October 2008

Urban Ecosystem Analysis City of Bellevue, Washington

Calculating the Value of Nature

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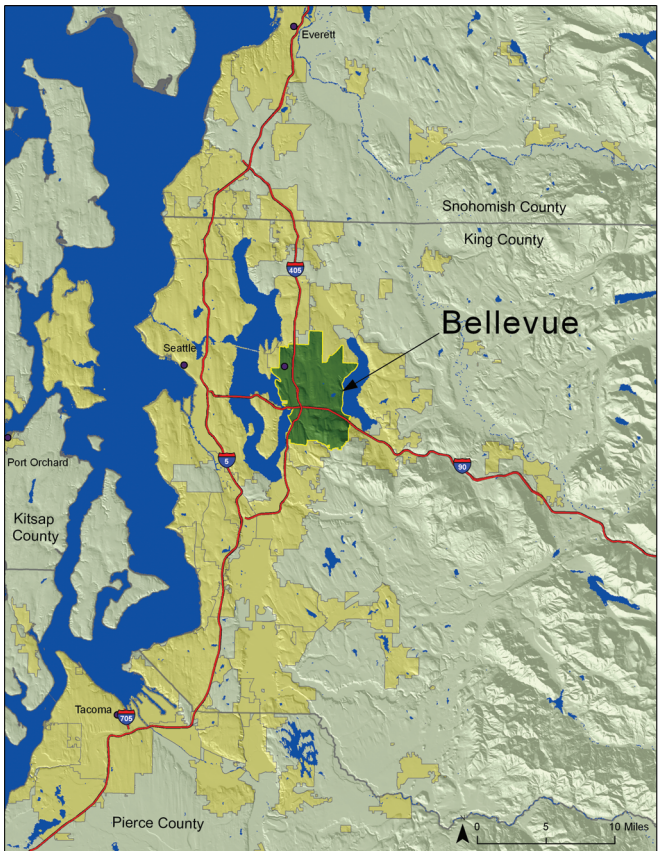

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Project Overview

Recognizing the many benefits that urban tree canopy brings to urban environmental quality, the City of Bellevue engaged American Forests to update their 1998 Urban Ecosystem Analysis (UEA), initially conducted using Landsat satellite data. This analysis examines forest, tree canopy and other landcover changes over the last decade and quantifies the ecosystem benefits of the City's green infrastructure. This study also takes a closer look at the shortfalls and potential for increasing tree canopy within distinct land uses and three land ownership categories: Public Park and Open Space, Public Street Right-of-Way and Private Property. Currently, 69% of the city's 21,377 acres of land is private property comprised of the central business district, industrial, commercial and mixed use, and residential land. City-owned Park and Open Space property occupies 12% of the city land and 18% of the city land base is public Right-of-Way.

The Urban Ecosystem Analysis in this study analyzed the ecology of landcover at two scales spanning two time periods. The first assessment addressed contiguous forest land conversion using moderate resolution (30 meter pixel resolution) from Landsat satellite imagery taken between1985 and 2006. While the resolution of Landsat data is too coarse for analyzing at the scale of individual trees and land use areas, this chronological analysis reveals both historic and future trends. The second assessment studied tree canopy and other urban landcover types using 2007 high-resolution (2 foot pixel resolution), digital imagery to analyze the City's existing landcover and ecosystem benefits by land use classification.

This study also conducted modeling scenarios to quantify the environmental benefits of enhancing Bellevue's tree canopy to American Forests' recommended canopy percentage levels. The evidence and data presented in this project will provide City leaders with the information to better integrate natural systems into future development decisions.

Data from this project gives the City staff the ability to conduct their own assessments for on-going planning decisions. From a broader perspective, the urban ecosystem analysis offers the entire community a role in developing and maintaining its tree canopy and improving environmental quality.

Major Findings

In 1998, American Forests conducted an initial Urban Ecosystem Analysis (UEA) of Bellevue looking at the change in canopy coverage. Between 1986 and 1996 the city had lost 12% of its tree canopy cover. This new analysis shows that the city has lost an additional 9% of tree canopy since then and quantifies the impacts this loss has had on stormwater management and air and water quality.

1996-2006 Landcover Change Trend Data Using 30 meter Landsat Satellite Imagery

- Since the initial UEA was conducted, tree canopy in Bellevue declined another 9% percent. This continuing negative trend is inversely related to urban development within the city of Bellevue. Although the canopy loss trend has slowed in recent years, the cumulative loss was measured at 20% since 1986.

1996-2006 Loss of Ecosystem Services

- The loss of forest land cover and tree canopy and resulting increase in urban areas has ecological consequences; loss of green infrastructure means the City's natural environment is less able to provide ecosystem services for air, water, and carbon.
- Bellevue's vegetative landcover lost its ability to remove approximately 30,000 pounds of air pollutants annually, valued at $68,000 per year. The loss of tree canopy equated to a loss in 15,000 tons of carbon stored in trees' wood and a loss of 113 tons of carbon sequestered annually.
- As the City continues to develop, the ratio of impervious to pervious surface greatly influences the amount of stormwater runoff Bellevue must manage. Currently, Bellevue is 46% impervious surface.
- Without tree canopy to reduce stormwater runoff volume, the City must manage an additional 755,000 cubic feet of stormwater, valued at $1.5 million (using a national cost of $2 per cubic foot.). Construction costs for stormwater detention in the Bellevue area is estimated to be $10 per cubic foot, resulting in a value of $15 million.
- Tree roots absorb water pollutants; based on American Forests' modeling, eight of these pollutants can be measured: Biological Oxygen Demand, Cadmium, Copper, Lead, Nitrogen, Phosphorus, Suspended Solids, and Zinc. Of these, each worsened, ranging from 15% for zinc to 42% for Cadmium because trees were removed from the land.

Quantifying Bellevue's 2007 landcover and its ecosystem benefits provides ecological opportunities for the future

- In 2007, the city of Bellevue had a 36% overall tree canopy. While this is higher than in many cities, it is less than American Forests' recommended 40%. When viewed from a land use perspective, Bellevue's existing canopy falls short of American Forests' recommendations in each category: Urban residential (-5%), Suburban residential (-15%), Central Business District (-8%), Commercial/Mixed Use (-4%), and Industrial (-6%).
- Trees slow stormwater runoff, decreasing the amount of stormwater storage needed. In 2007 Bellevue's tree canopy provided 62 million cubic feet in stormwater detention services, valued at $123 million.
  - Public ROW and Park Open Space trees provide 16.7 million cubic feet of stormwater retention services, valued at $33 million.
  - Trees on private property provide 42.5 million cubic feet of stormwater retention services, valued at $ 94 million.
- 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. Bellevue's tree canopy removes 687,000 lbs. of these pollutants annually at a value of $1.55 million per year.
- Trees have a direct impact on the carbon footprint. Trees help clean the air by storing and sequestering carbon. Total storage and the rate at which carbon is stored (known as sequestration) can be measured. Bellevue's tree canopy stores 332,000 tons of carbon in trees' wood and sequesters 2,582 tons of carbon annually.
- In 2007 Bellevue had 7,708 acres of tree canopy (36%), although 2% of it had impervious paving underneath the canopy which prevents stormwater infiltration. The city had 339 acres of shrubs (2%), 3,386 acres of open space with grass and scattered trees (16%), 9,700 acres of impervious surface (46%), 105 acres of bare soil (<1%), and 126 acres of water (<1%).
- The City's right of way (ROW) land has 3,895 acres, 20% of which is currently in tree canopy and 12% in open space with grasslands and scattered trees.
- The City's Park and Open Space land is comprised of 2,530 acres, 67% of which is currently in tree canopy.

Forest Landcover Change Trends

Bellevue is indicative of forest stand conversion 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 in metropolitan areas, 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 utilizing their natural capacity to clean air and water and slow stormwater runoff.

For the 2008 Urban Ecosystem Analysis, American Forests analyzed contiguous forest change trends from 1985, 1996, 2001 and 2006. This new data updates the City's forest change trend information produced by American Forests in the "*1998 Regional Ecosystem Analysis for the Puget Sound Metropolitan Area*". The 2008 study used classified Landsat satellite imagery developed by the U.S Geological Survey, now considered the gold standard for analyzing land cover change trends (Figure 1).

The Landsat data shows how rapidly forest was converted into different uses over the last two decades. Due to the forest conversion changes between 1996 and 2006, the City lost the ability to store 754,825 cubic feet of stormwater, valued at $1.5 million. A conservative $2 per cubic foot was used in the calculations but anecdotally, according to recent stormwater construction facilities in Bellevue, the cost is approximately $10 per cubic foot resulting in a loss of $15 million in stormwater benefit. Bellevue's tree canopy also lost $68,000 in annual air pollution removal value, 14,527 tons of carbon storage and 113 tons of sequestration annually. The chronological analysis provides valuable public policy information showing general trends in landcover changes. Even though Bellevue's rate of tree canopy loss has declined since the 1980s, the City continues to lose trees and ecosystem services.

Table 1. Forest Change in Ecosystem Services as Measured with Landsat Data

Bellevue	Initial Year Tree Canopy acres	Ending Tree Canopy acres	Tree Canopy Change acres	Tree Canopy Change percentage	Loss in Stormwater Value cu. ft.	Loss in Stormwater Value @ $2/cu ft. $	Loss of Air Pollution Removal lbs./yr	Loss of Air Pollution Removal Value $	Loss of Carbon Stored tons	Loss of Carbon Sequestered tons/yr
1985-1996	4,108	3,609	-499	-12%	-2,807,081	-$5,614,162	-44,548	-$100,176	-21,505	-167
1996-2006	3,609	3,271	-338	-9%	-754,825	-$1,509,650	-30,093	-$67,669	-14,527	-113

Forest Landcover Change Trends 1985-1996

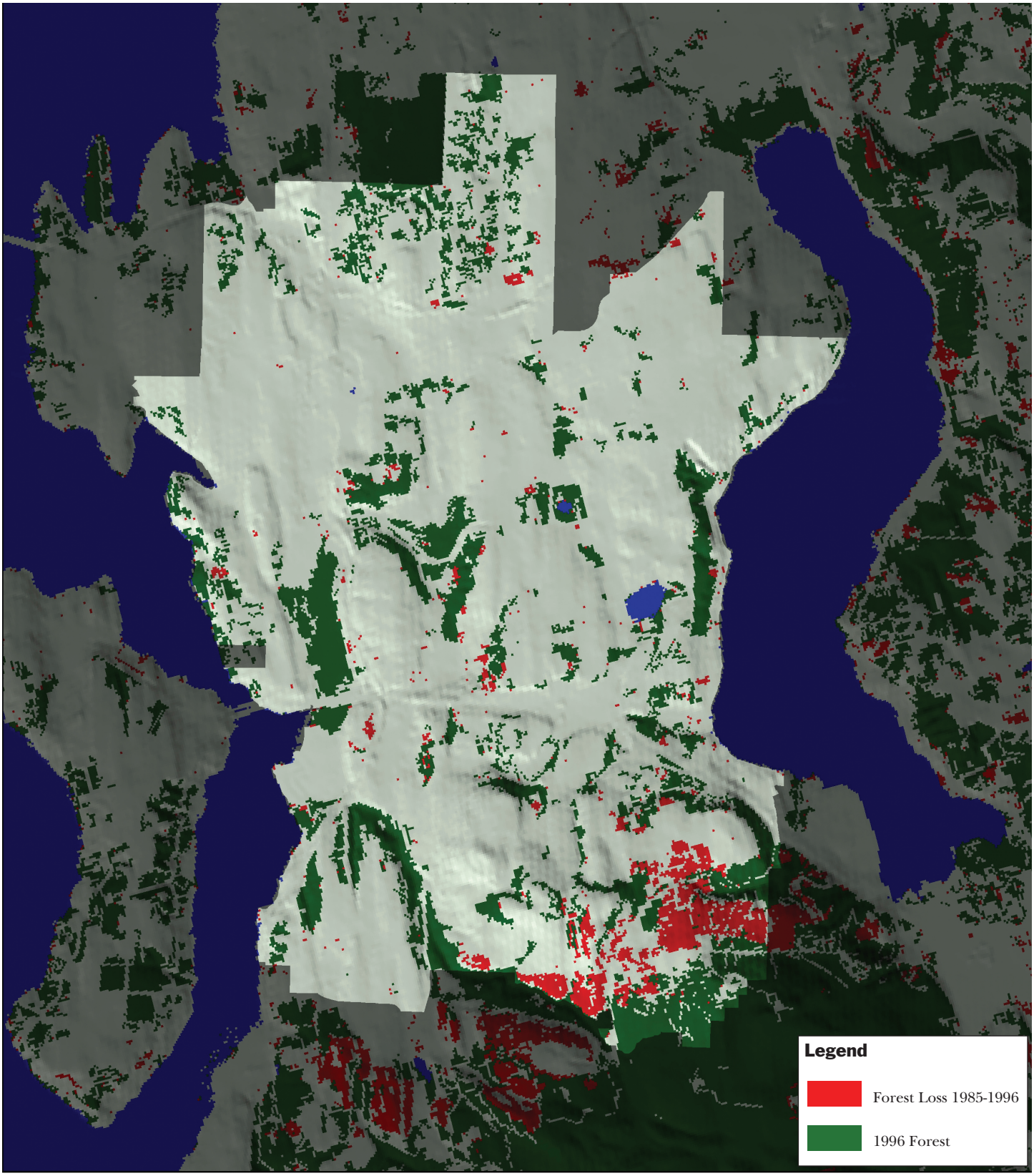
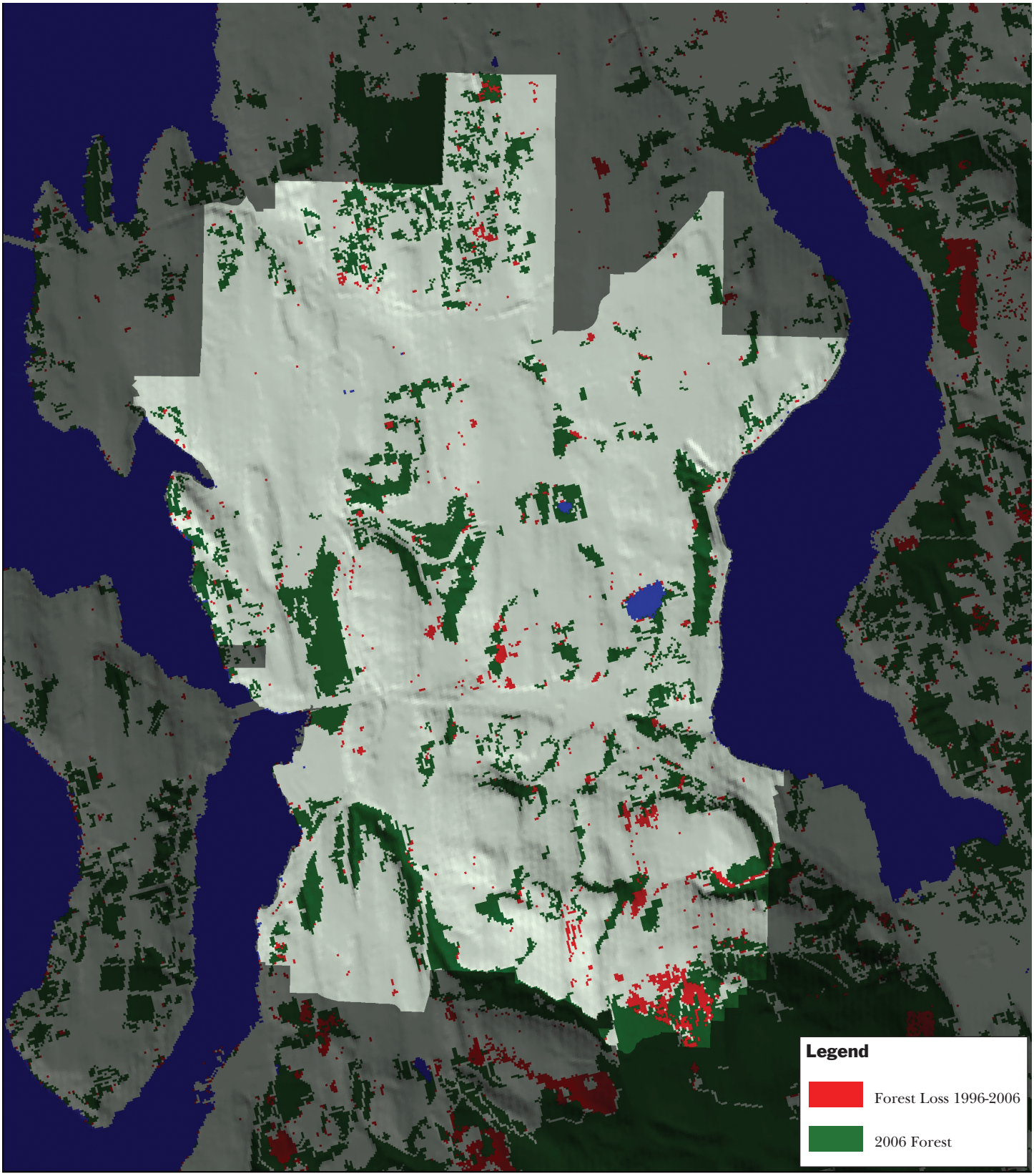
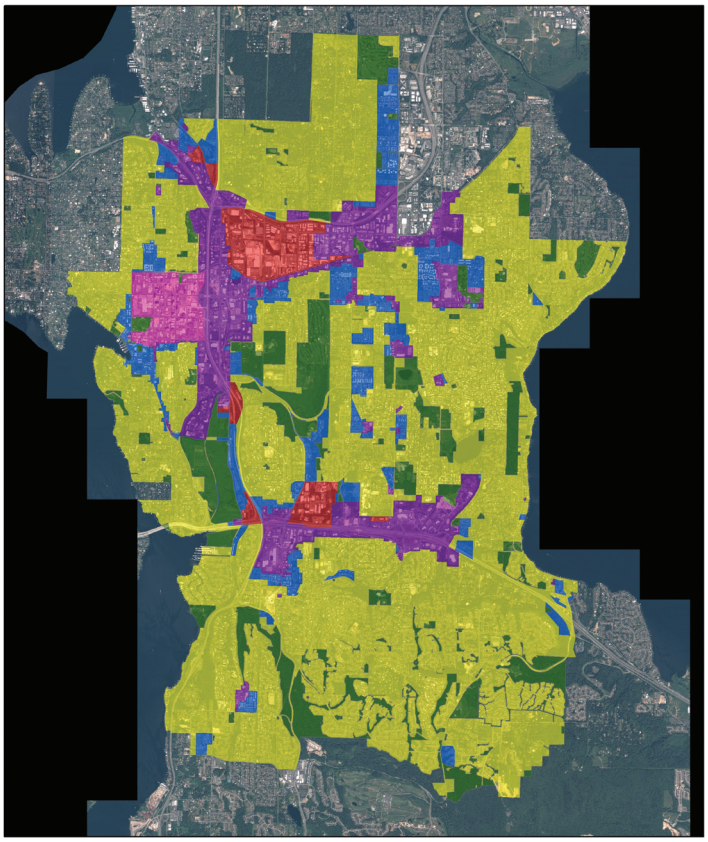


Figure 1: *The images show the forest landcover change trends over two time periods. The area in red denotes forest loss between 1985 and 1996 (left) and the forest loss between 1996 and 2006 (right).*

Forest Landcover Change Trends 1996-2006





Landcover was stratified into seven land use classes: Urban Residential, Suburban Residential, Business District, Commercial and Mixed Use, Industrial, Parks, and public Right of Way (ROW), based on land use and ownership categories within Bellevue.

Tree Canopy and Other Landcover Ecosystem Benefits by Landuse

To better understand how tree canopy and other urban landcover impacts ecosystem benefits, higher resolution imagery now allows us to examine trees in more detail within different land uses. High-resolution, (2 foot) multi-spectral satellite imagery taken in 2007 was classified into ten landcover categories: trees; trees with an impervious understory; shrubs; open space/grass/scattered trees; impervious surfaces general; impervious surface buildings/structures; impervious paved; other impervious; bare soil; and water. Landcover was also stratified into seven land use classes: Urban Residential, Suburban Residential, Business District, Commercial and Mixed Use, Industrial, Parks, and Rights of Way (ROW), based on land use and ownership categories within the City.

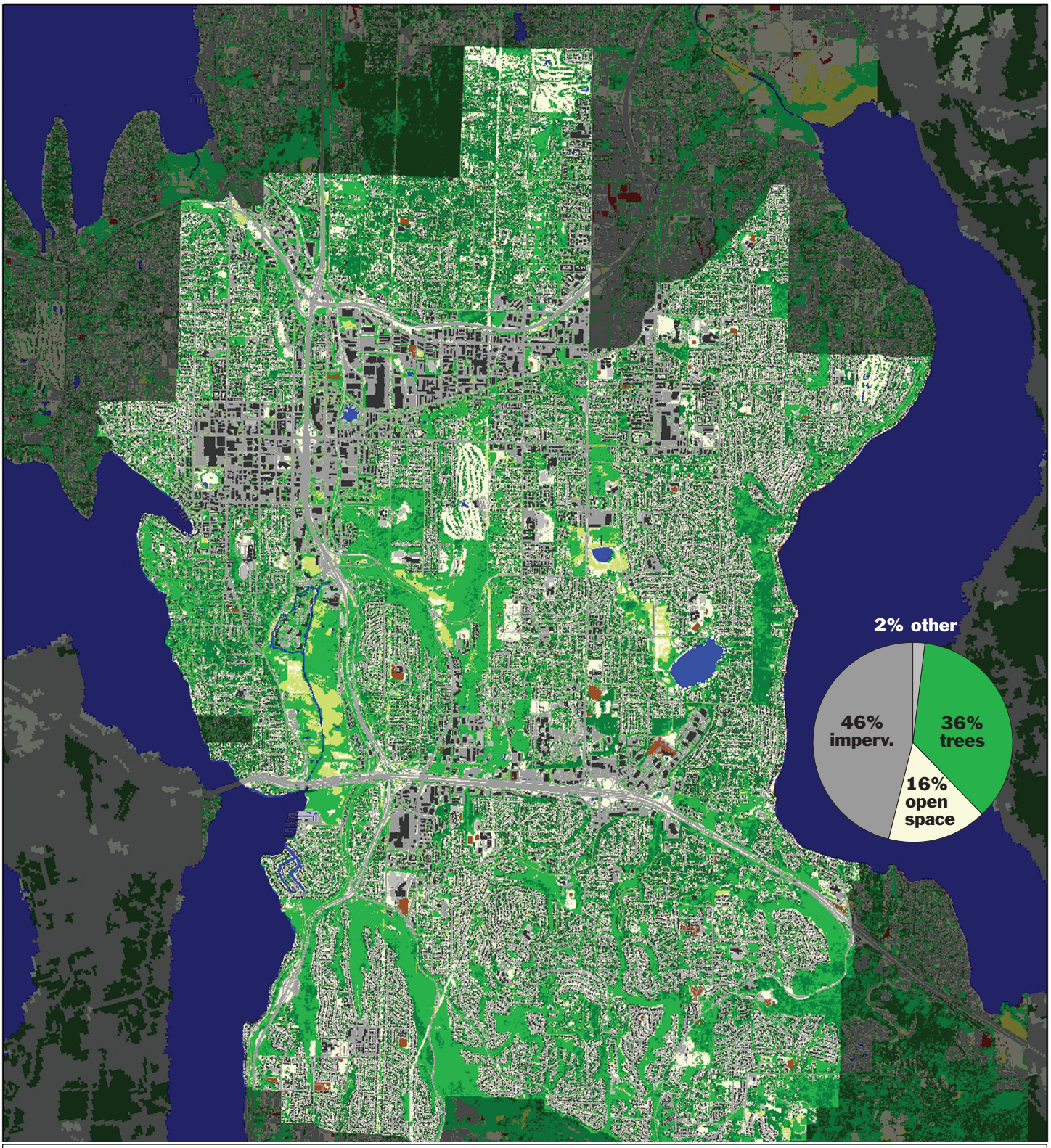
An Urban Ecosystem Analysis was conducted on each land use's landcover (Table 3 and 4). Table 4 lists American Forests' recommendations for tree canopy goals for each land use. As of 2007, Bellevue's 36% overall tree canopy cover is 4% short of American Forests' recommended goals for urban areas east of the Mississippi and in the Pacific Northwest (see http://www.americanforests.org/resources/urbanforests/treedeficit.php for more information on recommended tree canopy goals). Each land use category also falls short of recommended goals.

These recommendations should be considered an initial reference point. Each municipality must designate its own tree canopy goals based on their unique combination of existing tree canopy, climate, geography, soils, planting potential, and vision for the future.

Table 2. Bellevue 2007 High Resolution Data of Landcover by Landuse

	Citywide		Urban Residential		Suburban Residential		Central Business District		Commercial & Mixed Use		Industrial		Parks		ROW	
Landcover	2007 Acres	% Land-cover	2007 Acres	% Land-cover	2007 Acres	% Land-cover	2007 Acres	% Land-cover	2007 Acres	% Land-cover	2007 Acres	% Land-cover	2007 Acres	% Land-cover	2007 Acres	% Land-cover
Trees	7,708	36.1%	456.3	29.5%	4,932.0	35.4%	28.1	7.3%	465.4	20.6%	134.8	19.1%	1,691.4	66.9%	763.3	19.6%
Shrubs	339	1.6%	14.2	0.9%	99.4	0.7%	.06	0.2%	25.6	1.1%	10.4	1.5%	188.4	7.4%	25.8	0.7%
Open space*	3,386	15.8%	136.6	8.8%	2,558.9	18.3%	5.8	1.5%	188.0	8.3%	51.1	7.3%	445.4	17.6%	464.6	11.9%
Impervious	9,713	45.5%	932.5	60.3%	6,209.8	44.5%	351.1	91.1%	1,556.9	68.8%	503.1	71.0%	159.9	6.3%	2,635.1	67.7%
Bare	105	0.5%	1.3	0.1%	71.1	0.5%	0.0	0.0%	10.6	0.5%	4.5	0.6%	17.8	0.7%	4.0	0.1%
Water	126	0.6%	5.2	0.3%	77.0	0.6%	0.1	0.0%	16.3	0.7%	0.9	0.1%	26.9	1.1%	2.3	0.1%
Total Acres	21,377	100%	1,546	100%	13,948	100%	386	100%	2,263	100%	705	100.0%	2,530.0	100%	3,895.2	100%

* Grass/scattered trees



Landcover Classification from 2007 High Resolution Imagery

- Deciduous Trees
- Evergreen Trees
- Shrub
- Open Space
- Bare
- Paved Surfaces
- Buildings & Structures
- Trees over Impervious
- Other Impervious
- Water

Ecosystem Values of Green Infrastructure

A city's pervious landcover serves as its green infrastructure 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. Green infrastructure includes vegetation and their complex interactions with soil, air and water systems. As defined in this project, green infrastructure includes the land cover categories of tree canopy, shrub, open space/grass/scattered trees, bare soil, and water.

Bellevue's urban forest contributes to its multiple ecosystem benefits (Table 3). With 7,708 acres of tree canopy citywide, Bellevue's urban forest manages 61,644,489 cubic feet of stormwater, valued at $123.3 million, removes 687,129 lbs. of air pollutants annually, valued at $1.6 million per year, stores 331,702 tons of carbon and sequesters 2,582 tons of carbon annually.

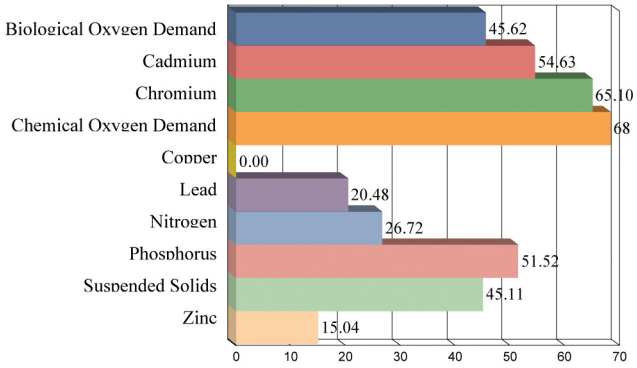
Stormwater Ecosystem Services

Trees reduce the volume of stormwater runoff by capturing some rain on their leaves and branches, which then evaporates back into the atmosphere. Other water infiltrates into the soil rather than running off the land which must be managed. Bellevue's urban forest manages 61,644,489 cubic feet of stormwater, valued at $123.3 million using a conservative $2 per cubic foot. Anecdotally, based on recent local stormwater construction costs of $10-11 per cubic foot, the value of stormwater management services could be much higher in Bellevue.

Water Quality Ecosystem Services

Tree roots absorb water pollutants; the impact of eight can be calculated from the stormwater runoff changes: Biological Oxygen Demand, Cadmium, Copper, Lead, Nitrogen, Phosphorus, Suspended Solids, and Zinc. Citywide, water pollution, as measured in percent change in pollutant loading would worsen by between 15% and 68% if trees were removed from the land (a detailed graph of water pollutant loading per land use resides in the map book that accompanies this report).

Percent Change in Contaminant Loadings



Air Quality Ecosystem Services

The ecological value of air quality ecosystem services is based on the UFORE model developed by the U.S. Forest Service. The dollar value is calculated based on externality costs to society of the additional air pollution. Externality values are established by State Service Commissions. Bellevue's urban forest removes 687,129 lbs. of air pollutants annually, valued at $1.6 million per year.

Trees have a direct impact on the carbon footprint. Trees help clean the air by storing and sequestering atmospheric carbon in their wood. Total storage and the rate at which carbon is stored (known as sequestration) can be measured. Bellevue's tree canopy stores 331,702 tons of carbon and annually sequesters 2,582 lbs. of carbon.

While this analysis does not address tree health per se, it stands to reason that the healthier the urban forest, the greater its' potential for maximizing the ecosystem services it provides. According to forest health sampling conducted by Bellevue Park Department Forestry staff, the health of Bellevue's natural areas and open space varies throughout the City. Site condition range from healthy and sustainable to degraded sites where new forest regeneration is minimal and forest successional processes have been disrupted by invasive plants. American Forests urges the City to continue its aggressive program of management of public trees as well as launching a public education program for tree care on private property to improve the health of the entire urban forest.

Table 3. Bellevue Ecosystem Services

	Area acres	2007 Tree Canopy acres	Air Pollution Removal lbs./ yr	Air Pollution Removal Value dollar value	Carbon Stored tons	Carbon Sequestered tons/ yr	Stormwater Value cu. ft.	Stormwater Value @$2 per cu. ft. dollar value
City of Bellevue	21,377	7,708	687,129	$1,545,150	331,702	2,582	61,644,489	$123,288,978
Urban res.	1,546	456	40,679	$91,476	19,637	153	4,049,992	$8,099,983
Suburban res.	13,948	4,932	439,642	$988,625	212,231	1,652	39,135,381	$78,270,761
Business District	386	28	2,503	$5,629	1,209	9	197,272	$394,544
Commercial & Mixed Use	2,263	465	41,482	$93,280	20,025	156	4,153,951	$8,307,902
Parks	2,530	1,691	150,769	$339,034	72,781	567	10,325,002	$20,650,005
ROW	3,895	763	68,045	$153,014	32,848	256	6,379,182	$12,758,365
Industrial	705	135	12,015	$27,018	5,800	45	1,281,229	$2,562,459

Note that the sum of the land uses stormwater values doesn't total to the citywide value. This is because the each land use has a specified soil type, whereas citywide, soil type must be generalized for the entire area.

Modeling Ecosystem Benefits of Recommended Tree Canopy Percentages

By increasing tree canopy cover to recommended goals, the city will increase their environmental services that tree canopy provides. The additional tree canopy percentage in each land use category was modeled to demonstrate these added ecological and economic benefits. Table 5 details ecosystem services of increasing tree canopy by decreasing impervious paved surfaces and changing impervious surface under trees to pervious surfaces.

If Bellevue increased its canopy cover by 4% overall, the ecosystem services would add an additional $169,000 in annual air pollutant removal value, an additional 36,000 tons of carbon stored and an annual 282 tons of carbon sequestered, as well as 4.4 million cubic feet of additional managed stormwater, valued at $8.7 million. If tree canopy were increased in the ROW from 20% to 25% by reducing impervious surface, the additional tree canopy would provide an additional 1.9 million cubic feet in stormwater management capacity, valued at $3.7 million.

Modeling demonstrates the benefits of changing impervious surface to pervious for controlling stormwater runoff. For example, in the central business district, if the 15.5 acres of trees with an impervious surface understory were changed so that the same trees had a pervious understory allowing storm water to infiltrate into the soil rather than rolling off paved surfaces, an additional 131,408 cubic feet of stormwater would be managed, valued at $262,816.

Recommendations

This project has quantified the City of Bellevue's green infrastructure—its landcover and corresponding ecosystem services. This digital data is packaged into a GIS interactive data layer compatible with existing GIS data so that City staff can use it in future planning decisions. American Forests recommends that the data and CITYgreen® software be used to run landcover scenarios, establish citywide tree canopy goals, quantify the progress made with current and new tree initiatives, and educate the public about the value of protecting and increasing tree canopy on private property.

Goals for Citywide Tree Cover

Establish unified tree canopy goals for the entire City and stratify these goals for land use categories. Base these goals on City mandates for achieving environmental goals for air and water. Incorporate these goals into planning and development policies.

- Use American Forests' canopy goals for the Pacific Northwest as a guide, but the City should develop its own goals and specific strategies to increase canopy cover and ecosystem services citywide.
  - 40% citywide
  - 50% in suburban residential
  - 35% in urban residential
  - 25% in commercial and mixed use
  - 25% in industrial
  - 15% in the central business district

Table 4. Tree Canopy Percentage by Land Use

	Citywide	Urban Residential	Suburban Residential	Central Business District	Commercial & Mixed Use	Industrial	Parks	ROW
Canopy %	36%	30%	35%	7%	21%	19%	67%	20%
AF Recommended Canopy %	40%	35%	50%	15%	25%	25%	25%	25%
Difference in Canopy %	-4%	-5%	-15%	-8%	-4%	-6%	-5%	-5%

Table 5. Modeling the Ecosystem Benefits of Increasing Tree Canopy to Recommended Percentages

If Bellevue land use zones increased its canopy cover to recommended percentages, ecosystem services would increase by:	Additional % Canopy	Stormwater Value cu. ft.	Stormwater Value @ $2 per cu. ft. dollar value	Air Pollution Removal lbs./ yr.	Air Pollution Removal Value dollar value	Carbon Stored tons	Carbon Sequestered tons/ yr.
Citywide	4%	4,358,258	$8,716,516	75,112	$168,904	36,259	282
Urban residential	5%	752,822	$1,505,643	8,936	$20,092	4,313	34
Suburban residential	15%	12,188,102	$24,376,204	182,033	$409,337	87,874	684
Business District	8%	342,357	$684,714	2,653	$5,965	1,280	10
Commercial & Mixed Use	4%	858,868	$1,717,735	8,947	$20,119	4,319	34
Industrial	6%	341,551	$683,102	3,691	$8,299	1,782	14
Business District w/ pervious understory	0%	131,408	$262,816	2,475	$5,565	1,195	9
ROW	5%	1,863,351	$3,726,701	18,760	$42,185	9,056	71

Note that Business District w/impervious surface doesn't add tree canopy, it changes the understory to pervious and in doing so, increases its ecosystem benefits as listed.
Note these landuses do not include park land

Strategies for Increasing Canopy Cover and the Benefits of Bellevue's Urban Forest

Develop a three pronged approach for increasing tree canopy cover within three land ownership categories:

1. City Parks and Open Space- Use the green data layer and CITYgreen to document the ecosystem services provided by existing forest and tree management programs and new strategies to protect environmental quality within different city departments

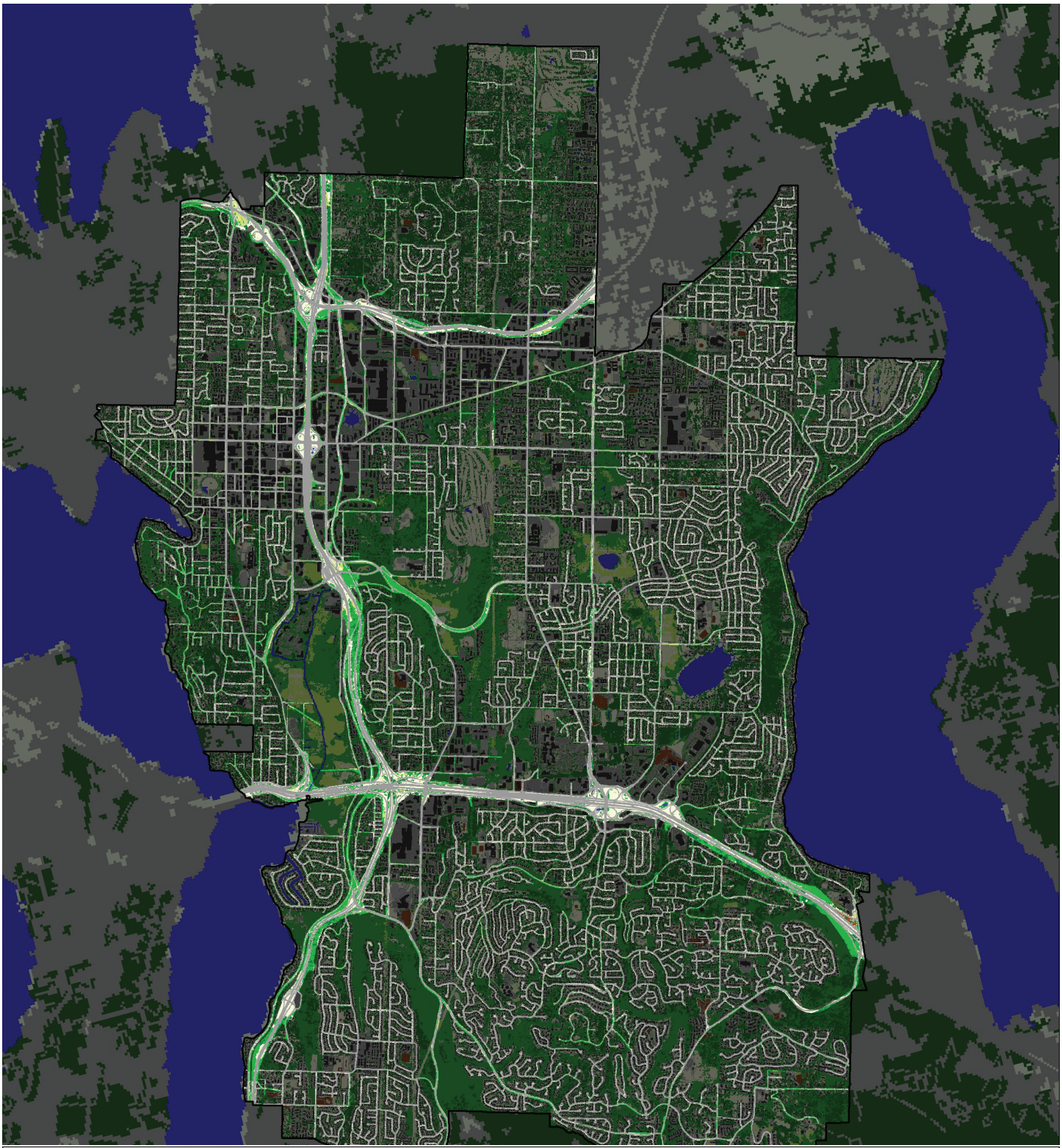
- Health of the Urban Forest
  - Along with enhancing the size of the urban forest it is also important to improve the health of the existing urban forest to maximize its potential to provide ecosystem services.
  - Through aggressive and proactive forest management practices, raise tree health for all classes of tree canopy to a healthy and sustainable state.
- Share the green data layer provided with this project with other city departments concerned with related ecosystem services. For example, Bellevue's stream buffers play an important role in providing a non-structural water quality best management practice. In 2007, Bellevue had 1,291 acres of stream buffers 64% of which was tree canopy. The combined ecosystem benefits provided $166,241 in air pollution reduction value, stored 35,687 tons of carbon, sequestered 278 tons of carbon annually, and reduced 6.9 million cubic feet of stormwater runoff, valued at $13.7 million.
- Use the modeling capabilities of CITYgreen software for planning. Test the impacts of changing tree canopy, impervious surfaces, and other land covers under different development scenarios.

2. Private - Launch a public education campaign to increase public awareness of the direct relationship between environmental quality and tree canopy and encourage private citizens to plant trees on private property

- Use analysis findings in popular media to educate the public about the importance of their role in increasing the urban forest and the positive impact planting on private property will make.
- 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.
- Implement a pro-active public education program so that the general public can contribute to protecting and enhancing the City's urban forest ecosystem by implementing best management practices, planting, and maintaining trees on private property.

3. Public ROW- With almost 4,000 existing acres of land provides a good opportunity to increase tree canopy on existing public land with an active planting program.

- Provide more pervious paving in areas where there is impervious understory for tree canopy. This will improve the stormwater reduction function of the existing tree canopy. For example in the Central Business District, if the 15.5 acres (4%) of existing trees that currently have an impervious understory were given pervious ground surface, it would further reduce stormwater runoff by 131,000 cubic feet, valued at $262,816.
- Initiate an active public tree planting program to meet increased canopy goals within ROW land. A 5% increase in ROW tree canopy can provide an additional 1.9 million cubic feet in stormwater runoff mitigation, valued at $3.7 million.



Right of Way Landcover Classification from 2007 High Resolution Imagery

Deciduous Trees	Open Space	Buildings & Structures	Water
Evergreen Trees	Bare	Trees over Impervious	
Shrub	Paved Surfaces	Other Impervious	

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

American Forests calibrated land cover change based on the USGS 2001 National Landcover Dataset (NLCD) to update the prior Urban Ecosystem Analysis (UEA) rather than updating the 1996 data from the original UEA. Imagery and classification techniques have changed substantially since the initial analysis. The U.S. Geological Survey's data is now the standard for Landsat-derived land cover change analysis. Imagery of Bellevue were classified from 1985, 1990, 1996, 2001, and 2006 and land cover change trends were quantified and documented. American Forests classified the imagery into four land classes: trees, urban, open space, and water.

For the high resolution imagery, Sanborn, American Forests' geospatial partner, acquired 4-inch resolution, true-color aerial photography in the late spring of 2007 and resampled the data to a 2ft. pixel resolution. Sanborn then conducted a knowledge-based classification to divide the landcover into ten categories: deciduous trees, evergreen trees, trees over impervious surfaces, shrubs, open space/grass/scattered trees, other impervious surfaces (such as gravel parking lots), impervious surfaces (buildings), impervious surfaces (paved), bare soil, and water. Sanborn also created a separate impervious layer utilizing building and street data provided by the city of Bellevue. This layer was essential in identifying tree canopy with impervious understory.

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. The following formulas are incorporated into CITYgreen software.

TR-55 for Stormwater Runoff: The analysis estimates the amount of stormwater that runs off a land area during a storm. 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, and particulate matter less than 10 microns are absorbed and filtered by tree canopies. 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. The UFORE model also estimates carbon storage capacity and annual amount of carbon sequestered by tree canopy in a given area.

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 ArcGIS products.

Environmental Stewardship Initiative

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