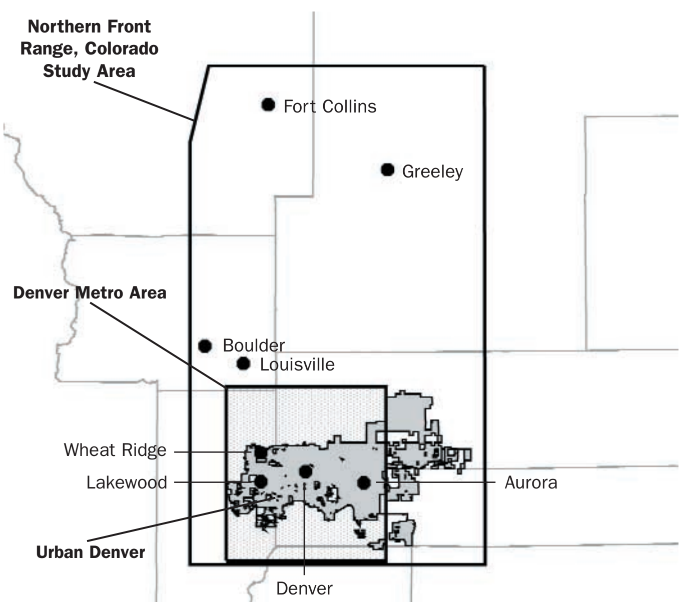
*April 2001*

# Regional Ecosystem Analysis for Metropolitan Denver and Cities of The Northern Front Range, Colorado

*Calculating the Value of Nature*

## Report Contents



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# Regional Ecosystem Analysis of the Northern Front Range

## Project Overview

AMERICAN FORESTS conducted a Regional Ecosystem Analysis of the Denver metropolitan area and cities along the Northern Front Range in Colorado. The study, extending from the Denver metro area on the south to Fort Collins on the north, determined how the landscape has changed from 1986-1998 and to what degree urban tree canopy provides environmental and economic benefits to cities within this region.

The findings in this report are intended to inform public policy makers and citizens of the past, present and future condition of the landscape. Those can then be used to adjust policies that guide growth and development.

The study was conducted at three scales providing: 1) A regional perspective of changing land use over 12 years on 2.24 million acres in the Northern Front Range study area including the Denver metro area, Boulder, Fort Collins, Greeley, and Louisville; 2) The changing land use over time in the Denver metropolitan area, totaling 424,700 acres; and 3) The ecological benefits of Urban Denver totaling 214,000 acres. For this analysis Urban Denver is defined as the cities of Denver, Wheat Ridge, Lakewood, and Aurora.

| Location | Acres |
|---|---|
| Northern Front Range study area | 2.24 million |
| Denver metropolitan area | 424,700 |
| Urban Denver | 214,000 |

The ecology of urban forests in the dry prairie landscape of the Front Range is quite different from the moist, historically tree covered landscapes of the East and Pacific Northwest, where average annual rainfall ranges from 30 to 60 inches. The prairie lands of the Front Range communities receive only 10-15 inches of precipitation annually, and prior to modern settlement, trees grew primarily along riparian areas and in the foothills. Extensive irrigation is used to establish and grow vegetation.

As people settled into communities along the Front Range and cities grew, so did tree planting efforts. Today urban tree cover has increased not only compared to pre-development times, but also compared to urban forest counterparts in the East and Pacific Northwest.

While this presents a positive picture of increasing tree canopy, trees are not being planted nearly as rapidly as they could be or should be—to counteract the ecological impact of development. This study focuses on metropolitan landscapes that house the vast majority of the people in the region and have the biggest impact on the environment.

The population of the Denver metropolitan area has increased 40 percent in the last 20 years, from 1.4 million in 1980 to 2 million in 2000 (based on Denver Regional Council of Government figures for incorporated cities, June 2000). When urban areas and populations increase so does energy use, stormwater management costs, and air pollution. Specific actions can and should be taken to reduce the environmental impacts of increasing urban development. One of the most effective and practical solutions is to increase the tree cover in developed areas.

While urban ecology is more complex than just trees, tree cover is a good indicator of the ecological health of the landscape. When urban trees are large and healthy, the ecological systems that supports them are also healthy. Healthy trees require healthy soils, adequate water, and clean air. In turn, healthy trees provide valuable benefits by improving stormwater quality, reducing atmospheric carbon, and slowing stormwater runoff and reducing peak flow.

As urban areas along the Front Range continue to grow, it is increasingly more important to manage green infrastructure as a way to mitigate the impacts of that growth such as reducing sprawl while promoting water conservation and air quality. This REA contributes to the decision making process by quantifying important ecological and economic benefits of existing vegetation and by modeling the added benefits of increased tree cover.

To conduct this study, AMERICAN FORESTS developed an analysis technique to: 1) measure changes in land cover over time; 2) measure the effects of the changing landscape on air, water, and energy; and 3) calculate dollar benefits of various land cover scenarios using scientific and engineering formulas.

Data for the three analyses were obtained from satellite imagery, aerial imagery, and ground sampling. The Regional Analysis initially analyzed an area 35 miles wide and 100 miles long using Landsat satellite images from 1986 and 1998 to create a general framework for measuring changes in the landscape over time. Then, the analysis zoomed in to the Denver metro area to focus on the urban landscape.

A Local Analysis provided a detailed look at Urban Denver (cities of Denver, Wheat Ridge, and Lakewood and Aurora) and its economic value. This analysis used digital aerial imagery of 39 selected sites within these cities and AMERICAN FORESTS' CITYgreen software.

## Major Findings

An analysis of satellite data classified the land cover into the following six types:

*Impervious surfaces:* such as parking lots, sidewalks and roofs;
*Irrigated cropland:* includes lawns and golf courses;
*Forested areas:* urban and native forests;
*Grassland:* pasture and native grasslands;
*Wetlands*: meadows and shrub lands;
*Nonirrigated cropland:* crops, bare soils and open areas;
*Water*

## The Denver Metro Area

***An analysis of the greater Denver metro area shows effects of urbanization from 1986 to 1998.***

- In 1986, impervious surfaces within the Denver metro area represented the largest percentage of land cover 30% (126,559 acres). Grassland comprised 25% (105,352 acres), nonirrigated cropland 19% (79,117 acres), irrigated cropland 13% (55,387 acres), wetlands 8% (32,214 acres), and forest land 4% (18,156 acres).

- By 1998 impervious areas had increased 31%, representing 39% of the total area. Forest canopy increased 45% (to 26,324 acres) but still only represented 6% of total land cover. Grassland increased 12% (to 118,326 acres), while wetlands decreased by 59% (to 13,368 acres) and irrigated cropland by 22% (to 42,979 acres).

***Tree canopy offers measurable economic benefits for reducing stormwater flow and improving air quality.***

- An environmental benefit analysis measured the ecological and economic benefits of trees in Urban Denver (214,000 acres) which includes Denver, Wheat Ridge, Lakewood and Aurora.

- In Urban Denver, the current urban forest provides the equivalent value of a $21 million stormwater facility. When calculated on an annual basis this equals $1.5 million. The urban forest also stores 546,000 tons of carbon, sequesters 9,000 tons of carbon annually, and reduces the amount of air pollutants by 1 million pounds annually at a value of $2.6 million.

- Expanding this measurement to the include the four other cities in the Northern Front Range study area, the existing urban forest reduces the need for storm water management by 50.1 million cubic feet. Using an 86 cent-per-cubic-foot stormwater management cost (Urban Drainage and Flood Control District), urban trees currently provide the equivalent services of a $44 million stormwater system or $3.2 million in annual services.

- The five-city urban forest also stores 870,000 tons of carbon, sequesters 15,000 tons of carbon annually, and mitigates 2.2 million pounds of pollutants at a value of $5.3 million annually. Trees also conserve $4.5 million in residential summer energy savings and provide about 1.5 million tons in avoided carbon emissions. The value of these combined benefits totals $13 million annually. Refer to Table 3 for city-specific benefits.

***Maintaining and increasing tree cover is a cost-effective way to improve urban infrastructure.***

- Increasing tree cover from 6.2% to 25% in cities within Urban Denver would provide $45.5 million in one time stormwater benefits (a 116% increase from current conditions), $4.4 million worth of air pollutant removal benefits annually (a 69% increase), and 850,000 tons in carbon storage (a 56% increase). Trees would provide $5 million in summer energy savings and save 1.7 million tons in avoided carbon emissions annually.

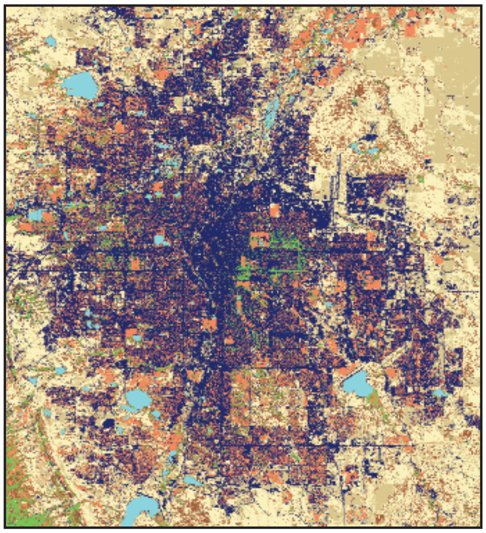
## The Region

***An analysis of satellite data from The Northern Front Range's 2.24 million acre study area shows that land cover has changed from 1986 to 1998.***

- In 1986 grassland comprised 605,432 acres (27%), nonirrigated cropland 623,352 acres (28%), forest land 128,347 acres (6%) and wetlands 160,367 acres (7%). The wetlands were created to support urban areas. Impervious surfaces represented 208,921 acres (9%), and irrigated cropland represented 481,024 acres (21%).

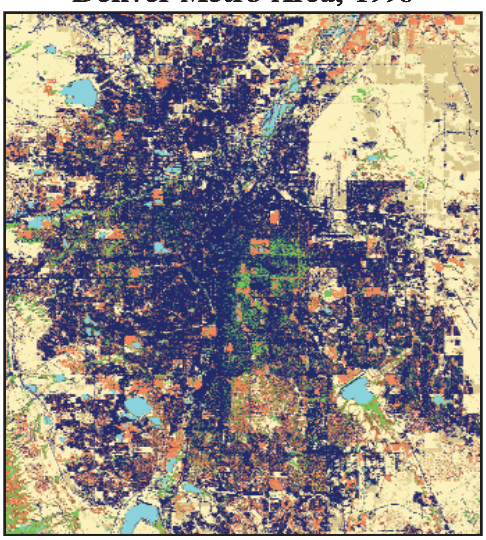
- By 1998, impervious surfaces had increased 32% to 275,612 acres. Irrigated cropland declined by 33% to 323,408 acres; some of which were converted to other uses including grasslands (844,607 acres). Wetlands also declined by 65% (to 56,578 acres) and non irrigated cropland by 10% (to 560,921 acres). While tree cover increased by 13% (to 144,992 acres), it still only represents 6.5 % of the total land area.

**Denver Metro Area, 1986**



*Landsat TM 30 Meter Pixel Resolution*

**Denver Metro Area, 1998**



*Landsat TM 30 Meter Pixel Resolution*

**Key to satellite images:**

- Water
- Impervious Surfaces
- Wetland
- Irrigated Cropland
- Forested Areas
- Grasslands
- Nonirrigated Cropland

**Table 1. Denver Metro Area's Land Cover Change**

| Land Use Category | 1986 Acres (%) | 1998 Acres (%) | Loss/Gain 1986-1998 |
|---|---|---|---|
| Impervious Surfaces | 126,559 (30%) | 166,049 (39%) | 31% |
| Grassland (native and pasture) | 105,352 (25%) | 118,326 (28%) | 12% |
| Nonirrigated cropland / open area | 79,117 (19%) | 49,370 (12%) | -38% |
| Irrigated cropland (includes golf courses and lawns) | 55,387 (13%) | 42,979 (10%) | -22% |
| *Land uses below make up 10% or less of the total area* | | | |
| Forested areas (urban and natural) | 18,156 (4%) | 26,324 (6%) | 45% |
| Wetlands | 32,214 (8%) | 13,368 (3%) | -59% |
| Water | 7,873 (1.9%) | 8,242 (1.9%) | 5% |
| TOTAL | 424,658 (100%) | 424,658 (100%) | |

**Table 2. Northern Front Range Land Cover Change**

| Land Use Category | 1986 Acres (%) | 1998 Acres (%) | Loss/Gain 1986-1998 |
|---|---|---|---|
| Impervious Surfaces | 208,921 (9%) | 275,612 (12%) | 32% |
| Grassland (native and pasture) | 605,432 (27%) | 844,607 (38%) | 40% |
| Nonirrigated cropland / open area | 623,353 (28%) | 560,921 (25%) | -10% |
| Irrigated cropland (includes golf courses and lawns) | 481,024 (21%) | 323,408 (14%) | -33% |
| *Land uses below make up 10% or less of the total area* | | | |
| Forested areas (urban and natural) | 128,347 (6%) | 144,992 (7%) | 13% |
| Wetlands | 160,367 (7%) | 56,578 (3%) | -65% |
| Water | 35,886 (2%) | 37,211 (2%) | 4% |
| TOTAL | 2,243,329 (100%) | 2,243,329 (100%) | |

# Local Level Analysis

A benefits analysis of urban tree cover was conducted within five study cities of the Northern Front Range. Using zoning categories identified by local municipalities, point samples were selected and low-level aerial imagery was used along with CITYgreen software to calculate the benefits of the urban tree canopy.

Thirty-nine sites within the cities of the Denver metro area (including Denver, Wheat Ridge, Lakewood, and Aurora) along with Louisville, Boulder, Fort Collins, and Greeley were selected to represent a variety of urban land uses and were analyzed for their ecological value. Sites selected represented different zoning classifications: residential, commercial/industrial, and open space. See Table 3 for a summary of each city's benefits.

Aerial imagery of study sites provide information about trees, grass, and impervious surfaces. Tree inventory data were collected at each sample site while other sources provided data on soil types, rainfall patterns, and land-use configurations. CITYgreen software was used to calculate ecosystem benefits for each sample site.

Two methods were used to extrapolate sample site findings to citywide benefits. To calculate air quality, stormwater, and carbon storage and sequestration, each sample site was placed into one of the three land use categories. Citywide benefits were calculated based on the average benefits for each land-use category. To calculate summer energy conservation and carbon avoided, only residential sample sites were used. When calculating these citywide benefits from the sample sites, a percentage of single-family homes with air conditioning was multiplied by the total number of single-family homes for each municipality.

## How CITYgreen is Used To Analyze Local Data

AMERICAN FORESTS uses CITYgreen software to conduct a detailed analysis of the structure of the landscape and to calculate the dollar benefits of trees. This analytical technique incorporates research and engineering formulas to place a dollar value on the work trees do. With CITYgreen it is possible to determine how various canopy cover classes affect stormwater movement, air quality, and energy conservation.

## Stormwater Runoff

Trees and soil function together to reduce stormwater runoff. Trees reduce stormwater flow by intercepting rainwater on leaves, branches, and trunks. Some of the intercepted water evaporates into the atmosphere and some soaks into the ground, reducing peak flows and thus reducing the total amount of runoff that must be managed in urban areas. Trees also slow storm flow, reducing the volume of water that must be managed at once. The TR-55 model, developed by the Natural Resources Conservation Service, provides a quantitative measure of stormwater movement called an "event model" (see page 11 for model explanation).

Communities that employ non-structural stormwater management strategies can reduce the cost of constructing stormwater control infrastructure. The value of trees for stormwater management has been calculated based on avoided costs of handling stormwater runoff. Local costs are multiplied by the total volume of avoided storage to determine dollars saved by trees.

Planting trees in new developments, which require100-year flood plans, does not eliminate the need for stormwater retention facilities. However, once they mature, trees can reduce stormwater runoff and thus reduce future stormwater expansion and maintenance costs. The urban forest within the five Northern Front Range study cities, reduces the need for stormwater management facilities by 50.1 million cubic feet. Using an 86 cent-per-cubic-foot stormwater management cost (Urban Drainage and Flood Control District), trees currently save the area $44 million in one-time construction costs; or $3.2 million in annual savings over a 30 year period.

## Air Quality

Trees provide air quality benefits by removing pollutants such as nitrogen dioxide, carbon monoxide, sulfur dioxide, ozone, and particulate matter less than 10 microns in size. To calculate the value for these 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. This figure represents costs that society would have paid in areas such as health care, if trees did not remove these pollutants. In the five urban areas of the Northern Front Range study, the existing tree canopy removes 2.2 million pounds of pollutants, with an annual value of $5.3 million.

## Stored & Sequestered Carbon

This 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 Northern Front Range's five urban areas' trees currently store an estimated 870,000 tons of carbon and sequester about 15,000 tons of carbon annually.

## Energy

Residents living in the Northern Front Range study cities spend an average of $260 per home on air conditioning per year (Public Service Company of Colorado). AMERICAN FORESTS' analysis shows the existing tree canopy in the 16 residential sample sites saves an average of $50 per home (Note: Value based on 1-2 story, single family detached homes. Also, USDA Forest Service research has thus far only modeled savings to residential sized buildings; values were not calculated for residential homes greater than two stories, commercial or open space sites.)

To estimate the area-wide energy conservation savings of trees, the average, annual savings of $50/home was projected across the cities estimated 308,495 single family detached residences (American Community Survey, U.S. Census Bureau). Assuming that an estimated, average 29% of these residences use air conditioning (American Community Survey, U.S. Census Bureau), the estimated annual residential savings is approximately $4.5 million. This savings not only conserves residential energy use, it also cools the urban heat island and improves air quality, since air pollutants increase as temperature rises.

In winter, tree windbreaks on the north and west sides of buildings can reduce the cost of heating by as much as 20%.

## Avoided Carbon

Reducing energy use also reduces the amount of carbon pollution produced by utility companies. CITYgreen calculates the amount of kilowatt hours of electricity conserved as a result of direct shading of trees. This number is multiplied by the fuel mix profile of Colorado's electricity production. The study cities in the Northern Front Range save about 1.6 million tons of carbon emission annually, as a result of direct tree shading of residences.

## Water Use

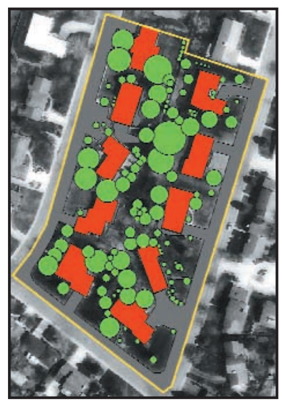
How will a significant expansion of the urban forest affect water resources in the region? Establishing new trees in a dry climate requires water—on the order of 5 gallons per week per tree in the hottest, driest months for the first two years.

Planting the right drought-tolerant species in the right season will minimize water use. The shade and evapotranspiration functions of trees will provide significant benefits from direct shading of buildings and for reducing heat islands. Both reduce the amount of air conditioning needed.

**Fort Collins** *Site #30*

**8.49 acres**
**43% tree cover**

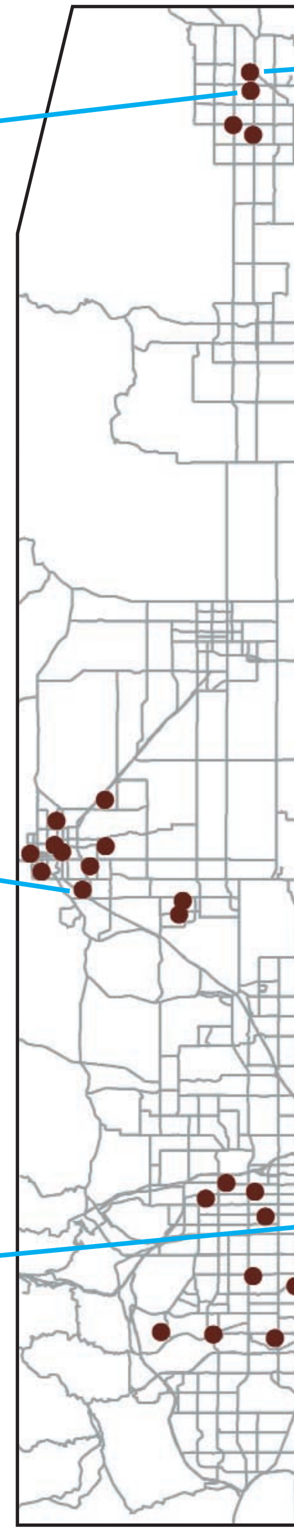
**Boulder** *Site #18*



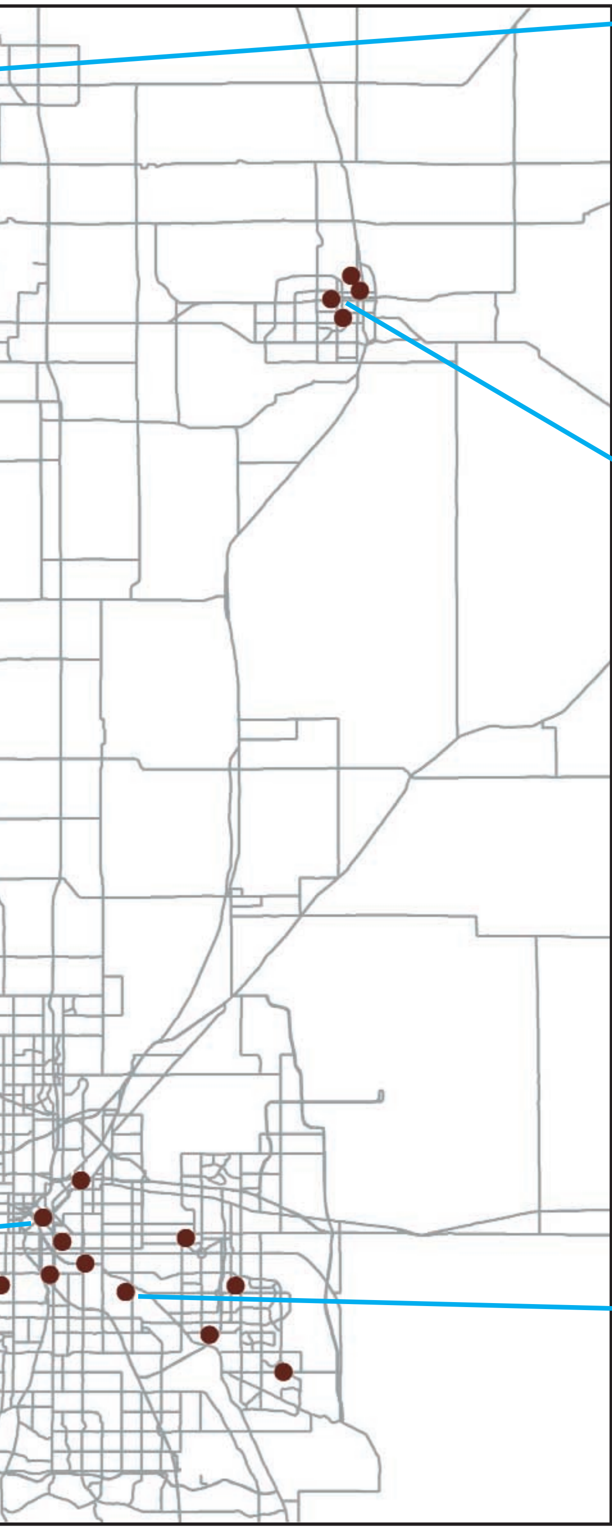
**4.18 acres**
**25% tree cover**

**Denver** *Site #39*

**15.32 acres**
**6% tree cover**



*Thirty-nine sample sites were chosen throughout the Northern Front Range area to represent a range of neighborhoods and canopy conditions. Six of the thirty-nine sites are shown in detail here, illustrating canopy coverage from 2-43%.*



**Fort Collins** *Site #29*

**7.79 acres**
**28% tree cover**

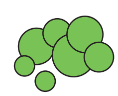
**Greeley** *Site #5*

**30.21 acres**
**2% tree cover**

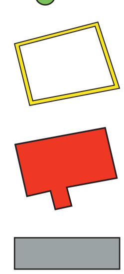
**Denver** *Site #38*

**36.04 acres**
**11% tree cover**

**Key to images:**



**tree cover**



**local site boundary**

**built structure**

**impervious surface**

**Table 3. Current Tree Canopy Benefits for Northern Front Range Study Cities[1]**

| | Urban Denver[4] | Boulder | Louisville | Ft. Collins | Greeley | Total |
|---|---|---|---|---|---|---|
| **Acres** | 214,509 | 14,421 | 4,906 | 26,318 | 18,159 | 278,313 |
| **Stormwater Management one-time Value[2] (cubic ft.)** | 24,548,093 | 6,401,131 | 857,308 | 11,735,090 | 6,623,096 | 50,164,718 |
| **(U.S. Dollars)** | $21,111,360 | $5,504,972 | $1,249,829 | $10,092,178 | $5,695,863 | $43,654,202 |
| **Stormwater Management annually[3] (U.S. Dollars)** | $1,533,717 | $399,930 | $90,799 | $733,186 | $413,798 | $3,171,430 |
| **Air pollution Removal Value annually (lbs.)** | 1,095,725 | 258,401 | 41,672 | 333,349 | 430,735 | 2,159,882 |
| **(U.S. Dollars)** | $2,600,401 | $613,142 | $308,769 | $790,775 | $1,031,338 | $5,344,426 |
| **Total Carbon Stored (tons)** | 545,800 | 52,635 | 16,597 | 92,403 | 161,343 | 868,778 |
| **Carbon Sequestered annually (tons)** | 9,029 | 1,187 | 371 | 740 | 3,635 | 14,962 |

1. Numbers may not add to 100% due to rounding. Energy and avoided carbon values could not be calculated per city due to small sample size.
2. Represents a one-time savings, and does not include additional savings from annual maintenance.
3. Annual benefits are calculated on a stormwater management facility's construction costs, plus the cost of the loan or bond to finance construction (assuming a 6% interest rate for a 30 year lifespan of the facility).
4. Urban Denver includes Denver, Aurora, Lakewood, and Wheat Ridge.

# Modeling Benefits with Increased Tree Canopy

Based on the region's existing canopy in some areas and the potential to increase environmental and economic benefits, AMERICAN FORESTS recommends increasing urban areas' tree canopy from 6% to 25%. If Urban Denver increased its tree canopy cover to 25% the environmental and economic benefits would be substantial.

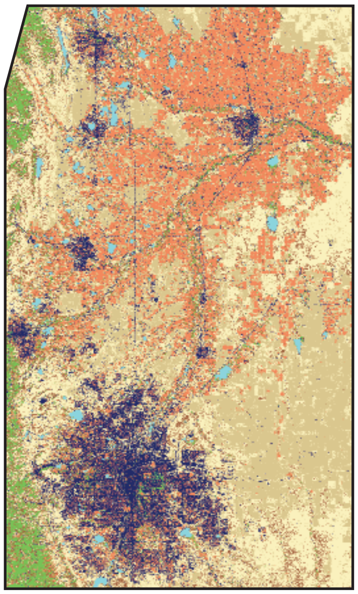
Using examples of increased tree canopy cover other Northern Front Range communities, AMERICAN FORESTS modeled the benefits for stormwater runoff reduction, air quality and energy savings (see Table 4).

**Table 4. Urban Denver[1]: Modeling Ecological Benefits With a 25% Tree Canopy**

| Ecological Benefit | Current 6% Canopy Cover | Model at 25% Canopy Cover |
|---|---|---|
| **Stormwater Management one-time Value[2]** | 24.5 million cubic feet; $21.1 million | 52.9 million cubic feet $45.5 million |
| **Stormwater Management (annually)[3]** | $1.5 million | $3.3 million |
| **Air Pollution Removal Value (annually)** | 1.1 million lbs.; $2.6 million | 1.8 million lbs.; $4.4 million |
| **Energy Savings[4] (annually)** | $3.5 million | $5 million |
| **Avoided Carbon[5] (annually)** | 1.2 million tons | 1.7 million tons |
| **Carbon Stored (total)** | 546,000 tons | 850,000 tons |
| **Carbon Sequestered (annually)** | 9,000 tons | 19,000 tons |
| **Total Annual Value for Stormwater, Energy and Air Pollution Removal** | $7.6 million[6] | $12.7 million[6] |

1. Urban Denver includes Denver, Aurora, Lakewood, and Wheat Ridge.
2. Represents a one-time savings, and does not include additional savings from annual maintenance.
3. Annual benefits are calculated on a stormwater management facility's construction costs, plus the cost of the loan or bond to finance construction (assuming a 6% interest rate for a 30 year lifespan of the facility).
4. Residential summer energy savings from trees' direct shading of one-and two-story detached residences.
5. Avoided carbon emission as a result of reduced air conditioning use.
6. Numbers have been rounded.

# Regional Level Analysis



Landsat TM 30 Meter Pixel Resolution, 1986

**Key to satellite images:**

- Water
- Impervious Surfaces
- Wetland
- Irrigated Cropland
- Forested Areas
- Grasslands
- Nonirrigated Cropland

Landsat TM 30 Meter Pixel Resolution, 1998

## Northern Front Range Area Satellite Images

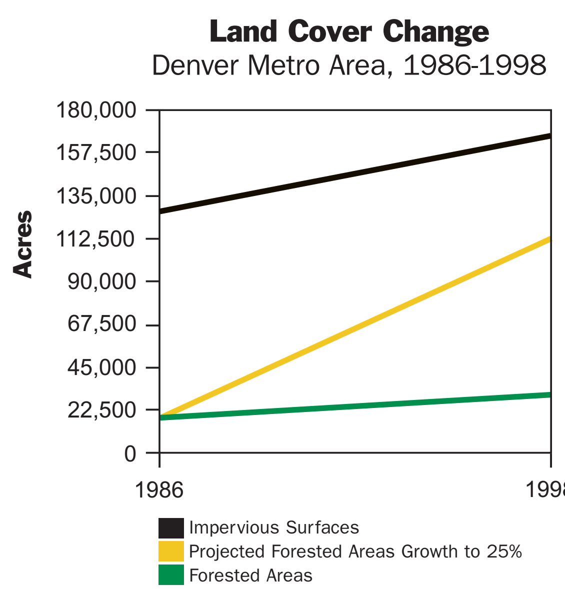
Satellite images show that urban areas have increased in size and number in the Northern Front Range over a recent 12-year period. Landsat TM images of the land cover taken in 1986 and 1998 were initially grouped into 100 "classes," such as grassland and irrigated cropland. The data was verified by comparing it to existing land cover maps. The 100 classes were grouped into seven summary categories of land cover as listed in the legend (above).

The Front Range is a dryland, semi-arid ecosystem and is more sensitive to urbanization than its eastern counterparts. The 12-year time span recorded by the two images show many land cover changes; interpreting the implications of some of these changes is beyond the scope of this report and should be evaluated by local experts. As for tree canopy cover, AMERICAN FORESTS interpretation is that while it has grown with urbanization, it still needs to be increased substantially to compensate for the expanding imperviousness of urban land cover.

The tree canopy is depicted as green and is a mix of urban and rural ecology. The effect of urbanization on the ecosystem's ability to reduce stormwater problems or improve air quality far outweighs the benefits produced by modest increases in tree cover. Our analysis suggests that tree cover should increase by 3 to 4 times to compensate for the increase in urban area.

## Graphing Changes

The 12-year change for the Denver metro area depicted in satellite images (above) are represented by a line graph (below). The chart shows how the impervious surface areas have increased at a much faster rate than tree canopy cover between 1986 and 1998. The third line shows a 25% projection in tree canopy, a recommended goal to compensate for the environmental impacts of urban development. While this might seem like an ambitious goal, Denver currently has some older, historic neighborhoods that have been settled for 130 years and have 40% canopy cover. Residential sites in this study measured 26-29% canopy cover. Boulder has several neighborhoods with more than 40% tree canopy cover.



# What's Next for the Cities Within The Northern Front Range?

## Recommendations

The Regional Ecosystem Analysis measures land cover changes over a 12-year period and calculates their impact on fundamental elements of the community such as air, water, and energy. The findings from the analysis show that while tree cover has increased, the percentage is not great enough to offset the impacts of urban growth.

As the Front Range communities continue to develop, it will be important to moderate impacts of growth by increasing the green infrastructure, especially with trees. A critical issue for local leaders is to reverse the declining condition of the ecology by establishing public policies that increase the area's tree cover and to assist the community in creating and maintaining a robust green infrastructure. While community leaders have made progress in this direction, the recommendations below are intended to provide a set of additional guidelines for reversing negative trends measured by this analysis and utilizing natural systems as natural capital.

***1. Include tree cover data in all natural resource and land development decision making. This can be done by incorporating a "green" data layer into a city's central data base or data engine, using a Geographic Information System and by recognizing the tree cover as "green infrastructure."***

- Establish a system for creating and maintaining a green layer of data in the central data file that is used by all departmental managers in the community for planning and maintenance.
- Include the economic benefits of tree cover for slowing stormwater and increasing air quality in a city's planning models. CITYgreen will allow staff to model various tree cover scenarios and calculate the dollar benefits produced.

***2. As cities continue to grow, increase tree cover to offset stormwater runoff and improve air quality.***

- Tree cover can be increased by planting more trees, saving trees during development, and improving the system for maintaining trees.
- Use local experts to determine the best species, placement, planting and maintenance strategies.

***3. Each city within the Northern Front Range should address its issues locally.***

- Develop specific, measurable urban tree canopy goals for each city within the Northern Front Range. See City of Boulder's Urban Ecosystem Analysis www.ci.boulder.co.us/publicworks/utilities/conservation/Urban_forest/citygreen web/welcome.html; final report in May 2001).
- AMERICAN FORESTS established the following guidelines for cities within the Front Range. These goals should be further refined to account for local geographic and climatic variations.

  25% tree canopy overall
  35% tree canopy in suburban residential zones
  15% tree canopy in urban residential zones
  10% tree canopy in the central business districts

- Conserve mature trees, recognizing their contribution in improving the ecology of the city.
- Use more detailed image data (Ikonos satellite or aerial photography) to provide better information for smaller communities.
- Use "leaf-on" aerial photography with 2-foot or better ground resolution for determining the location, size, and value of tree cover. CITYgreen software can calculate the stormwater, air quality, and energy values of trees.

***4. Determine the contributions trees make to air, water, and energy needs of the community during the design and engineering phase of construction, repair, or development projects.***

- Create new incentives for developers to add canopy cover in new developments, rather than relying solely on homeowners to plant. Adding trees to new developments will help future land decisions.
- Create enough planting space for trees to reach their full potential, using examples from developments where this has been achieved.
- Use trees as one method to cool homes and decrease energy consumption during the summer, to prevent any potential electrical brownouts.

# About the Regional Ecosystem Analysis

## Ecostructure Classification

AMERICAN FORESTS' Regional Ecosystem Analysis is based on the assessment of *ecostructures*, unique combinations of land use and land cover present in a city. Each ecostructure performs ecological functions differently and thus provides different values. For example, a site with a heavy tree canopy provides more stormwater reduction benefits than one with a light tree canopy.

In this study, the Regional Analysis provided an overview of land cover change in the cities of the Northern Front Range and the Denver metro area. Using land use and tree cover percentage categories to model the area's ecostructures, sample study sites were selected to further examine the effects of different tree canopy cover percentages on air quality, energy, and stormwater management.

## Data Used in this Study

For regional analysis, Landsat TM images from 1986 and 1998 were classified with ERDAS Imagine software, using an unsupervised classification method. Pixels in each of the images were first grouped into 100 "classes," (all classifications), based on their spectral values, and labeled with a land cover type, such as grassland and irrigated cropland. Each type is referenced to ancillary data that included points collected on the ground to existing digital land cover type maps. Similar classes were combined into seven summary land cover categories.

For the local analysis, AMERICAN FORESTS used geo-rectified .tif images (digital aerial photos). Field data collection was coordinated by Jennifer Sherry, of Boulder, CO with the assistance of forestry staff from participating cities and the Colorado State Forest Service.

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

## Analysis Formulas

***Stormwater Runoff:*** Stormwater runoff calculations incorporate formulas from US Natural Resources Conservation Service (NRCS) Technical Release 55 (TR-55). TR-55 is a model for estimating stormwater runoff in small urban watersheds, and is widely used across the country for stormwater planning and urban engineering analyses. Don Woodward, PE, a hydrologic engineer with NRCS, customized the formulas to determine the benefits of trees and other urban vegetation with respect to stormwater management. CITYgreen calculates stormwater runoff volume, peak flow and time of concentration and can model the percent change between two land cover scenarios.

***UFORE Model for Air Pollution:*** CITYgreen uses formulas from a model developed by David Nowak, PhD, of the US Forest Service. The model estimates how many pounds of ozone, sulfur dioxide, nitrogen dioxide, PM10 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 50 US cities. Dollar values for air pollutants are based on the median value of the externality costs set by the State Public Service Commissions in these states.

***Avoided Carbon:*** CITYgreen avoided carbon module begins with kWh savings estimated in the energy module. Because different fuel sources emit different levels of carbon per unit of electricity production, the impact of a conserved kWh will vary depending on local fuel sources. To account for this, the amount of saved kWh from the energy module is multiplied by Energy Information Administration (EIA) data for state-level fuel sources used in electricity production.

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## For More Information

AMERICAN FORESTS, founded in 1875, is the oldest national nonprofit citizen conservation organization. Its three centers–Global ReLeaf, Urban Forestry, and Forest Policy–mobilize people to improve the environment by planting and caring for trees. Global ReLeaf 2000 is AMERICAN FORESTS' 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 and 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.

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