March 2003

Urban Ecosystem Analysis Delaware Valley Region

Calculating the Value of Nature

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FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

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Project Overview

AMERICAN FORESTS conducted an urban ecosystem analysis of the Delaware Valley region to provide community leaders with detailed information about the region's tree cover and its environmental and economic impacts. This analysis documents the landscape changes that have occurred over time and identifies the impact these changes have made on the environmental services provided by the region's urban forests. The study used Geographic Information Systems (GIS) technology to connect image analysis of the area to ecological assessment of tree cover change trends over the last 15 years. In addition, AMERICAN FORESTS created a "green data layer" –a digital tool that local communities can use to integrate urban forest ecology into their future planning.

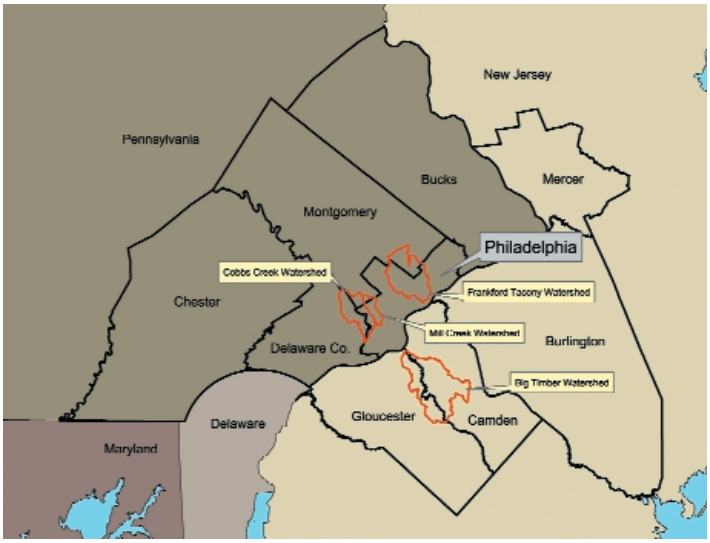
The Delaware Valley region in this analysis covers an area of more than 2.4 million acres, including five counties in southeastern Pennsylvania (Bucks, Chester, Delaware, Montgomery, and Philadelphia) and four counties in southern New Jersey (Burlington, Camden, Gloucester, and Mercer). There are 353 cities, townships, and boroughs in the nine-county region. The four largest cities are Camden and Trenton in New Jersey and Philadelphia and Chester in Pennsylvania. The Delaware Valley Regional Planning Commission (DVRPC) guides planning in the region.

Over the last 25 years, the region has grown and developed as evidenced by:

- Land for single-family homes increased by 116,831 acres between 1970 and 1995, an area as large as Delaware County.
- Commercial development increased by 97,271 acres.
- Grasslands/ag. diminished by 230,516 acres.

This land development reflects a sprawl growth pattern that has consumed undeveloped land in areas further from developed urban centers. Older cities like Philadelphia have lost population. City leaders struggle with a declining tax base and overall diminished quality of life. The 31,000 vacant lots in neighborhoods attest to the outward migration to the suburbs.

In 2001 Philadelphia Mayor John Street adopted a *Green City Strategy* as a basic component of his Neighborhood Transformation Initiative to revitalize Philadelphia's neighborhoods. Developed by Philadelphia Green, a program of the Pennsylvania Horticultural Society, the strategy uses greening and open space as a foundation and tool for urban revitalization. By clearing blighted vacant lots and planting trees and other vegetation, these open spaces breathe new life into the neighborhoods, retaining and attracting residents and businesses.



As community leaders plan for future regional development and urban revitalization, the information and tools provided in this project will become even more useful. The data from Urban Ecosystem Analysis along with the GIS software, provided by AMERICAN FORESTS, offers green infrastructure planning as a strategy for calculating the benefits of the Green City Strategy, implementing the Clean Water Act at the watershed level, and visualizing the smart growth goals of DVRPC's Projected 2025 Plan.

Urban Ecosystem Analysis

Trees and other natural features are part of the region's green infrastructure. Local governments seldom have detailed data about green infrastructure to integrate into their land use planning or land management. To address this void, AMERICAN FORESTS developed a technique using Geographic Information systems (GIS) technology and satellite or aerial imagery to create a green data layer for use with other existing planning and decision-making tools.

Three different kinds of imagery were used in this study. First, regional change trends in the landscape were measured between 1985 and 2000 through remote sensing image analysis of Landsat, a low-resolution satellite imagery.

Second, Ikonos, a high-resolution satellite imagery taken in 2002 was used along with a landcover classification technique to create a "green data layer" to analyze four urban watersheds within the study area in greater detail. A third type—aerial imagery demonstrated how analyses could be conducted at the site level. Both high resolution and aerial imagery were used to model how tree cover positively affects stormwater and air quality of different development scenarios.

AMERICAN FORESTS used these data with CITYgreen® software to assess the economic and environmental impacts of the urban forest and to model scenarios for future growth. Air and stormwater benefit values calculated from representative study sites were extrapolated to the Delaware Valley, providing region-wide environmental benefits. This software and training has been provided to a dozen people in the Delaware Valley so they can investigate the benefits provided by the green infrastructure in future growth and development projects. The findings in this report document how the region's green infrastructure contributes to cleaner air and water.

Major Regional Findings and Recommendations

Over the last 15 years, the landcover changes of the nine-county region, including forests, urban development, and agriculture are not dramatic. This is not unusual for the older northeastern metropolitan regions like Philadelphia. But for the faster growing counties in the region, the land cover changes are significant. Extending the linear trend of the land cover changes to 2025, using Landsat satellite imagery, there are dramatic changes in environmental benefits provided by tree cover.

The Urban Ecosystem Analysis of the region shows changes in the landcover over the last 15 years.

■ Overall, the nine-county Delaware Valley region is dominated by agricultural, grasslands, and other open space land. In 1985, this grasslands/ag. category comprised 41% of the area (1,011,525 acres). Heavy, tree canopy (50% or greater) comprised the next largest land cover with 36% (880,715 acres) followed by urban areas making up 16% (387,167 acres). The remaining land cover was comprised of medium tree canopy (20-49%) at 3%, water at 2% and light tree canopy (less than 20%) at 1%.

■ By 2000, urban land cover increased most dramatically by 22% to 473,067 acres; however other landcover trends did not change as much. Grasslands/ag. declined by 8% to 925,249 acres and heavy canopy declined by 1.5% to 849,444 acres. Medium and low density forest both increased by 10% (82,399 acres) and 14% (31,320 acres) respectively. However since their size is small compared to urban, grasslands/ag and heavy canopy, these increases are not as significant.

Even though the changes in landcover were modest over the last 15 years, the ecological impact of tree loss when calculated over the 2.4 million acre area is huge.

■ Trees slow stormwater runoff, reducing peak flows and decreasing the amount of stormwater storage needed. With the decline in tree cover, the Delaware Valley's urban forest lost the ability to detain almost 53 million cubic feet of stormwater, a service valued at $105 million. This represents the cost to build stormwater retention ponds and other engineered systems to intercept this runoff. The region stored 2.9 billion cubic feet of stormwater in 2000, valued at $5.9 billion. Stormwater costs were calculated for a typical 2-year peak storm event and a $2.50 per cubic foot construction costs for the 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. The Delaware Valley's tree canopy lost its ability to remove approximately 1.7 million pounds of air pollutants annually, at a value of $3.9 million per year. In 2000, the region's trees removed 73 million lbs. valued at $167 million.

■ Trees help clean the air by storing and sequestering carbon in the wood. Total storage and the rate at which carbon is stored (sequestration) can be measured. If the regions' trees had not declined since 1985, they would have stored an additional 633,000 tons of carbon and sequestered an additional 1,373 tons annually. In 2000, the region's urban forest stored 26.8 million tons of carbon and sequestered 8,585 tons per year.

The local governments within the Delaware Valley should set tree cover targets for specific areas or land uses in the community and develop strategies to reach these goals.

■ Average tree cover for a metropolitan area in the Delaware Valley should be 40%.

■ The Green City Strategy in Philadelphia is an example of a specific strategy to increase the area's tree cover.

If the Delaware Valley Region and its local communities were to reverse the tree loss trend and increase tree canopy, the environmental benefits would be significant. Setting tree canopy goals to maximize the benefits of tree cover in urban areas is a cost effective way to improve the environment.

■ The natural landscape should be recognized for its economic and ecological value. Tree cover is a good measure of the ecological health of the Delaware Valley.

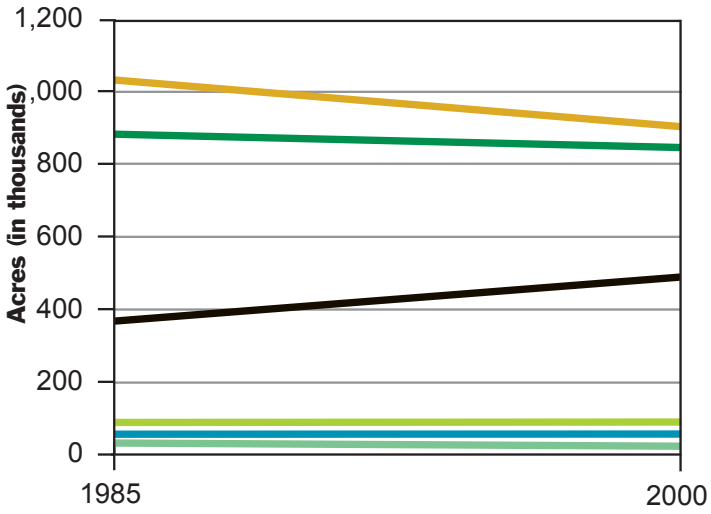
■ Sprawl development has large, measurable negative environmental and economic consequences.

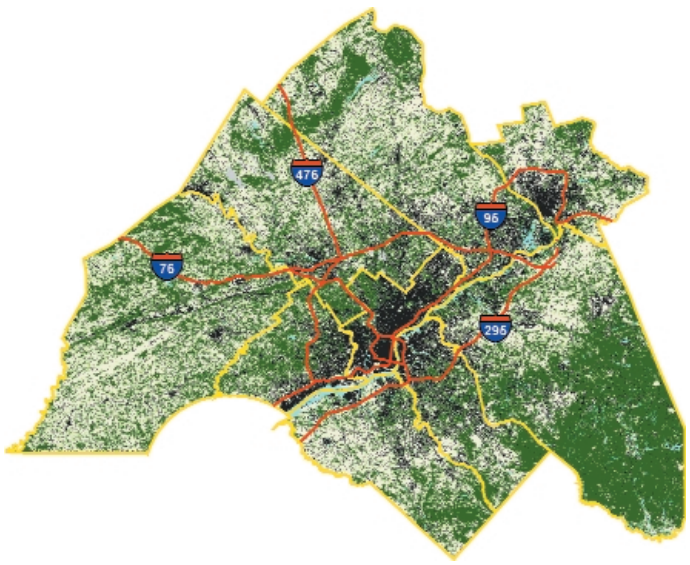
■ As rural areas outside of established cities develop, it will become even more important to increase tree cover to offset the environmental impacts of increased impervious surfaces, stormwater runoff, and air pollution.

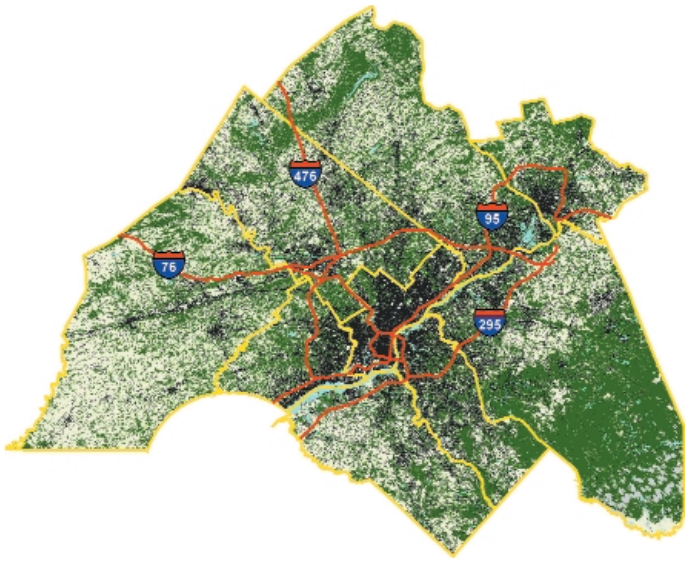
Regional Ecosystem Analysis

The Regional Ecosystem Analysis provides the community with a historical perspective of the landcover changes that have taken place. This data is most useful for public policy rather than day-to-day management decision making. AMERICAN FORESTS conducted a Landsat image analysis to determine tree cover trends for the entire 2.4 million acre study area including the nine counties of the Delaware Valley Region located in Pennsylvania and New Jersey. The images below are classified Landsat TM images of the study area in 1985 and 2000. These Landsat images provide a measure of the landcover in "pixels" approximately 30 meters on a side. The analysis measures seven categories of land use. Open space, grass and agriculture lands are grouped together in beige. Heavy tree cover (50% or greater) is indicated in dark green, medium tree canopy (20-49%) is in medium green, and areas of light canopy (less than 20%) are in light green. Urban areas are shown in black and water in blue. Areas with cloud cover or no data are designated in gray.

Delaware Valley Region Landcover Change







Key

Water	Urban	Grasslands/ag
Heavy Tree Cover	Medium Tree Cover	Light Tree Cover

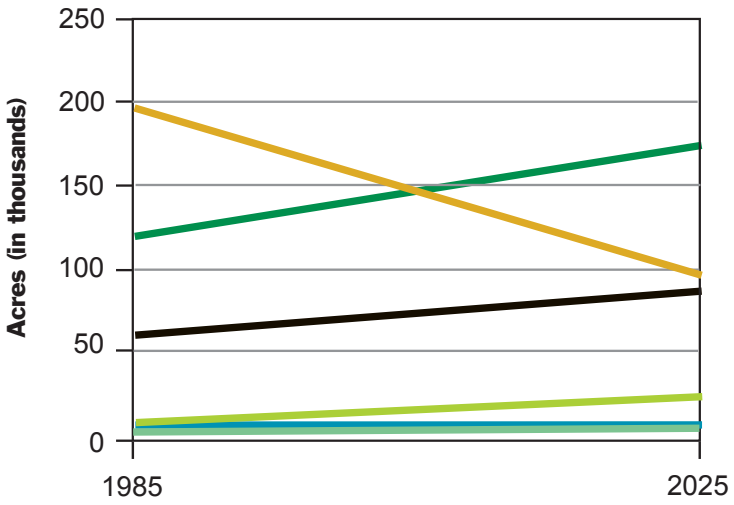
Even though the changes in landcover were modest over the last 15 years, the ecological impact of the loss is great when spread over this 2.4 million acre region. Landsat imagery classified into different landcovers show changes that occurred between 1985 (left) and 2000 (right).

Landcover Trends in Three Fast Growing Counties

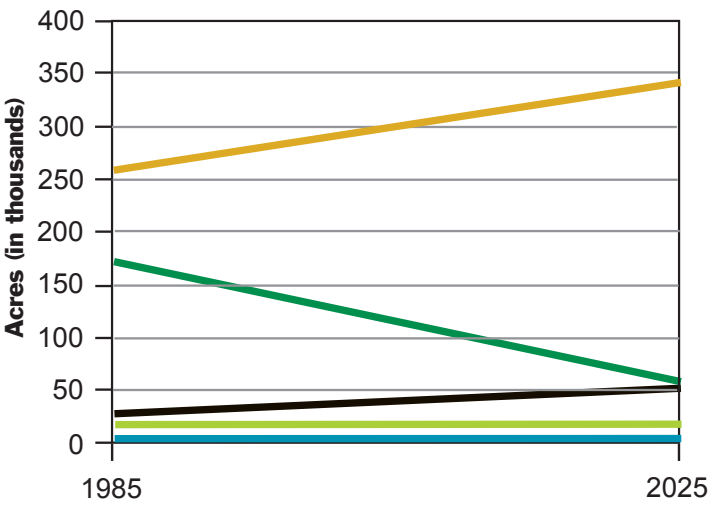
	Bucks		Chester		Gloucester	
Landcover	Actual % change 1985-2000	Projected % change 2000-2025	Actual % change 1985-2000	Projected % change 2000-2025	Actual % change 1985-2000	Projected % change 2000-2025
Population growth	25%*	25%	37%*	27%	27%*	27%
Grasslands/ag.**	-18%	-36%	12%	18%	-9%	-16%
Urban	18%	26%	44%	51%	34%	42%
Heavy tree canopy	17%	24%	-24%	-51%	-6%	-10%
Medium tree canopy	28%	37%	-11%	-20%	20%	27%
Light tree canopy	20%	28%	-6%	-10%	24%	32%

Taken from US Census for 1980-2000* * Includes: fallow farmland, shrubland, and bare soil*

Bucks County Landcover Change



Chester County Landcover Change



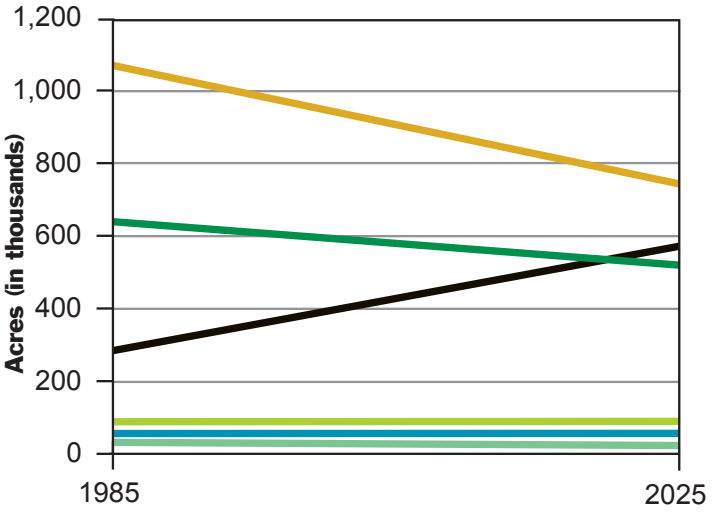
Graphing Change

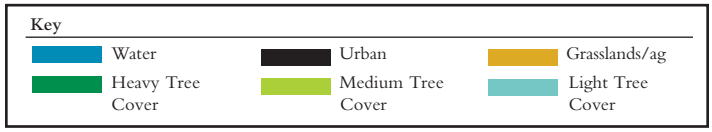
The change in landcover measured using Landsat satellite imagery is represented by the line graphs for the region (page 4) and three counties (page 5). These graphs use the same land cover categories as the Landsat images on the previous page.

Overall, the graph of the region shows little change over the 15-year span of the study. However, in its 2025 Plan, the Delaware Valley Regional Planning Commission forecasts that the region will grow by 11 percent in the next 25 years, mostly in the outer ring of suburbs. Chester, Bucks, and Gloucester counties will experience population growth of about 27%, 25% and 27%, respectively. Land cover changes become more apparent in these three counties. When projected to the year 2025, future development will produce distinct changes in grasslands/ag, tree cover, and urban areas. These changes are likely to decrease the tree cover in the region, which would have a negative impact on air and water quality.

In Chester County, high tree cover will decline most dramatically as both open space and urban areas increase. In Gloucester County, a dramatic increase in urban land is projected as heavy tree canopy and open space decline. A gain in moderate and light tree cover is indicative of urban development. In Bucks County, open space is projected to decline dramatically as urban area increases. Unlike the other counties, tree cover in Bucks County is expected to increase if this trend continues.

Gloucester County Landcover Change





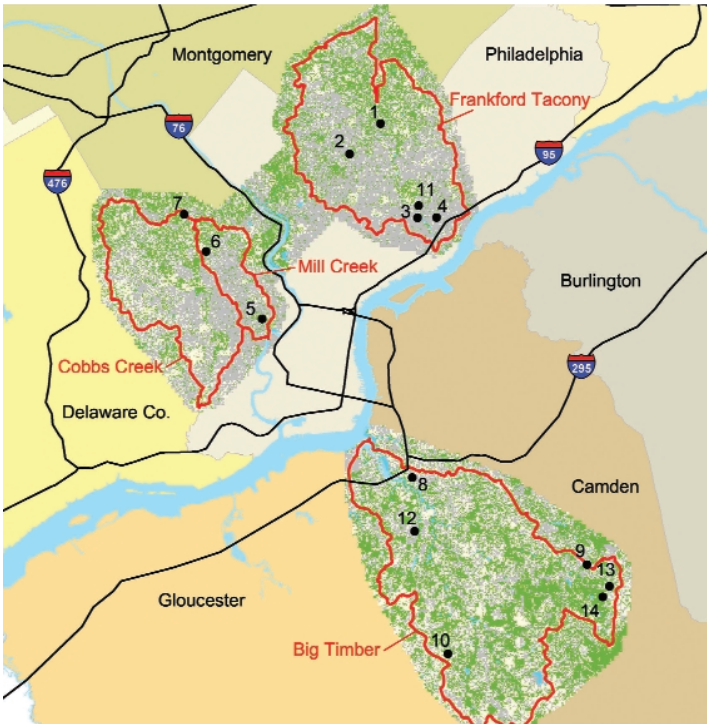
Watershed Analysis

Four watersheds—Frankford Tacony, Mill Creek and Cobbs Creek in Pennsylvania and the Big Timber in New Jersey were selected for additional analysis. The detailed analysis used a high-resolution satellite image to create a "green data layer" or classified land cover image. This digital mapping tool enables planners to integrate green infrastructure into their future planning.

These watersheds, which empty into the Delaware River, were selected to assist local communities in the development of their watershed management plans, now underway. The green data layer helps evaluate tree-planting opportunities as a retrofit best management practice in these highly urbanized watersheds.

While Landsat images at a 30-meter pixel resolution can identify general trends of tree canopy cover change over time, high-resolution multi-spectral imagery produces a detailed green data layer where individual trees, with crowns greater than six feet in diameter, are visable. Not only can the urban forest be seen more clearly, but this image allows tree cover data to be directly analyzed for its ecological benefits. When used with CITYgreen software, stormwater runoff and air quality benefits can be determined for the entire area of interest (e.g.: a region, watershed, or neighborhood) rather than extrapolating benefits from sample sites.

Adding a green data layer to the decision making process introduces a new dimension to planning and development, one that considers the dollar benefits of trees and associated natural resources. Planning with green infrastructure provides a way to take advantage of the natural cycles of air and water, instead of solely building costly "gray" infrastructure to manage these systems.



A green data layer of four selected watersheds provides data to conduct urban ecosystem analysis by ecological or political areas of interest. This green data layer was created from a classification of a multi-spectral 4-meter resolution satellite image. Dark green represents tree cover, light green represents grass and open space, and gray designates impervious surface. Study site locations are numbered and referenced in Tables on pages 8 and 10.

Environmental Benefits of Four Watersheds

					Air Quality (annual benefits)		Stormwater (capital improvement benefits)*		Carbon Benefits	
Watershed	Area (sq. miles)	% trees	% grasslands and ag.	% urban	Pollutants removed (lbs.)	$ value	Cubic ft. avoided (millions)	$ value	Carbon stored (tons)	Carbon sequestered (tons/yr)
Big Timber	59.53	41%	31%	27%	1.8 million	$4.1 million	65	$3.3 billion	666,000	5,200
Cobbs Creek	22.12	26%	29%	45%	436,000	$993,000	20	$1 billion	159,000	1,241
Mill Creek	6.58	23%	18%	59%	114,000	$260,000	6.7	$350 million	42,000	325
Frankford Tacony	37.08	27%	20	53%	761,000	$1.7 million	38	$2 billion	278,000	2,165

**These urban watersheds have Combined Stormwater/Sewer Overflow (CSO) systems that use $52 per cubic foot construction costs.*

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Analysis Report

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Site Statistics

Analysis Area:	**Frankford**
Scenario:	Current Conditions
Area:	
37.08	sq. miles
23,728.74	acres
9,603.02	hectares

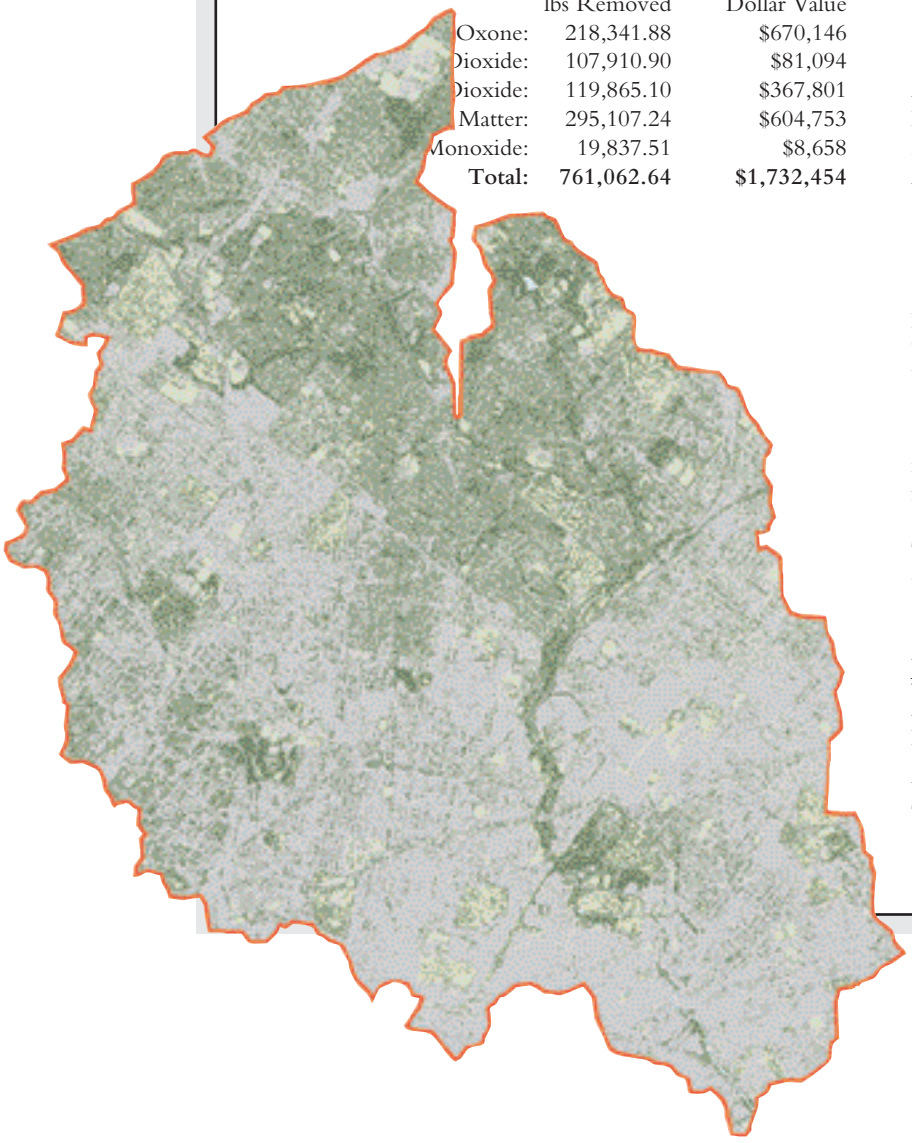
Lancover distribution:		**Acres**
0%	Cropland	0.00
0%	Impervious	0.00
20%	Open Space/Pasture/Meadow	4,727.35
0%	Shrubs	0.00
27%	Tree Canopy	6,461.73
53%	Urban Land Use	12,503.82
0%	Water	35.83

Ecological Benefits

Air Pollution Removal

Air Quality Reference City: Philadelphia

	lbs Removed	Dollar Value
Oxone:	218,341.88	$670,146
Dioxide:	107,910.90	$81,094
Dioxide:	119,865.10	$367,801
Matter:	295,107.24	$604,753
Monoxide:	19,837.51	$8,658
Total:	**761,062.64**	**$1,732,454**



Carbon Storage and Sequestration

Age Distribution of Trees:	Average or Unknown
Carbon Storage:	278,048.27 tons
Carbon Sequestration:	2,164.68 tons/year

Stormwater Control

Average 2-yr. 24-hour Rainfall:	3.25 in.
Rainfall Distribution Type:	II
Hydrologic Soil Group	B
Average Slope:	10%

	Conditions: Current	w/o trees*
Curve Number:	78	85
Runoff (in.)	1.31	1.80
Time of Concentration (hrs.)	6.42	5.12
Peak Flow (cu ft/s):	4,098	7,175

Storage volume needed to mitigate the change in peak flow:	38,832,840.00	cu. ft.
Construction cost:	$52.00	per cu. ft.
Total	**$2,019,307,680**	

* Replaced by default landcover: Urban

Economic Benefit Summary

Annual Air Pollution Removal Savings:	**$1,732,454**
Annual Stormwater Savings*:	**$176,052,455**
Total Annual Savings:	**$177,784,900**

*Annual Stormwater savings is based on financing over 20 years at 6%.

An analysis of the Frankford Tacony Watershed demonstrates how this green data layer is used with CITYgreen to produce a one page Analysis Report of the watershed's environmental benefits. An enlargement of Frankford Tacony area from page 6 illustrates the gray and green areas of the urban infrastructure.

Planning Using Local Analysis

CITYgreen

CITYgreen analyzes the land cover information provided by the satellite and aerial imagery and calculates the dollar benefits resulting from the work trees and other natural features of the landscape provide.

Ten study sites were selected to represent the typical land uses in the region. This level of detail was required in order to calculate the environmental benefits of tree canopy cover. The DVRPC and the Philadelphia Water Department provided aerial imagery and collected tree-specific information used to run a CITYgreen analysis. These results were extrapolated to the Delaware Valley region in order to calculate the environmental values for the area as a whole. The following describes how trees provide environmental benefits and how CITYgreen measures them.

Stormwater

The value of trees for stormwater management is calculated based on avoided costs of handling stormwater runoff. The total volume of avoided water storage is multiplied by local stormwater retainment facility construction costs to determine the dollars saved by trees. The analysis results of the ten study sites are quite dramatic depending on the amount of tree canopy the site has and the type of stormwater facility each site uses. The commercial Tacony site with only a 2% tree cover and a 97% impervious surface provides no stormwater benefits. Whereas the Cobb single family site of approximately the same size has a 30% tree cover and provides $5,400 in stormwater savings. In areas that have separate stormwater sewer management systems, like the Tacony and Cobb single-family residential sites, tree canopy provides $5,828 and $5,454 in stormwater savings respectively (using a $2 per cubic foot stormwater construction cost).

However, in more urban areas like the multi-family residential sites of Tacony and Mill, stormwater is handled with a combined stormwater/sewer overflow (CSO) system. Building additional storage costs $52 per cubic foot. With such an expensive construction cost, a 30% tree canopy in the Mill multi-family site saves over $308,000. Increasing tree cover while decreasing impervious surfaces can avoid building expensive stormwater storage in the future.

Air Quality

To calculate the value of air pollutants, economists multiply the number of tons of pollutants removed by "externality costs", or costs to society not reflected in marketplace activity, as established by state public service commissions. The value represents costs that society would have paid in areas such as health care, if trees did not remove these pollutants. Air pollution benefits are calculated annually. Among the ten study sites, there is a clear correlation between the amount of tree cover and impervious surfaces and the amount of air pollutants that are removed. The Tacony manufacturing site, with only a 1% tree cover, provided $13 in air pollution benefits. In contrast, the Big Timber manufacturing site in New Jersey with a 48% tree canopy provided $340 in annual benefits.

Stored and Sequestered Carbon

The carbon-related function of trees is measured in two ways: storage, or the total amount currently stored in tree biomass, and sequestration, the rate of absorption per year. Tree age greatly affects the ability to store and sequester carbon. Older trees store more total carbon in their wood and younger trees sequester more carbon annually. Trees ability to absorb atmospheric carbon reduces greenhouse gases, thought to contribute to global warming. The Cobb site sequesters the most carbon of the study sites, at 1,400 tons per year due to its 30% canopy and young age of its trees.

Environmental Benefits of Ten Study Sites

					Air Quality (annual benefits)		Stormwater (capital improvement benefits)*		Carbon Benefits	
Site	Area (acres)	% trees	% grasslands and ag.	% urban or imperv	Pollutants removed (lbs.)	$ value	Cubic ft. avoided	$ value	Carbon stored (tons)	Carbon sequestered (tons/yr)
PA Sites										
1. Tacony: single-family	4.21	24	69	31	120	$274	2,914	$5828	55	320
2. Tacony: commercial*	3.41	2	3	97	9	$21	0	0	3	120
3. Tacony: multi-family*	4.89	6	32	68	37	$83	4,869	$253,188	14	40
4. Tacony: manufacturing*	3.24	1	0	99	5	$13	0	0	2	0
5. Mill: multi-family*	5.18	20	38	62	125	$285	5,938	$308,776	47	160
6. Mill: Transportation*	4.33	8	28	72	39	$88	3,992	$207,584	15	60
7. Cobb: single-family	3.19	30	61	39	114	$259	2,727	$5,454	31	1,400
NJ Sites										
8. Big Timber: manufacturing	3.79	11	14	86	48	$110	3,849	$7,698	22	120
9. Big Timber: multi-family	2.64	48	59	41	149	$340	2,209	$4,418	68	380
10. Big Timber: single-family	3.03	6	74	26	20	$46	1,653	$3,306	6	240

**These urban watersheds have Combined Stormwater/Sewer Overflow (CSO) systems that use $52 per cubic foot construction costs. The other sites use $2 per cubic foot construction costs. Sites are located on the map on page 6.*

Modeling the Future

By developing policies and programs like Philadelphia's *Green City Strategy*, which preserve and increase green infrastructure, the Delaware Valley can change sprawl patterns, and revitalize core cities and inner suburbs. The CITYgreen software tool can be used to evaluate the environmental impact of different development and retrofit scenarios.

Modeling green infrastructure can show the environmental and economic benefits of redeveloping industrial, commercial and residential lands in older neighborhoods. For example, the Townhouses at Frankford Creek infill development is one of Mayor Street's Neighborhood Transformation Initiative projects to revitalize Philadelphia's neighborhoods. This 5-acre brownfield will be transformed into 50 new homes with a green, open space buffer adjacent to Frankford Creek. The site currently has a 4% tree cover, 86% impervious surface, and 14% open space. When redeveloped with townhouses and vegetation, the site schematic could have a 25% tree canopy, 48% open space, and 52% impervious surfaces. Environmental benefits increase dramatically (see table on page 10).

The stormwater benefits are dramatic when compared to other sites. The Townhouses at Frankford Creek are located in a combined storm sewer overflow system, typical of older cities. Building stormwater storage for this system is $52 per cubic foot, seven times the cost of detention ponds used in systems that separate sewerage from stormwater. Using trees as a non-engineered stormwater management strategy may allow the community to avoid such costly investments.

Using a commercial site scenario, the Deptford Mall has a minimal 6% tree cover, 11% grass/openspace and an 82% impervious surface. If tree cover were increased to 15% by adding trees in parking lots and along the perimeter, an additional 63,348 cubic feet of stormwater (valued at $126,696) would be detained.

Looking at the benefits of canopy cover within residential development, a suburban development in New Jersey illustrates the benefit of preserving mature trees and forests in new housing. In two similar housing developments, the south site is a bit larger but has fewer trees (21%) than a nearby development to the north (39%). With an additional 18% tree cover, the north site provides an additional 91 lbs. of air pollutant removal valued at $222 annually and an additional 3,248 cubic feet of stormwater benefits valued at $6,496.

The Townhouses at Frankford Creek, a brownsfield site is slated for redevelopment existing (left) and one possible housing scenario (right). If tree canopy and open space were increased and impervious surface decreased the site would provide an additional $303,000 in stormwater benefits and remove an additional 151 lbs. of air pollutants annually.

Modeling Environmental Benefits of Study Sites

					Air Quality (annual benefits)		Stormwater (capital improvement benefits)*		Carbon Benefits	
Site	Area (acres)	% trees	% open space, ag, meadow	% urban	Pollutants removed (lbs.)	$ value	Cubic ft. avoided	$ value	Carbon stored (tons)	Carbon sequestered (tons/yr)
11. Frankford Creek-existing*	5.14	4	14	86	22	$51	0	0	10	60
11. Frankford Creek-proposed*	5.14	25	48	52	151	$343	5,826	$302,952	69	400
12. Deptford Mall-existing	203.65	6	11	82	1,480	$3,371	215,520	$431,040	541	8,420
12. Deptford Mall-proposed	203.65	15	11	74	3,598	$8,190	278,868	$557,736	1,314	20,460
13. NJ residential north site	4.22	39	32	29	191	$436	7,357	$14,714	70	1,080
14. NJ residential-south site	3.87	21	38	41	94	$214	4,109	$8,218	34	540

**The Townhomes at Frankford Creek use a Combined Stormwater/Sewer Overflow (CSO) system that uses $52 per cubic foot construction costs. The other sites use $2 per cubic foot construction costs. These sites are located on the map on page 6.*

Deptford Mall

New Jersey Suburban Development

Recommendations

All the communities in the metropolitan area need to incorporate tree cover into their planning and development process. Tree cover is directly related to environmental quality. The economic value of this green infrastructure can be measured and quantified for decision-making.

Establish Tree Cover Goals

■ Include a tree canopy cover goal for specific land use categories in comprehensive land use or zoning plans. Maintain those targets as the community changes or develops over time.

■ AMERICAN FORESTS recommends the following generalized goals for different land uses, but recognizes that every community is different and needs to set their own goals. For a visual representation of different tree canopy percentages, examples using sites in this report are listed.

- 40% tree canopy overall (N.J residential north site)
- 50% tree canopy in suburban residential (Big Timber multi-family)
- 25% tree canopy in urban residential (Tacony single-family)
- 15% tree canopy in central business district (Big Timber manufacturing)

Develop specific management strategies to achieve tree cover goals.

- Plant trees in suitable spaces such as vacant lots, parks, and riparian areas
- Plant trees to meet stormwater management goals
- Use trees to decrease peak storm flow
- Require trees as part of redevelopment and new development projects
- Reforest parklands
- Maintain trees to prolong life and environmental benefits

Use green data layer and CITYgreen to document the environmental benefits of strategies to achieve tree cover goals.

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

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

Incorporate the urban green data layer and use CITYgreen in land use, development, and watershed planning processes.

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

■ Continue to use Landsat data to identify areas of change in conjunction with other planning documents such as the 2025 Plan. Then conduct urban ecosystem analyses using the green data layer to understand and direct future growth and incorporate the green infrastructure.

■ Use modeling to demonstrate the impact that tree cover would have with New Jersey's proposed Stormwater Management Rules that require maintaining 100% of the average annual groundwater recharge, statewide. These rules would also require Best Management Practices for new development to reduce pollution runoff levels by 80%.

Encourage local greening partners, like the Pennsylvania Horticultural Society, to use the green data layer and CITYgreen to document the environmental benefits of their work.

■ Use modeling to demonstrate the environmental benefits of greening Philadelphia's vacant lots.

■ Use analyses findings to demonstrate and educate the public about the environmental benefits of urban revitalization programs.

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 structure performs ecological functions differently and thus provides different values. For example, a site with a heavy tree canopy and few impervious surfaces provides more stormwater reduction benefits than one with low tree canopy.

In this study, the regional analysis provided tree cover change trends in the Delaware Valley region. These areas were then modeled to assess the past, current, and future benefits of tree cover at its current rate of decline. Aerial imagery of ten study sites was used to conduct CITYgreen analyses. These values were extrapolated to the Delaware Valley to obtain region-wide benefits.

Data Used in this Study

For the regional analysis, Landsat satellite TM (30 meter pixel) images were used as the source of land cover data. AMERICAN FORESTS used a full pixel classification technique and divided land cover into nine vegetation categories. Tree benefits of the region were calculated using CITYgreen® software on the satellite images.

AMERICAN FORESTS used high-resolution satellite data to create a "green data layer" of four watersheds within the study area. The analysis used multispectral, 4-meter resolution satellite imagery collected in 2002 and employed a full pixel classification technique. Tree benefits were calculated using CITYgreen software on the satellite, high-resolution and aerial images. The aerial imagery used was black and white, digital orthophotography collected in 2000. All imagery was provided by the Pennsylvania Bureau of Forestry, DVRPC, and USDA Forest Service. Local partners collected site-specific information of the ten study sites, used in the analysis.

AMERICAN FORESTS developed CITYgreen software to help communities analyze the value of local trees and vegetation as part of urban infrastructure. CITYgreen is an extension of ArcView for Windows, a Geographic Information Systems (GIS) software program developed by ESRI.

Analysis Formulas

TR-55 for Stormwater Runoff: The stormwater runoff calculations incorporate formulas from the Urban Hydrology of Small Watersheds model, (TR-55) developed by the US Natural Resources Conservation Service (NRCS), formerly known as the US Soil Conservation Service. Don Woodward, P.E., a hydrologic engineer with NRCS, customized the formulas to determine the benefits of trees and other urban vegetation with respect to stormwater management.

UFORE Model for Air Pollution: CITYgreen uses formulas from a model developed by David Nowak, PhD, of the USDA Forest Service. The model estimates how many pounds of ozone, sulfur dioxide, nitrogen dioxide, and carbon monoxide are deposited in tree canopies as well as the amount of carbon sequestered. The urban forest effects (UFORE) model is based on data collected in 12 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 of this pollution, such as rising health care expenditures.

Acknowledgements for this Study

We gratefully acknowledge the support of the following agencies, and companies in conducting this study:
USDA Forest Service, Northeastern Area (USDA FS)
Pennsylvania Bureau of Forestry District 17 Valley Forge
Pennsylvania DCNR Bureau of Forestry
Philadelphia Water Department
Delaware Valley Regional Planning Commission (DVRPC)
Pennsylvania Urban and Community Forestry Council

Special thanks to:

Howard Neukrug, Philadelphia Water Dept.
Chad Pindar, Philadelphia Water Dept.
Glen Abrams, Philadelphia Water Dept.
Rick Deppen, PA Bureau of Forestry
Sandy Insalaco, PA Bureau of Forestry
Barry Seymour, DVRPC
Mindy Katz, DVRPC
Patrice Carroll, USDA Forest Service
Donna Murphy, USDA Forest Service
Scott Harris, Keystone College
for providing satellite imagery, aerial photography, handheld computers and software, technical assistance and site surveying

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 their 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:

AMERICAN FORESTS
P.O. Box 2000 Washington DC 20013
Phone: 202/955-4500; Fax: 202/955-4588
E-mail: cgreen@amfor.org
Website: www.americanforests.org