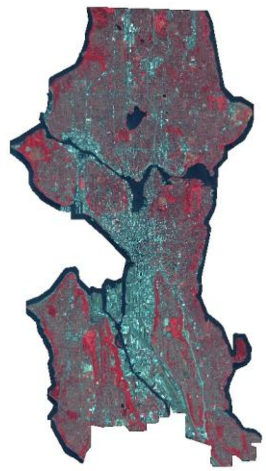
Seattle, Washington

Urban Tree Canopy Analysis

Project Report: Looking Back and Moving Forward



NCDC IMAGING

May 7, 2009

Seattle, Washington
Urban Tree Canopy Analysis
Project Report: Looking Back and Moving Forward

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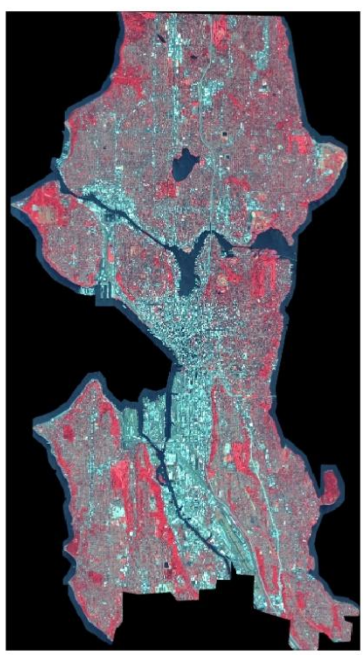
Project Background & Summary

The City of Seattle adopted an Urban Forest Management Plan (UFMP) in 2007 with a goal of increasing the city's tree canopy to 30%. In order to prioritize investments to those actions that will create the greatest tree canopy gain, the City determined that they needed a better understanding of current canopy cover, recent trends in canopy gain and loss, the impacts of development, and tree planting potential. They also wanted to create a baseline to monitor progress against the 30% canopy cover goal.

NCDC Imaging & Mapping ('NCDC') worked closely with professionals at the City of Seattle using GIS and remote sensing data technologies to look at canopy in 2002 and 2003 and comparing that to 2007. Methods from a study in Los Angeles developed by the USFS Center for Urban Forest Research and the University of California-Davis were incorporated and expanded upon to help Seattle achieve their goals.

The latest geospatial tools & technologies were applied to increase the city's understanding of their current and potential urban forest as well as provide GIS-ready land cover data useful to other city departments and agencies for a variety of planning and management purposes. The area of interest (AOI) included the City of Seattle, Washington, which is an area of a just under 100 square miles.

Quickbird multi-spectral satellite image of the Seattle Project Area of Interest (AOI)



The primary tasks included planning & consultation, ortho-rectifying 2-ft resolution 2002/2003 and 2007 QuickBird satellite imagery, developing a land cover classification dataset, performing an urban tree canopy (UTC) assessment on existing and potential tree cover and comparing the tree cover from the 2002/2003 ortho-mosaic used to obtain full coverage and minimal haze over the area of interest, to tree cover from the 2007 ortho imagery, compiling, updating and mapping GIS data, calibrating the UTC model, and creating visual and communicable products.

High-resolution multi-spectral satellite imagery and supporting GIS datasets provided by the city of Seattle were used to develop a GIS-ready land cover dataset which served as the baseline information to assess past, current, and potential urban forest conditions. Each potential planting site was attributed by tree size, land use type, proximity to major transportation corridors, potential to cover impervious surfaces or replace other open space.

The city of Seattle currently has about 22.9% tree cover whereas in 2002 the urban forest cover was approximately 22.5%, and while this canopy provides significant ecosystem services, there are significant opportunities to improve canopy cover in strategic locations to improve environmental quality, public health, property values and reach sustainability goals.

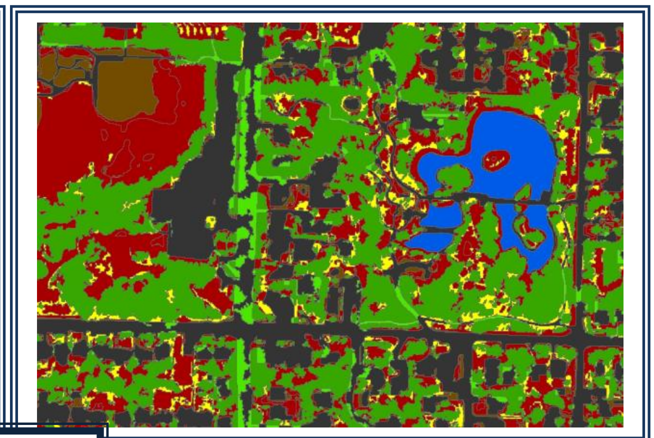
Data Analysis, Land Cover Classification & Land Use

To develop baseline conditions and corresponding GIS data layers for the analysis of current conditions, recent trends and potential planting sites, existing GIS data was first incorporated, assessed, updated using image classification & manual digitizing techniques, and then compiled into final land cover datasets. Provided data included aerial imagery, building outlines, water bodies, transportation/streets and pavement areas (DWW) , parcel, UFMP (land use category), Community Reporting Areas (CRA's), Urban Villages (UV's), and re-development sites.

Land cover classification is probably the most critical aspect of these types of projects because all modeling and analysis is derived from this base information. Since 2000, NCDC Imaging has specialized in advanced remote sensing processes using next generation image analysis software like Visual Learning System's Feature Analyst to derive such land cover maps. "Accelerated feature extraction" (AFE) technology, aka geographic object-based image analysis (GEOBIA), in conjunction with high-resolution digital imagery works via an iterative, machine-learning approach to image classification. The final comprehensive ("wall-to-wall") land cover classification map was created in this way and included the following 7 feature classes; impervious surfaces, shrub/scrub, trees, trees with impervious understory, grass (all low-lying vegetation), bare soil (includes dry vegetative cover) and water. The impervious surfaces layer was first refined utilizing selected attributes from the DWW layer provided and the updated buildings data. Within the attribute table of the DWW layer there were two fields labeled IMPSURF_SU and IMPSURF_FE. A selection of all the solid (SOL) attribute types was sorted from the impervious surfaces (IMPSURF_SU) field within the DWW layer. From that (SOL) selection another sorting was performed upon the IMPSURF_FE attribute field to derive only the following impervious surface types for use in the classification: DRV (driveway), ELV OTH (other elevated structures), PRK (parking lot), PUL (swimming pool or other constructed pool), SDW (sidewalk), STR (street or alley), and WLK (walkway or patio).

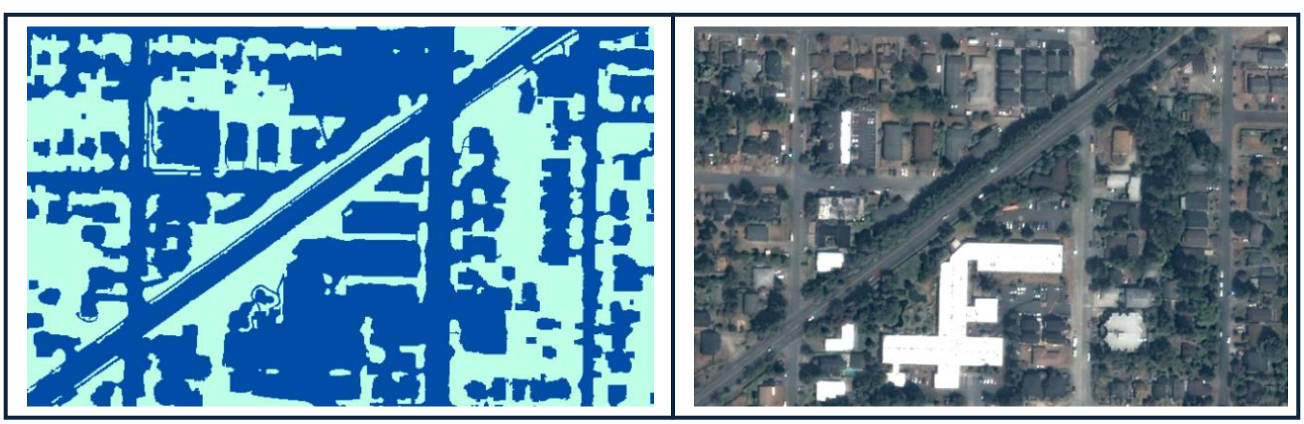
Multispectral Satellite Imagery

7 Class Landcover classification



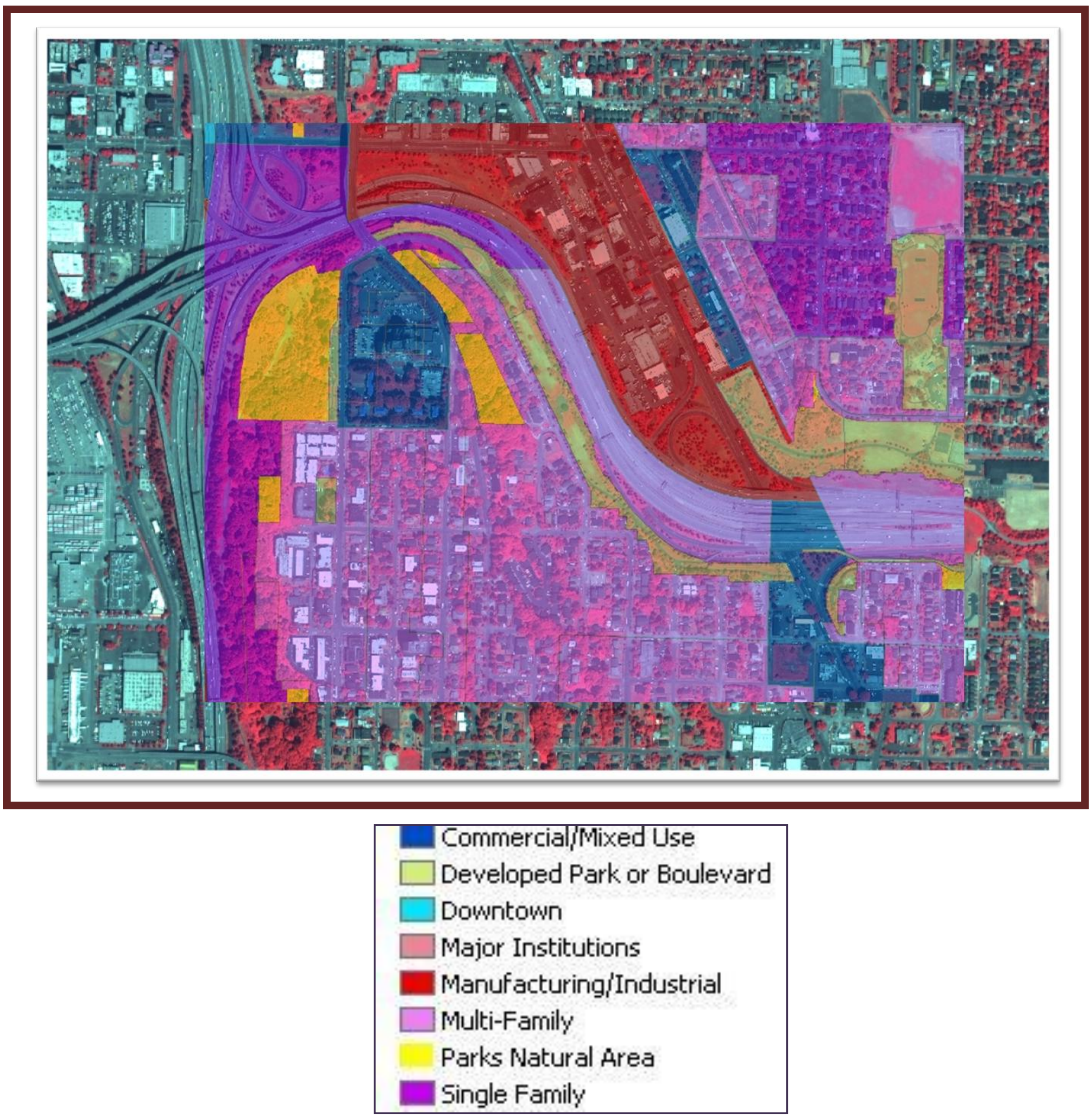
A 2-class pervious vs. impervious surface layer was also compiled for Seattle, by dissolving the appropriate classes from the original 7-class land cover.

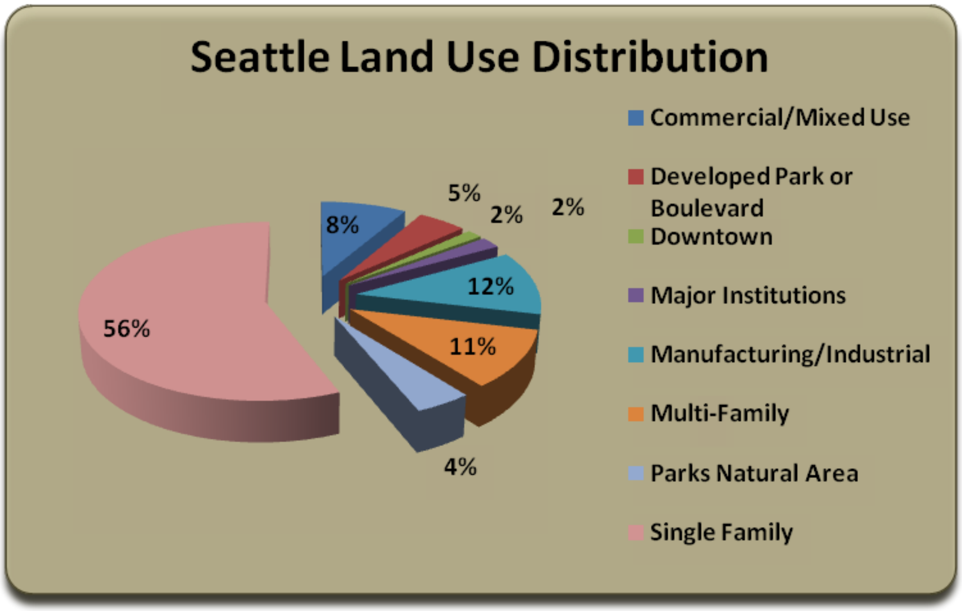
Example of 2-Class Pervious vs. Impervious Landcover



Seattle's land use data was provided to assess existing & potential UTC by the types of land use. All given land use types were generalized into the eight categories illustrated in the graphic below.

Multispectral Imagery with GIS Overlay of Land Use Types for Seattle, Washington





Seattle's City-wide Land Use Distribution

Analysis of Urban Tree Canopy (UTC) & Potential Planting Sites

The model developed for this type of UTC analysis determines possible tree planting opportunities by first excluding existing tree canopy, then buildings, streets, and water. Shrub/scrub, bare soil, and grass layers were then assessed for planting potential.

The following GIS rule-sets and processes were used to create GIS data layers representing potential planting areas in order to avoid conflicts with existing infrastructure and to eliminate obviously un-plantable areas such as golf courses tees, beaches, and the airport.

- A 5-ft buffer around existing tree canopy was established to avoid crowding of mature canopy cover
- A 3-ft buffer around buildings was established to avoid planting too close to structures
- Minimum size requirements for very small, small, and medium tree planting spaces were implemented in the following way:
    - Sites less than 36 square feet were removed from potential
    - very small sites were = less than 100 square feet
    - small sites were = 101-300 square feet
    - medium sites were = 301-900 square feet
- Any potential planting sites that appeared on beaches were removed
- A negative buffer was created around the provided golf course tees and greens shapefile of 50 feet and potential planting sites within it were removed to reflect more realistic numbers of planting sites within golf courses

- Any potential planting sites that appeared within the bounding shapefile provided of airports were removed

The resulting layers represent the potential maximum planting areas given the constraints of buildings, impervious surfaces etc. It is important to note that this method underestimates planting potential in areas such as downtown where potential planting area could include impervious surfaces where tree pits are constructed within existing sidewalk. Conversely, planting potential is overestimated in other areas where sports fields, utility infrastructure etc. was not excluded due to a lack of readily available data.

Overall the potential planting sites data is intended to provide a general sense of maximum possible planting and to form the basis for further evaluation of planting opportunities.

With the attributes such as tree size, land use, and number of potential sites embedded in the potential tree planting sites shapefiles for each target geography, many combinations of queries are possible from within the GIS database in order to quantify and qualify tree planting opportunities, communicate this information with stakeholders, and ultimately develop a plan for tree planting success moving forward. A few visual examples of query outputs are provided throughout the report.

Progressive Illustration of Satellite Imagery, Planting Sites, & Existing Tree Cover

City-wide, the Seattle analysis returned over one million potential planting sites, as seen in the following table. Therefore the assessment has revealed significant possibilities for improvement in the canopy for Seattle.

Citywide 2002/2003 to 2007 Existing Tree Canopy Comparison

Area (sq ft)	Area (Acre)	Tree Cover 2002 (Acre)	Tree Cover 2002 (%)	Tree Cover 2007 (Acre)	Tree Cover 2007 (%)	Tree Cover Change, 02 - 07 (Acre)	Tree Cover Change, 02 - 07 (%)	Potential Planting Sites
2314189332.8	53126.5	11996.6	22.6	12206.6	22.9	210.0	0.4	**1,081,480**

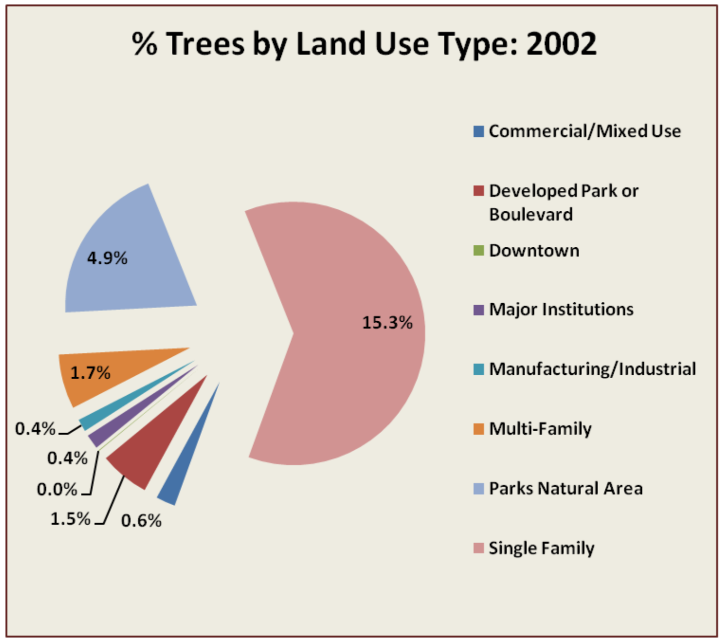
The City of Seattle wanted to compare the canopy in 2002 to the canopy as it existed in 2007, by land use category, in order to better understand recent trends as well as opportunities and barriers to expanding tree canopy based on how the land is used. The following tables compare results computed for each land use category for the ROW and non-ROW portion of parcels.

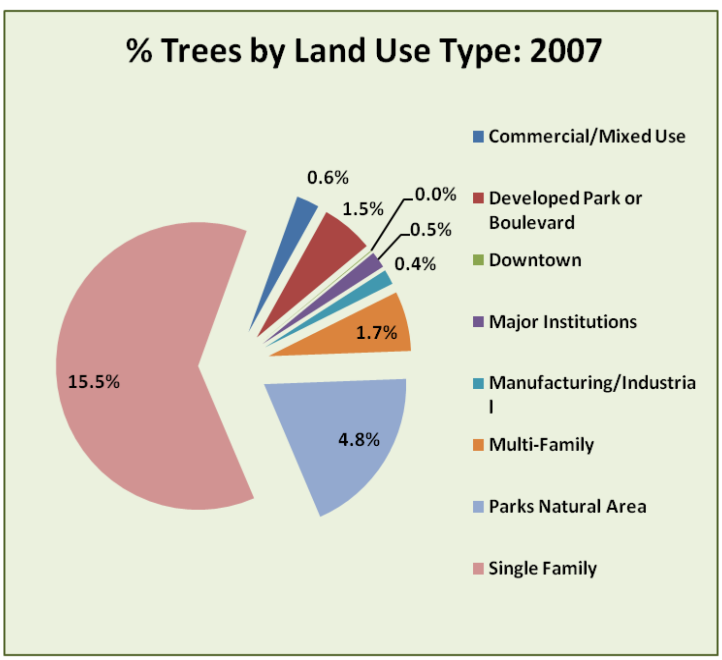
Parcels 2002/2003 to 2007 Existing Tree Canopy Comparison									
Zoning Category	**Area (sq ft)**	**Area (Acre)**	**Tree Cover 2002 (Acre)**	**Tree Cover 2002 (%)**	**Tree Cover 2007 (Acre)**	**Tree Cover 2007 (%)**	**Tree Cover Change, 02 - 07 (Acre)**	**Tree Cover Change, 02 - 07 (%)**	**Potential Planting Sites**
Commercial/Mixed Use	126021781.3	2893.1	226.4	7.8	248.8	8.6	22.4	**0.8**	19991
Developed Park or Boulevard	100580786.4	2309.0	584.0	25.3	568.7	24.6	-15.3	-0.7	63443
Downtown	19520248.5	448.1	8.1	1.8	9.2	2.0	1.2	0.3	691
Major Institutions	40368610.9	926.7	171.2	18.5	180.	19.5	9.0	**0.9**	16383
Manufacturing/Industrial	203321606.5	4667.6	147.1	3.1	163.0	3.5	15.9	0.3	16194
Multi-Family	163207089.9	3746.7	639.6	17.0	646.7	17.3	7.1	0.2	65523
Parks Natural Area	99496427.3	2284.1	1889.3	82.7	1844.6	80.8	-44.7	**-1.9**	23922
Single Family	924936305.2	21233.6	5881.1	27.7	5973.8	28.1	92.7	0.4	597873
Total	**1677452856.0**	**38509.0**	**9546.9**	**24.8**	**9635.2**	**25.0**	**88.2**	**0.2**	**804020**

ROW 2002/2003 to 2007 Existing Tree Canopy Comparison									
Zoning Category	**Area (sq ft)**	**Area (Acres)**	**Tree Cover 2002 (Acre)**	**Tree Cover 2002 (%)**	**Tree Cover 2007 (Acre)**	**Tree Cover 2007 (%)**	**Tree Cover Change, 02 - 07 (Acre)**	**Tree Cover Change, 02 - 07 (%)**	**Potential Planting Sites**
Commercial/Mixed Use	70967393.3	1629.2	154.9	9.5	188.6	11.6	33.7	**2.0**	8979
Developed Park or Boulevard	11724280.5	269.2	83.3	30.9	87.6	32.6	4.3	1.6	6824
Downtown	15991830.0	367.1	26.2	7.1	29.3	7.9	3.1	0.9	413
Major Institutions	7594657.1	174.4	31.4	17.9	33.7	19.3	2.4	**1.4**	2001
Manufacturing/Industrial	66347346.2	1523.1	88.5	5.8	104.5	6.9	15.9	1.0	11017
Multi-Family	82709718.2	1898.8	296.1	15.6	316.8	16.7	20.7	1.0	27448
Parks Natural Area	3108390.7	71.4	53.8	75.4	49.8	69.8	-3.9	**-5.5**	1272
Single Family	378304293.6	8684.7	1662.5	19.1	1726.8	19.9	64.3	0.7	219594
Total	636747909.6	14617.7	2396.8	16.4	2537.2	17.4	140.5	0.9	277548

Overall, the urban forest canopy coverage throughout the city has increased slightly. There is a level of uncertainty associated with these results due to automated feature extraction limitations including but not limited to haze in the ortho-imagery, building lean obscuring trees, long tree shadows, seasonal changes from one image collection to another, and image quality. In the following graph, the approximate percent of tree canopy throughout the city is broken out by land use types and for each time period as a comparison.

Comparison of Total Percentage of Trees by Land Use Category City-wide





To enable the City to better understand trends and opportunities, tree canopy change and planting potential was evaluated in neighborhoods, areas targeted for growth, re-developed properties, and the public ROW separate from the non-ROW portion of property parcels. Several target geographies were chosen upon which computations were run and the attribute table for each was updated with pertinent information. The target geographies included: Urban Villages (UV's), Community Reporting Areas (CRA's), parcels, UFMP land use categories, ROW, and re-development sites. Having numerous target geographies is useful in that these datasets can be analyzed individually and opportunities and barriers for improving canopy cover can be more easily identified.

Potential planting sites were determined for each of the target geography datasets and attributed by tree size and land use type. The graphics below are an illustration of just 3, of 41, Urban Villages highlighting tree canopy cover and potential tree planting sites sorted by land use category. These same types of statistics were generated for all target geopgraphies.

Graphic Spotlight on 3 Urban Villages: 12th Ave, First Hill, Chinatown-International District

Urban Villages 2002/2003 to 2007 Existing Tree Canopy Comparison

Urban Village Name	Zoning Category	Area (sq ft)	Area (Acre)	Tree Cover 2002 (Acre)	Tree Cover 2002 (%)	Tree Cover 2007 (Acre)	Tree Cover 2007 (%)	Tree Cover Change, 02 - 07 (Acre)	Tree Cover Change, 02 - 07 (%)	Potential Planting Sites
12th Avenue	Commercial/Mixed Use	1825753.36	41.91	2.84	6.77	3.17	7.57	0.33	0.80	450
12th Avenue	Developed Park or Boulevard	19819.46	0.45	0.02	5.38	0.05	10.37	0.02	4.99	18
12th Avenue	Major Institutions	3079566.80	70.70	7.15	10.12	8.58	12.14	1.43	2.02	910
12th Avenue	Multi-Family	2036733.70	46.76	5.15	11.01	6.63	14.19	1.49	3.18	783
First Hill	Commercial/Mixed Use	1511500.54	34.70	2.88	8.29	3.13	9.03	0.26	0.74	78
First Hill	Developed Park or Boulevard	217476.84	4.99	2.91	58.36	2.37	47.37	-0.55	-10.99	91
First Hill	Major Institutions	2364245.74	54.28	4.20	7.74	4.28	7.88	0.07	0.14	174
First Hill	Multi-Family	5841047.37	134.09	20.93	15.61	21.45	16.00	0.52	0.39	1283
Chinatown-International District	Commercial/Mixed Use	2357469.05	54.12	1.42	2.63	2.34	4.32	0.92	1.69	363
Chinatown-International District	Developed Park or Boulevard	52958.21	1.22	0.16	12.79	0.26	21.14	0.10	8.35	16
Chinatown-International District	Downtown	3653917.09	83.88	3.73	4.44	4.71	5.62	0.99	1.18	198
Chinatown-International District	Manufacturing/Industrial	1224866.75	28.12	2.36	8.38	2.44	8.67	0.08	0.29	283
Chinatown-International District	Multi-Family	81257.34	1.87	0.03	1.49	0.06	3.33	0.03	1.84	82
Chinatown-International District	Parks Natural Area	48422.72	1.11	0.47	42.06	0.61	54.53	0.14	12.47	24
Chinatown-International District	Single Family	43585.09	1.00	0.00	0.00	0.00	0.00	0.00	0.00	19

Graphic Spotlight on 3 Urban Villages: 12th Ave, First Hill, Chinatown-International District
continued with
Potential Planting Sites Symbolized by Land Use Type

These are just a few examples of the kinds of information that can be pulled from these datasets. Whether small, very small, or medium sized, these planting sites represent a myriad of opportunities for augmenting the urban forest landscape and increasing the environmental, economic and community benefits of the urban forest. The impact of trees on air pollution reduction, carbon sequestration, energy conservation, storm water runoff, ground water contaminant loading, and overall public health is very significant.

Opportunities for Additional Analysis

This project aimed to illustrate existing urban forest conditions, recent trends in canopy gain and loss, and opportunities for improved tree canopy to help the City prioritize investments. Other recommended tools & technologies provided below are available if and when this project is re-visited.

In a citywide mapping project, potential tree planting sites and associated attributes used for queries & prioritization can be improved upon to include watershed boundaries, soil types, above & below ground power line locations, demographic data (income, public health data) and other GIS overlays. Such data would increase the accuracy and utility of the results. However in order to maximize use across varied audiences, a web-mapping service (WMS) or customized GoogleEarth interface, where both technical and non-technical map-users can access, query, display and share the information for their particular purposes would be useful.

An ecosystem benefit study could be conducted. There are several studies out and various groups attempting to update known effects of watershed runoff, contaminant loading, air pollution, carbon sequestration, and costs associated with each and to improve existing databases of baseline data and techniques for processing the data.

One of the most well known and widely used tree canopy benefits analysis software packages is CITYgreen. Produced by the organization known as American Forests, it utilizes decades of research conducted and refined by well-known institutions and experts to analyze not only current tree canopy benefits but also modeled tree canopy benefits useful for guiding urban forest public policy.

CITYgreen software analyzes and places a dollar value associated with air quality pollutant removal savings, total carbon storage capacity in tons, and because trees also impact storm water runoff in a number of ways, CITYgreen software analyzes possible savings to the city as a result of reduced storm water runoff.

The CITYgreen water quality model works hand-in-hand with the CITYgreen watershed management model (TR-55) and can predict contaminant loadings using the L-THIA spreadsheet developed by Purdue University and the EPA. The more runoff, the higher the percentage of contaminant loadings are possibly suspended within the water. Default values for loadings are based on expert findings and used to systematically model and assess pollutant loadings.

CITYgreen reports are quick and simple to run and are cost-effective, often thousands of dollars less than a full potential UTC analysis depending on the size of the analysis area, to assess the overall value of a city's urban forest resource. The payback of doing the assessment and subsequent improvement of tree canopy based on the results includes the possibility of thousands of pounds of widespread air pollutant removal, greater than before health benefits, lesser costs associated with poor health, and an aesthetically more pleasing cityscape, just to name a few.

CITYgreen however, is primarily a modeling tool used to influence public policy and decision-making and it has its limitations. Other studies however, are being pioneered that can provide statistics and dollar savings values for strategically planted trees. The USDA forest Service is currently improving upon several Urban Forest Effects (UFORE) models that together are more comprehensive that CITYgreen and can calculate a range of items such as the urban forest structure, carbon storage and sequestration, air pollution removal rates, storm water runoff rates, contaminant loadings and energy conservation. It would take another research paper to describe each model in detail and how it helps but with the accurate baseline land cover data already created for this project, a good DEM, stream gauge data and weather data it would be possible to run at least the USFS UFORE-Hydro model to find a better between urban infrastructure and tree canopy.

Lastly, an energy conservation modeling component is being pioneered by NCDC Imaging and the Texas Trees Foundation utilizing the potential tree planting locations, such as those created in this project and the USFS Community Tree Guides to map resource units and compute dollar savings values from strategically located trees. For example, on which corner of a lot do you get the most energy savings from a shade tree? And at what distance from a building do you get the most value from it? Energy conservation savings are commonly applied to single-family residential properties, Multi-family residential properties, as well as public and commercial property types and could be considered for the citywide mapping project to better reflect overall potential energy savings. This approach is still a work in progress and needs to be improved upon as it largely un-tried and consequently these values are and need to be carefully applied to GIS & remotely sensed data.

Final Project Deliverables

All GIS data was provided in ESRI-based shapefile format accompanied by FGDC compliant metadata.

- A 7-class land cover classification – polygon shapefile for each City sector including impervious, shrub/scrub, trees, trees with impervious understory, grass, bare soil and water.
- A 2-class pervious vs. impervious surface layer.
- UTC Analysis – tables, graphs and charts of UTC statistics (metrics) by CRA, Urban Village, UFMP, re-developed sites, Parcels by UFMP, ROW by UFMP, and City-wide
- Potential Planting Sites; locations of very small, small, and medium tree planting spaces (point and/or polygon area) attributed by impervious understory, size (small/medium/large), land use type, and transportation.
- Report summarizing methods, final geospatial rule-sets used, potential planting site results, outcomes and recommendations on use of the data from this study.

APPENDIX

Company History

NCDC Imaging & Mapping (www.ncdcimaging.com) is a private Native American-owned business based in Colorado Springs, Colorado. Founded in 2000, NCDC's mission is to provide its customers with innovative Remote Sensing and GIS solutions through the use of high-resolution satellite imagery and automated feature extraction (AFE). NCDC Imaging specializes in image processing, mapping services and training for tribal, federal, state and local agencies in addition to rural community organizations, fire protection districts, private companies and individual organizations.

NCDC works with a variety of strategic partnerships on both software and hardware in order to deliver customized solutions from start to finish.
NCDC utilizes state-of-the-art remote sensing, mapping and assessment technologies designed specifically for use with high-resolution imagery to support the market sectors and applications listed in the following table.

NCDC has specialized in remote sensing and GIS applications using high-resolution imagery for the past nine (9) years. We have performed numerous natural resource, forestry and environmental analysis projects for local, state and federal clients throughout the U.S. using advanced image analysis and automated feature extraction technology (AFE). We are very proud to be the recipient of the 2005 and 2006 Visual Learning Systems "AFE Analyst of the Year" award. Our technicians, analysts and project managers have all received a minimum of one accredited undergraduate degree in environmental studies, forestry or a related field. The staff at NCDC is encouraged and aided in the pursuit of continuing education for both personal and professional development, so that we might as a company, always be on the cutting edge of new developments in the remote sensing industry.

NCDC brings to the remote sensing industry a lead in analytical solutions aimed at helping managers deal with large areas, complexity, unknowns, short project timelines and tight budgets.