, state and federal on shared land management issues.

The classified land cover data and analysis tools provided to Palm Beach can be used in conjunction with regional and statewide data, such as the Florida Natural Areas Inventory.

By analyzing a statewide network of protected natural areas in combination with other data layers such as land use, transportation, and routes of commerce, planners can begin to think more comprehensively—from a systems perspective. In doing so, the County and the region can make their restoration and future development decisions in tandem, making them both even more effective.

Recommendations

Use ArcGIS with the data provided in this project for strategic planning, analysis, and management of County land to bring the benefits of the natural areas into developed areas. Some examples:

- Create shape files to identify natural corridors, natural drainage areas or stream inlets. How would a land use plan look if the functions of the natural areas were the highest priority?

- Make shape files for buffer plantings
  - How big will the planting be? How many native species?
  - How much of the buffer is currently native soils?
  - What are the actions and the costs to bring the soil up to the quality needed for the native species to thrive?

- Create shape files to identify areas of non-native and native tree species and rate them in terms of hurricane hazard, cost of potential property damage and priority for replacement.

- Create shape files to identify areas of native trees that require habitat improvement to increase resiliency for future hurricanes and to decrease property damage. Analyze the value of these areas in terms of air and water, but also in terms of the long term health of the entire natural area. Model boosting natural areas within urban development and calculate the added financial benefits of the ecosystem services.

Instigate the development of workshops where staff and community leaders of various County departments and municipalities develop a countywide Urban Forestry Program that addresses areas of common concern.

- Strategize ways to incorporate additional green infrastructure (vegetation and its supporting habitat) into urban areas. Use the urban ecosystem analysis to substantiate value.

- Take the findings from the workshop and produce a new map for planning and a new map for ERM that will guide both groups achieving a desired balance between development and conservation.

Establish Tree Cover Goals

- Establish an overall tree canopy goal for Palm Beach County. Establish goals for specific land use categories. These goals are based on achieving environmental requirements for air and water. Incorporate these goals into planning policies and test achieving them with the UEA process. Maintain those targets as the County develops over time.

- Use American Forests' canopy goals as a guide, but the County 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.

- Local communities should adopt Countywide goals to be consistent across political boundaries. The apparent lack of consistency makes local compliance of achieving tree canopy goals very difficult.

Use the green data layer and CITYgreen to document the ecosystem services in fulfilling Countywide strategies to protect environmental quality.

- Share the green data layer provided with this project with County departments and local municipalities.

- Use the modeling capabilities of CITYgreen software when planning restoration of the urban forest (ERM) or when planning for future growth (Department of Planning). 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, remove wetlands and water when calculating stormwater runoff and water quality. Maintain wetlands 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 public schools to increase awareness of environmental issues, by teaching practical applications of GIS, math, science and geography. Curriculum is available through American Forests.

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 1996-2006 temporal change analysis (page 11), landcover was derived from the Landsat 30 meter pixel resolution imagery taken in March of each year. Sanborn conducted a knowledge-based classification to divide the landcover into five categories (water, trees, urban, open space/grass, and bare soil).

To create the green data layer (page 5), 2004 Digital Orthoquads (DOQs) high-resolution (1 meter pixel) multispectral imagery, provided by Palm Beach County was resampled to 2.5 meter pixel resolution to match the SPOT data. The 2006 imagery was obtained from SPOT new collect imagery, collected in fall. Sanborn conducted a knowledge-based classification to categorize different the land covers as above. Wetlands data was provided by the Southeast Florida Water Management District from 1999. Natural areas data was provided by Palm Beach County.

Analysis Formulas

Urban Ecosystem Analyses were conducted using CITYgreen software. 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, wetlands and water were removed when calculating stormwater runoff and were classified as a particular landcover (trees, open space/grass, water, or bare soil) 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 U.S. Natural Resources Conservation Service (NRCS), formerly known as the U.S. 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.

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.

Acknowledgements for this Study

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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 Ecosystem Center, and Forest Policy Center–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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