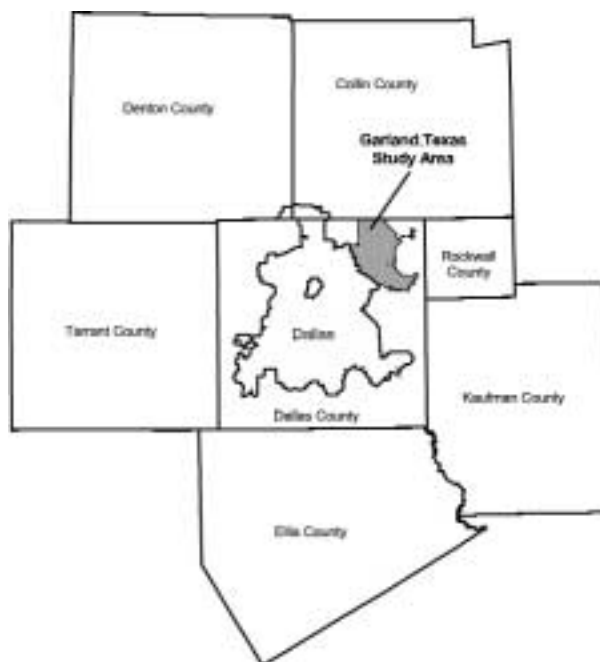

April 2000

Local Ecosystem Analysis Garland, Texas

Calculating the Value of Nature

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Local Ecosystem Analysis

Garland, Texas

Project Overview

AMERICAN FORESTS conducted an Urban Ecosystem Analysis of the City of Garland to map, measure and analyze the value of the city's tree cover for stormwater management, air quality and energy conservation. Stormwater management was the central focus of the analysis.

Trees provide significant stormwater management functions. They slow runoff by intercepting water with their leaves and branches. Under their crowns, they create highly permeable soils that allow water to soak into the land rather than run rapidly over the surface. Their root systems absorb polluting nutrients like nitrogen and phosphorous that would otherwise be deposited into city drainage. Trees are very effective at moderating the negative environmental effects of a city's built infrastructure, and their effectiveness at doing so can be calculated and used for managing urban stormwater. By maintaining a healthy green infrastructure, a city makes a sound investment in its future. Trees are indicators of the quality of the overall city environment. When tree cover is high (around 30% for Garland) and the trees are healthy, the quality of the green infrastructure is good. This green infrastructure can become a valuable part of the city's stormwater management system, by doing the same stormwater management work of costly physical structures.

The Urban Ecosystem Analysis technique conducted in Garland used Geographic Information System (GIS) technology along with scientific research and time-tested engineering practices to calculate the effects of trees on the urban environment. Using the spatial maps and data provided by the city, along with aerial photography and ground sampling techniques, AMERICAN FORESTS created a working model of Garland's green and gray infrastructure. Detailed information from 10 ground samples was used to calibrate this ecological model and GIS technology provided the mathematical engine to drive the model so it emulated the city's green infrastructure.

Major Findings

Urban Forest Canopy Cover: Analysis of sample sites from residential, commercial and industrial land use categories revealed a 10.6% average tree canopy coverage in Garland. While this existing tree canopy provides significant dollar benefits to the city, the benefits could be double or triple what they are today.

Stormwater Runoff Reduction: In Garland, tree cover in residential, commercial and industrial areas currently reduces stormwater runoff by 19 million cubic feet during a major storm event*. This finding compares Garland's existing tree canopy cover with a no-canopy cover condition. A very conservative estimated cost of constructing stormwater retention facilities to handle this runoff is valued at \$38 million (assuming a \$2 per cubic foot construction cost). Annually, the savings is estimated to be \$2.8 million. Actual avoided cost savings may be as much as three times this conservative estimate, depending on local construction costs in Garland (figure unavailable at time of publication).

Carbon: By removing and storing carbon, as well as cooling urban heat islands and reducing energy consumption, trees reduce atmospheric carbon. The city's trees currently store approximately 209,000 tons of carbon and sequester—the rate at which carbon is stored—approximately 531 tons of carbon per year. In addition, the residential energy conservation impact of Garland's trees results in 4,400 tons of avoided carbon emissions annually.

Air Pollutant Removal: Forest canopy removes five major air pollutants, SO₂, NO₂, CO, O₃ and PM₁₀. In Garland, trees remove 497,000 pounds of pollutants valued at \$1.2 million per year, based on estimates of economic impact established by state Public Service Commissions.

Energy Savings: Garland's direct residential summer energy savings, as a result of trees shading homes, is estimated at \$1.3 million annually. USDA Forest Service research suggests that the indirect cooling from evapotranspiration will produce an additional savings of roughly equal size.

Total Value: The total annual value of Garland's existing urban forest is calculated by adding stormwater, air quality, and summer energy savings together and is estimated at \$5.3 million. If Garland were to increase its tree canopy to 30%, a national goal recommended by AMERICAN FORESTS, benefits of the tree cover would increase substantially.

*Reduction in stormwater runoff from an average maximum two-year, 24-hour storm event.

Local Analysis

Garland's Ecological Issues

The City of Garland, TX has already adopted an innovative approach to managing stormwater by charging a stormwater utility fee to property owners based on the amount of impervious surfaces they have. While it is widely known that impervious surfaces exacerbate stormwater runoff and result in extra costs, few cities make a financial connection between the cause and effect of these stormwater problems like Garland does. Combining information on tree cover with existing data documenting the impervious surface area will provide Garland with a sophisticated stormwater management model that will further improve this innovative approach. Using CITYgreen® software, Garland can model proposed changes in the infrastructure and tree cover and calculate the resulting effects on stormwater flow.

In 1990, the City of Garland established a stormwater utility to fund flood control improvements, water quality treatment, groundwater recharge, and ecological preservation projects. The city has mapped all its impervious surfaces to better estimate stormwater flow. Landowners are assessed a stormwater fee based on impervious surface area, which correlates to the amount of runoff and pollutants contributed by the site.

Increasing urban tree canopy cover can significantly reduce the volume and impact of stormwater runoff, which improves water quality. While it may be difficult for individual land owners to significantly reduce impervious surface area on site, it is very possible to increase the number of trees and other vegetation, thus lowering stormwater runoff. Garland could lower runoff from private property by providing citizens and business owners with landscaping incentives that increase tree canopy. Property owners could lower their stormwater utility fees by increasing tree canopy on-site.

Analysis Methods

Building an ecosystem model for Garland starts by visualizing the structure and function of its natural resources. AMERICAN FORESTS' Urban Ecosystem Analysis method is based on the assessment of land units called ecostructures. Ecostructures are unique combinations of land-use (residential, commercial, etc.) and land cover (grass, impervious surface, trees) information. Each ecostructure performs a different set of ecological functions, which can be evaluated for its economic impact and value.

The City of Garland provided black and white digital orthophotography and selected 10 study sites ranging in size from 3.86 to 27.17 acres. These sites represent a broad spectrum of land use and land cover, including single family residential, commercial and industrial.

ArcView GIS and CITYgreen® were used to map elements of the landscape and build a mathematical model for analysis. Each of the land elements was digitized as a GIS layer (trees, buildings, and impervious surfaces). City staff and urban forestry consultants from Davey Tree Expert Company conducted ground truthing and collected data on tree species, size, and health within each site.

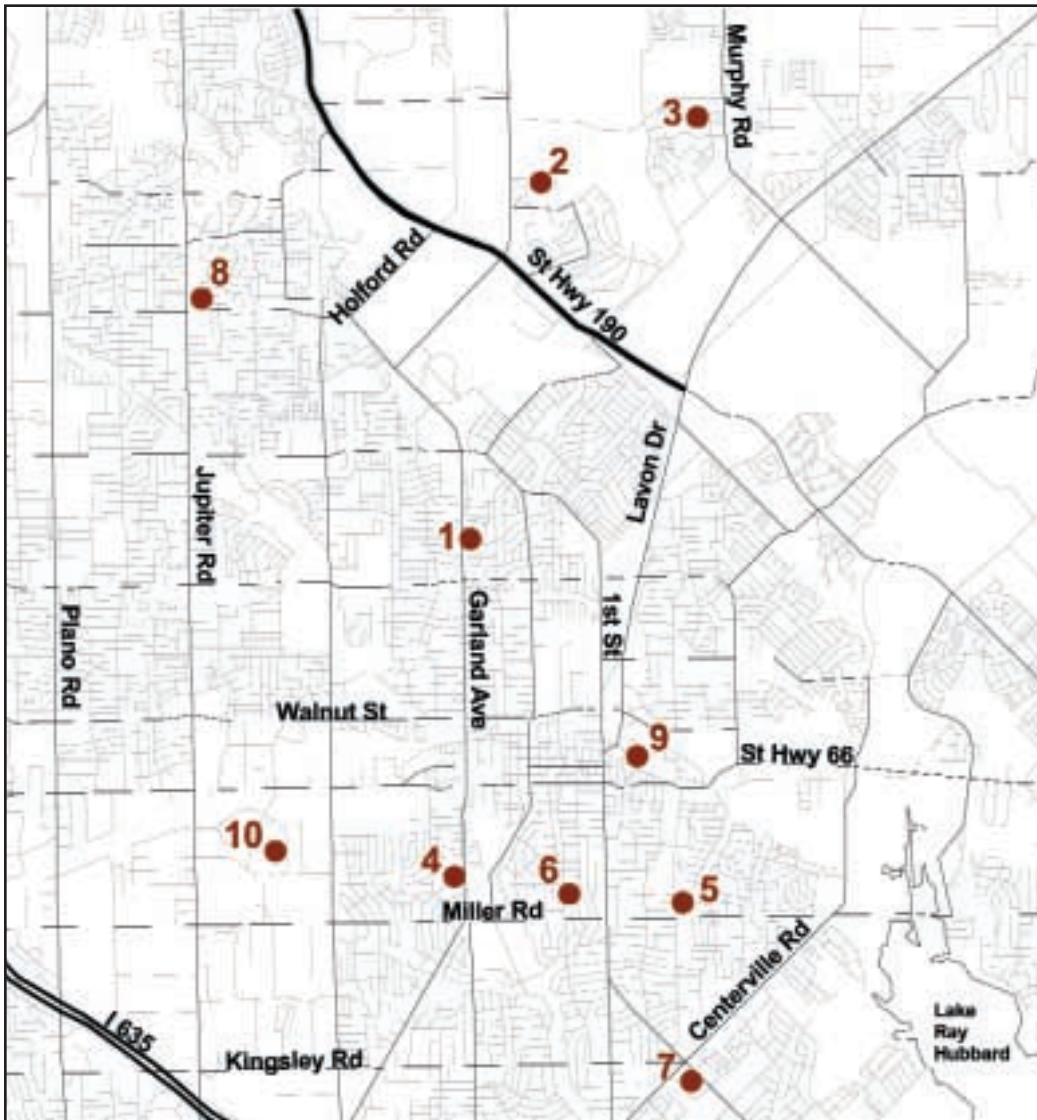
AMERICAN FORESTS entered the inventory data for the sites into CITYgreen®. Once the data was prepared, CITYgreen® was used to assess the environmental and economic value of trees in each study site. Finally, citywide values were estimated by projecting analysis results from sample sites across acreage with similar land use types. Citywide projections are shown in Table 1.

Table 1. Annual City-Wide Benefits of Garland's Existing Urban Forest





Benefit Categories	Environmental Benefits	Annual Dollar Value of Benefits
Stormwater Management	19 million cu. ft. retention facility with 30 yr. lifetime	\$2.8 million*
Air Pollutants Removed	497,000 lbs. per year	\$1.2 million
Energy Savings	\$28/home per year	\$1.3 million
Total Annual Value		\$5.3 million

*Reduction in stormwater runoff from an average maximum two-year, 24-hour storm event. The total cost is calculated by multiplying the volume by an estimated \$2.00 per cubic foot of constructed stormwater containment facilities, plus the cost of the loan or bond to finance construction (6% for 30 years). Construction costs in Garland may be 2 or 3 times higher.

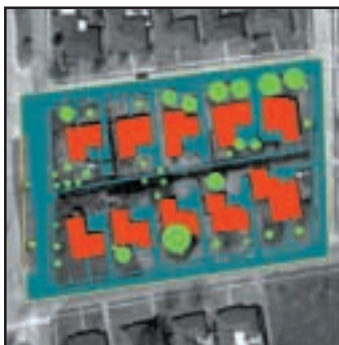
Garland Study Sites



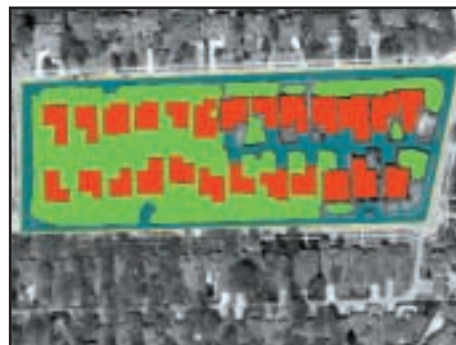
Legend

-  tree cover
-  local site boundary
-  built structure
-  impervious surface

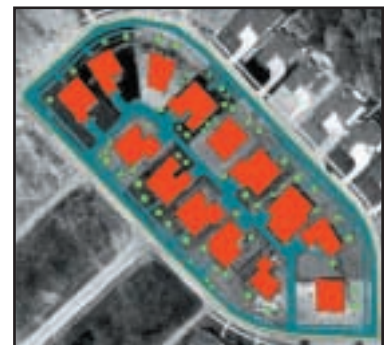
Digital photographs of each site shown with GIS coverage of trees, buildings, and impervious surfaces.



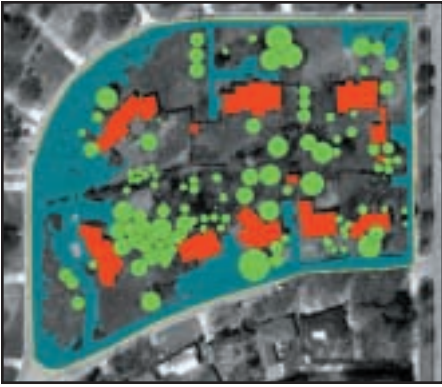
Site 1
Medium-size, residential
Canopy coverage: 8%
Study area: 3.86 acres



Site 2
Medium-size, residential
Canopy coverage: 43%
Study area: 6.05 acres



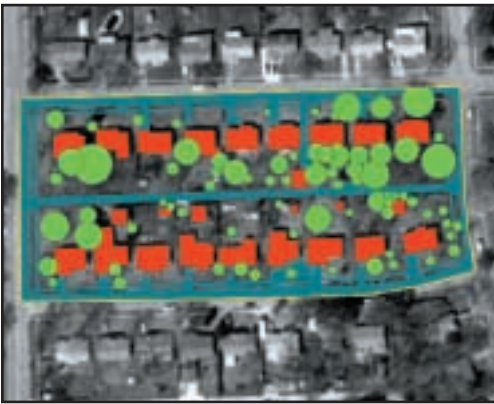
Site 3
Large-size residential
Canopy coverage: 4%
Study area: 4.61 acres



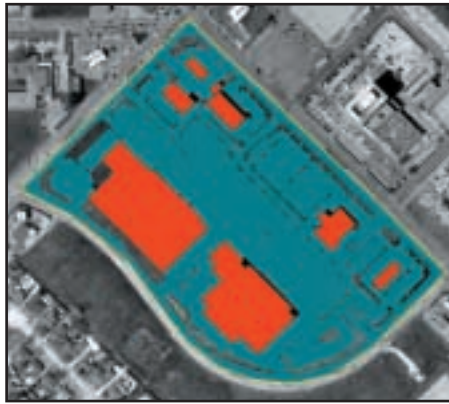
Site 4
 Large-size residential
 Canopy coverage: 17%
 Study area: 8.36 acres



Site 5
 Small-size residential
 Canopy coverage: 7%
 Study area: 5.34 acres



Site 6
 Small-size residential
 Canopy coverage: 19%
 Study area: 4.87 acres



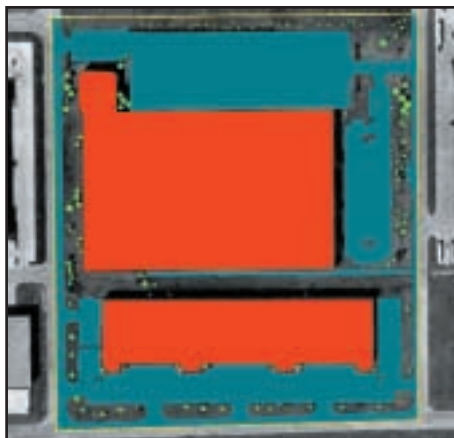
Site 7
 Commercial
 Canopy coverage: 1%
 Study area: 27.17 acres



Site 8
 Commercial
 Canopy coverage: 0%
 Study area: 10.68 acres



Site 9
 Industrial
 Canopy coverage: 5%
 Study area: 8.75 acres



Site 10
 Industrial
 Canopy coverage: 2%
 Study area: 21.38 acres

Analysis Findings

Forest Health

Forest health was assessed on a 1-5 ranking, with 1 indicating very poor health and 5 indicating excellent health. Relatively consistent health conditions were found across the city's urban forest. Tree health in the seven study sites where health data was collected ranged between 1 and 4 with an average rating of 3.6, which is defined as better than "good."

Air Quality

Trees provide air quality benefits by removing pollutants such as NO₂, SO₂, CO, O₃ and PM₁₀. A dollar value for these pollutants was determined by averaging the "externality costs" set by state Public Service Commissions. Externality costs are costs to society that are not reflected in marketplace activity. In Garland, the existing tree canopy removes 497,000 pounds of pollutants per year, at an annual value of \$1.2 million.

Carbon

The study also analyzed the amount of carbon stored and sequestered per year. Carbon accounts for about half the dry weight of most trees. The carbon-related function of trees is measured in two ways: storage, or the amount currently stored in tree biomass, and sequestration, the rate of absorption per year. The city's urban forest currently stores an estimated 209,000 tons of carbon and sequesters about 531 tons of carbon annually. Since trees reduce summer energy costs, 4,400 tons of utility-based carbon emissions are avoided annually.

Energy Use

Garland experiences a long summer, and residents spend approximately \$408 per home (Lawrence Berkeley National Lab) on air conditioning per year. AMERICAN FORESTS' analysis suggests that the existing tree canopy in residential sample sites saves an average of \$28 per home. (Note: Because USDA Forest Service research has thus far only modeled savings to residential-size buildings, values were not calculated for residential homes greater than two stories, commercial or open space sites.)

To estimate the citywide energy conservation savings of trees, the average savings of \$28/home was projected across the city's 48,742 single-family detached residences in Garland (1990 Census data). Assuming that 95% of residences have air conditioning (McPherson et al, 1993), the estimated annual residential savings is approximately \$1.296 million.

Stormwater Runoff

Trees slow storm flow, reducing the volume of water that must be managed in urban areas and reducing the amount of runoff that containment facilities must store. Trees and soil work together in this stormwater reduction effort. Trees reduce stormwater flow by intercepting rainwater on leaves, branches, and trunks, slowing its movement into channelized drainage areas. Stormwater volume is also reduced because some intercepted water evaporates directly back into the atmosphere or soaks into the soil. The net effect is a reduction in time of concentration and potential flooding, a critical concern during heavy rains. During light rains, trees provide their greatest benefit by promoting soil permeability to facilitate groundwater recharge. Reducing impervious surfaces and increasing tree cover promotes the movement of water into the water table.

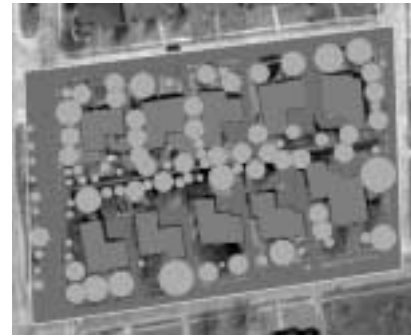
The TR-55 stormwater engineering model, developed by the Natural Resources Conservation Service, was used to measure stormwater runoff in Garland. Used as a planning tool in more than 300,000 communities, TR-55 was developed from 50 years of NRCS data collection in the nation's major ecosystems.

To estimate the dollar benefits of stormwater reduction provided by trees, AMERICAN FORESTS multiplied the total volume of avoided stormwater runoff (19 million cubic feet) by the construction cost for building retention ponds (\$2 per cubic foot, see explanation pg.2). Including the cost of construction financing, trees currently save roughly \$38 million over 30 years, or \$2.8 million annually.

AMERICAN FORESTS estimates runoff volume ranging from 2.54-3.67 inches (based on an average 24-hour, 2-year storm event) across Garland sample sites. Generally speaking, areas with little tree canopy, little grass and significant impervious surface area had the highest runoff rates. The effects of vegetation on stormwater flow is most apparent by comparing runoff volume on Site 2 (residential) to Site 8 (commercial). Site 2 contains 29% impervious surface, 28% grass and 43% tree canopy, resulting in a runoff reduction of 16%. Site 8 contains 94% impervious surface, 6% grass and 0% canopy, resulting in no appreciable runoff reduction.

Table 2. Stormwater Runoff in Garland Study Sites

Site	Study Area (Acres)	% Canopy	% Grass	% Impervious (Including Buildings)	Land Use	Runoff Volume (Inches)	% Runoff Reduction
1	3.86	8%	39%	53%	residential	3.03	3%
2	6.05	43%	28%	29%	residential	2.54	16%
3	4.61	4%	49%	47%	residential	2.96	1.4%
4	8.36	17%	57%	26%	residential	2.62	6.6%
5	5.34	7%	59%	34%	residential	2.77	2.7%
6	4.87	19%	41%	40%	residential	2.79	7.3%
7	27.17	1%	12%	87%	commercial	3.54	.3%
8	10.68	0%	6%	94%	commercial	3.67	0%
9	8.75	5%	40%	55%	industrial	3.07	2.1%
10	21.38	2%	22%	76%	industrial	3.38	.6%



25% tree cover



35% tree cover



45% tree cover

Stormwater Modeling

Using CITYgreen® stormwater models, AMERICAN FORESTS calculated the effect of various levels of tree cover on stormwater flow for a residential site with 8% canopy cover (see Site 1 on pg. 4). When tree canopy was increased, impervious surface and grass were decreased in equal amounts to make up the difference. The results in Table 3 show that stormwater, air quality, carbon sequestration, and summer energy savings benefits all increase with canopy cover.

In the original site containing 8% canopy, stormwater runoff is reduced by 1,315 cu.ft. A CITYgreen® analysis of canopy models showed that as canopy increased runoff benefits increased. At a 25% canopy, stormwater volume is reduced by 4,223 cu.ft.; 35% canopy, 5,941 cu.ft.; 45% canopy, 7,635 cu.ft. As canopy increased, so did savings on related stormwater constructions costs. For an 8% canopy, the city saved \$2,630; at 25% canopy, \$8,446; at 35% canopy, \$11,881; at 45% canopy, \$15,270.

Table 3. Tree Canopy Modeling Scenarios for Site 1

Tree Canopy*	Stormwater			Energy	Air Quality	
	Runoff Reduction**	Avoided Storage*** (cubic feet)	Dollar Savings****	Energy Savings (per year)	Carbon Sequestration (tons per year)	Pollution Removal (per year)
8%	3%	1,315	\$2,630	\$103	0.02	\$76
25%	9.3%	4,223	\$8,446	\$270	0.07	\$244
35%	12.8%	5,941	\$11,881	\$370	0.1	\$341
45%	16.1%	7,635	\$15,270	\$431	0.13	\$438

* When tree canopy is increased, grass area and impervious surfaces are decreased equally.

** Stormwater benefit based on existing trees compared with a 0% tree canopy condition.

*** Volume of water to manage if existing trees were removed.

**** \$2/cubic foot estimated cost of storing stormwater; construction savings received over the 30-year estimated life of the retention facility.

Recommendations

These findings address public policy questions for land-use planning and growth management in Garland, Texas. The city has an opportunity to engineer more tree cover into its infrastructure and utilize the substantial benefits trees provide to reduce stormwater management costs and improve overall environmental quality. A large, healthy urban forest is indicative of healthy soil, air, and water resources. These recommendations offer guidelines for improving Garland's green infrastructure.

1. Develop public policies that increase the city's tree cover, promote green infrastructure as nonstructural stormwater management facilities, and offer public incentives.

- Incorporate a natural resource data layer into the GIS information used by the city.
- Use tree cover and green infrastructure as part of stormwater management strategies.
- Promote green infrastructure as a stormwater management strategy with The North Central Texas Council of Governments (NCTCOG) and regulatory agencies.
- Use CITYgreen® to promote public awareness of the connections between urban forests and water quality.
- Use stormwater utility fees to enhance the city's urban forestry program and provide incentives for property owners to plant and maintain their trees.

2. Include trees and the values associated with trees when making land-use decisions.

- Implement innovative land-use planning techniques and engineering guidelines for saving existing trees as well as planting new ones.
- Determine local cost per cubic foot for managing stormwater in Garland and use this number to estimate trees' impact to stormwater management.

3. Set tree cover goals for the city and institutionalize a system to maintain this goal.

- Specific Goals for Garland Based on Existing Land Use Categories:

40% tree canopy in "large residential"
 30% tree canopy in "medium residential"
 20% tree canopy in "small residential"
 15% tree canopy in "commercial"
 15% tree canopy in "industrial"

Acknowledgments

This analysis was commissioned by the City of Garland, Texas. AMERICAN FORESTS also acknowledges the support of ESRI for GIS technology and ERDAS for remote sensing technology.

Analysis Formulas

TR-55 for Stormwater Runoff: The stormwater runoff calculations incorporate formulas from "Technical Release 55: Urban Hydrology for Small Watersheds" developed by the US Natural Resources Conservation Service (NRCS). The agency has also provided considerable technical advice on the application of this model to urban areas.

UFOR Model for Air Pollution: CITYgreen uses formulas from models developed by David Nowak, PhD, for the USDA Forest Service to calculate the air pollutant removal and carbon sequestration.

Energy Conservation: CITYgreen uses formulas for energy conservation developed by E. Gregory McPherson for the USDA Forest Service and by Lawrence Berkeley Laboratory in California.

For More Information

AMERICAN FORESTS, founded in 1875, is the oldest national nonprofit citizen conservation organization. Its three centers—Global ReLeaf, Urban Forests, and Forest Policy—mobilize people to improve the environment by planting and caring for trees. Global ReLeaf 2000 is a campaign to plant 20 million trees for the new millennium.

AMERICAN FORESTS' CITYgreen® software provides individuals, organizations, and agencies with a powerful tool to evaluate development and restoration strategies affecting urban ecosystems. AMERICAN FORESTS provides regional training workshops and technical support for CITYgreen and is a certified ESRI developer and reseller of ArcView products. For further information contact:

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