Strategic Urban Forests Assessment: Baltimore, Maryland

Frederick M. Irani, Remote Sensing and GIS,
Chesapeake and Coastal Watershed Service
Watershed Management and Analysis
Michael F. Galvin, Supervisor,
Urban and Community Forestry
Forest Service
Maryland Department of Natural Resources
Tawes State Office Building
580 Taylor Avenue
Annapolis, Maryland 21401
Firani@dnr.state.md.us
Mgalvin@dnr.state.md.us

ABSTRACT

The SUFA: Baltimore City is a partnership between the USDA-Forest Service, Maryland DNR (Forest Service, Chesapeake and Coastal Watershed Service), Baltimore City Department of Planning, the Parks and People Foundation, and other local NGOs. This project took concepts of the Maryland Department of Natural Resources' Strategic Forest Lands Assessment (SFLA) and applied them to an urban scale. The grant provided for a high-resolution tree canopy and land cover analysis of the city. Leaf-on IKONOS satellite imagery was obtained by the MD DNR for the entire city of Baltimore, Maryland for October 2, 2001. The ERDAS Imagine Resolution Merge application was used to sharpen the 4-meter multi-spectral data. A vegetation mask was created from the NIR-to-Red, (Band4:Band3) ratio image. A texture image of the ratio image was produced to separate tree canopy from vegetation pixels. The resultant vegetation and tree canopy bit-masks were exported to ESRI GRID files from ERDAS Imagine. Initial statistics generated from these GRID files show total vegetation (trees and other vegetation) as 47 percent, non-tree vegetation at 27 percent and tree canopy as 20 percent of the Baltimore land area. The Baltimore City Department of Planning will overlay in-house GIS layers of site types to establish baseline canopy cover. The bit masks were used in combination with other data reported by the Baltimore Neighborhood Indicators Alliance (BNIA). The SUFA: Baltimore will serve as a long-term green infrastructure and planning template for Baltimore City and partners.

INTRODUCTION

Urban trees lessen the 'heat island' effect, reduce summer heating costs, sequester carbon, intercept airborne pollutants, and reduce storm water runoff problems. A recent study by the USDA-Forest Service Northeast Research Station (Nowak, et al., 2002) determined that Baltimore's tree canopy, which the authors estimated covers approximately 25% of the city, benefits the city by: Reducing building energy use with a net energy saving of $3.3 million per year; avoiding carbon emissions from power plants due to building energy conservation at an estimated 9,300 metric tons of carbon per year and storing approximately 527,300 metric tons of carbon at an estimated total value of $10.7 million. This amount of carbon is equivalent to the amount emitted from Baltimore's population in about 54 days based on average per-capita carbon emissions. Baltimore's trees also remove about 10,800 metric tons of carbon per year at a value of $219,000 annually and remove about 700 metric tons of air pollution per year at a value of $3.8 million annually. The report also estimates that 25,000 new trees will need to be established annually to sustain current tree cover and maintain existing benefits 30 years from now.

Baltimore has been working diligently on maintaining its urban forest. Under the city's Forest Conservation program between July 2000 through June 2001, 35 development projects were reviewed on 214.5 acres, 30.3 of which were forested, 3.2 acres of forest were cleared while 9.1 were required to be

planted resulting in 122% of pre-development forest acres. A study performed by the USDA-Forest Service in 1999 (Riemann, 2001) found that non-forest trees in the 5-county Baltimore metropolitan area added at least 41% to the tree volume in forests in that area. A study of roadside trees in the Baltimore-Washington corridor (Cumming, et al., 2001) performed by USDA-Forest Service, MD DNR, MD Department of Agriculture, and West Virginia University found, however, that the number of trees along roadways in that area was at only 14% of potential.

Project partners sought to conduct a detailed analysis of 'hubs', such as existing urban parks, other public lands, and large land holdings of nonprofit organizations, and connective 'corridors', such as greenways, hiker-biker paths, primary street tree corridors and riparian forest buffers. The assessment included potential opportunities for green re-investment, including potential Brownfield sites, vacant lots, and properties scheduled for demolition. Approximately 12,000 city-owned and 28,000 privately owned lots which are vacant or scheduled for demolition currently exist. The current distribution of urban forest resources, the proximity of the area to streams or waterways, site imperviousness, soil conditions, the potential to link green spaces via hydrologic systems, and other factors will be included in the assessment.

A high-resolution tree canopy / land cover analysis of Baltimore, Maryland was made possible via a grant from the USDA-Forest Service. The grant enabled MD DNR to provide Baltimore City with $150,000 worth of tools to initiate implementation of the Strategic Urban Forest Assessment (SUFA) including: an IKONOS satellite image of Baltimore; the tree canopy and vegetation masks created from the image; $114,000 worth of trees scheduled for planting in locations identified as appropriate for planting according to the assessment; and, $16,000 worth of computer hardware and software for the Departments of Planning and Recreation and Parks for management of the satellite image and related databases. Baltimore City supplied matching funds for the grant with $168,000 worth of city tree planting.

STRATEGIC FOREST LANDS ASSESSMENT

This part of the SUFA took concepts of MD DNR Strategic Forest Lands Assessment (SFLA) and applied them to an urban scale. The SFLA is a place-based approach to identifying a sustainable forest resource base. It integrates forest resource lands characterization, forest resource socioeconomic assessment, forest resource vulnerability assessment, and forest conservation programmatic assessment, providing a landscape-level decision making tool (Wolf, J.C., 2002). This project applied the SFLA to focus on trees' provision of services rather than goods and considered tree canopy cover on all land uses rather than looking only at large tracts of forested lands as little exists within the city's boundaries.

PARTNERSHIPS

The SUFA: Baltimore City is a partnership between USDA-Forest Service, Maryland DNR (Forest Service, CCWS), Baltimore City, the Parks and People Foundation, and other local NGOs. It is built on the foundation established by the Revitalizing Baltimore (RB) coalition. RB is a regional partnership strengthening community-based efforts to improve urban natural resources, supported by the USDA-Forest Service and managed by the Baltimore-based non-profit Parks & People Foundation in cooperation with the Maryland State Forester.

This national model for community forestry and watershed organizing equips people to care for natural resources and to employ these resources to revitalize their neighborhoods (Parks and People, 2002). Over the last eight years, Revitalizing Baltimore (RB) has focused its efforts along stream valleys and in neighborhoods with significant tree deficits helping green 45 neighborhoods by planting more than 5,500 street trees and 11,800 riparian plants in over 500 projects involving more than 3,000 volunteers annually, and by providing stewardship education to over 10,700 students and 600 adults. RB's twenty partnering organizations include the Maryland Department of Natural Resources Forest Service, Baltimore City, Baltimore County, several nonprofit organizations, three watershed associations, businesses, and academic institutions. RB actively reaches out to culturally diverse communities to help residents plant trees along

streets and streams, transform vacant lots to community green space, restore parks and schoolyards, and support youth education and adult training to foster stewardship of natural resources.

IMAGE DATA PREPROCESSING

Leaf-on IKONOS imagery was collected of the entire city of Baltimore, Maryland on October 2, 2001 at 16:14 GMT. The data was delivered under Space Imaging Province, State and Local (PSLG) license in GeoTIFF format in Maryland State Plane NAD 83 feet, as requested by Baltimore City Planning, as a Precision, 4m CE 90 horizontal level of accuracy, product. The horizontal accuracy was intended to allow Baltimore City to readily overlay its own precise vector renderings of streets, building foot prints, public property, etc. The request for the IKONOS imagery specified that the entire image be collected on the same day. The IKONOS satellite has a pointing capability that allowed it to scan the site three times during a single fly-over. The final image covered over 240 km (93 square miles). The three resulting data swaths were delivered to the MD DNR on two CDs as 11 bit-per-pixel, 4-meter multispectral bands and one 1-meter resolution panchromatic bundled product (Space Imaging, 2002).

The ERDAS Imagine software was used to mosaic each of three image swaths of the panchromatic band into a single image of the city. The corresponding swaths for each multispectral band were also mosaiced and then stacked into a single 4 band image of the entire city. The 4-meter resolution multi-spectral mosaic was then combined with the 1-meter panchromatic mosaic to produce a sharpened image using the Brovey Transform method for four output bands applying the Nearest Neighbor resampling technique. The resultant 16 bit per pixel four band image of the entire city was over 3.5 gigabytes in size (Figure 1).

The data collect was originally requested to begin at some time in September, 2001. The events of September 11, 2001 intervened, however, and MD DNR accepted the October collect. The low October sun angle effects produced more shadows within tree canopy than was originally desired. This shadow, however, may have actually contributed to the success of the texture analysis method of separating tree crown from grassy vegetation by increasing texture values in tree crowns relative to grassy areas.

VEGETATION AND TREE MASK GENERATION

A combination of ERDAS Imagine applications and scripts were applied to create a vegetation mask from the NIR-to-Red, (Band4:Band3) ratio image. Visual experimentation showed that higher Band 4 to Band 3 ratio values appeared to correspond well with vegetation. A breakpoint value was obtained by trial and error below which all values were mapped to zero and above which were mapped to 1. A 5x5 majority filter was subsequently applied to slightly smooth and despeckle this vegetation mask.

A texture image was then created from the band 4 over band 3 ratio image to separate tree canopy from other vegetation pixels. This approach was inspired by Zhang (Zhang, Y., 2001) with the exception that the texture image was not fed back into a subsequent multi-spectral analysis. That is to say that texture alone was used to distinguish tree crown from fields, lawns, etc. The bright edges that arise from texture analysis (Ferro, C.J.S, 2002) were also handled by locating breakpoints. Upper and lower breakpoints were selected from the image histogram on a trial and error basis to remap very bright as well as very dark texture values to zero (Figure 2 a-e). At first values were selected visually using the Imagine Viewer Contrast Breakpoints functionality. These approximate breakpoints were then refined by adjusting values in a graphical modeling script. Very bright edges were virtually eliminated in this way. The remaining non-zero pixels were then mapped to a digital number of one to create a rough tree canopy mask. This binary mask was then smoothed iteratively by 3x3 and 5x5 majority filters; each filtering pass being checked visually for improvement or impairment of the mask quality.

The vegetation and tree canopy bit-masks were exported to ESRI GRID files from ERDAS Imagine. Creation of the 1-bit files made a substantial data reduction from the 2.6 gigabytes of the entire 4-band

sharpened image to 40 megabytes for the 1-bit masks and finally to 8 megabytes for the compressed ZIP files (Figure 3).

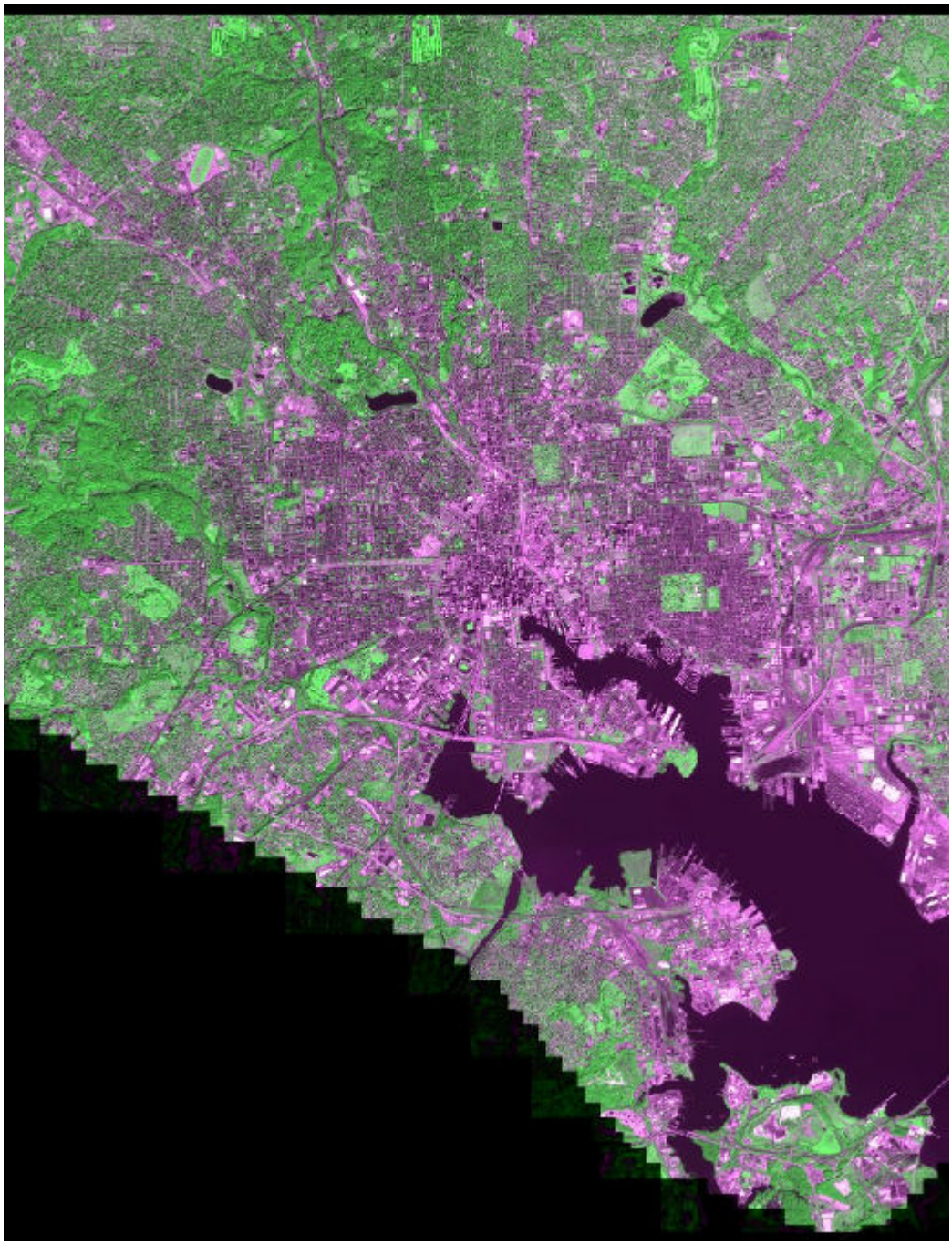
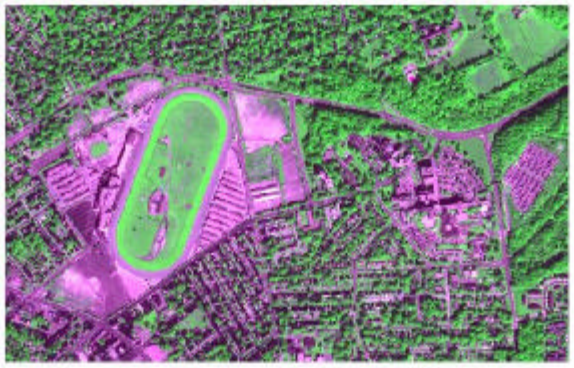


Figure 1. Baltimore, Maryland: IKONOS Bands 2, 4, 3 as Red, Green, Blue, Respectively after Mosaic and Sharpening.

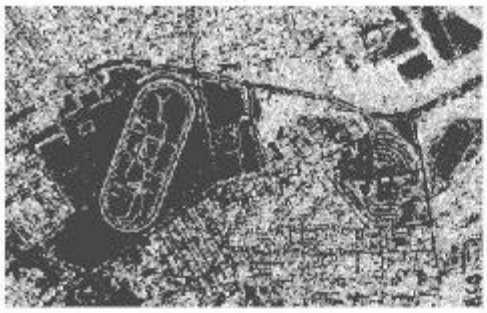
Baltimore, Maryland Pimlico Racetrack and Vicinity



(a)

(b)

(c)



(d)

(e)

Figure 2. (a) Bands 2, 4, 3 as Red, Green, Blue (b) Band 4/Band 3 (c) Vegetation Mask (d) Texture Image (e) Tree Mask

APPLICATION AND UTILITY

The resultant GRID files were input to the ESRI ArcView V3.x software to generate statistics on vegetation and tree canopy coverage for the land area within the city in conjunction with existing vector data delineating the Baltimore City boundary, land area, etc. Spatial analysis under, ArcView, of the vegetation and tree canopy grid files produced statistics indicating total vegetation at 47 percent, non-tree vegetation at 27 percent and tree canopy at 20 percent of the Baltimore land area (Figure 4).

The tree mask accuracy was evaluated by juxtaposition of raw IKONOS data and the semi-automated theme masks (Figure 5). The masks provide reasonable general maps of tree canopy and have been deemed useful for tree planting targeting activities within the city limits. The utility of these masks for input to the City Green Urban Forestry software produced by American Forests is now being investigated at the MD DNR (American Forests, 2002).

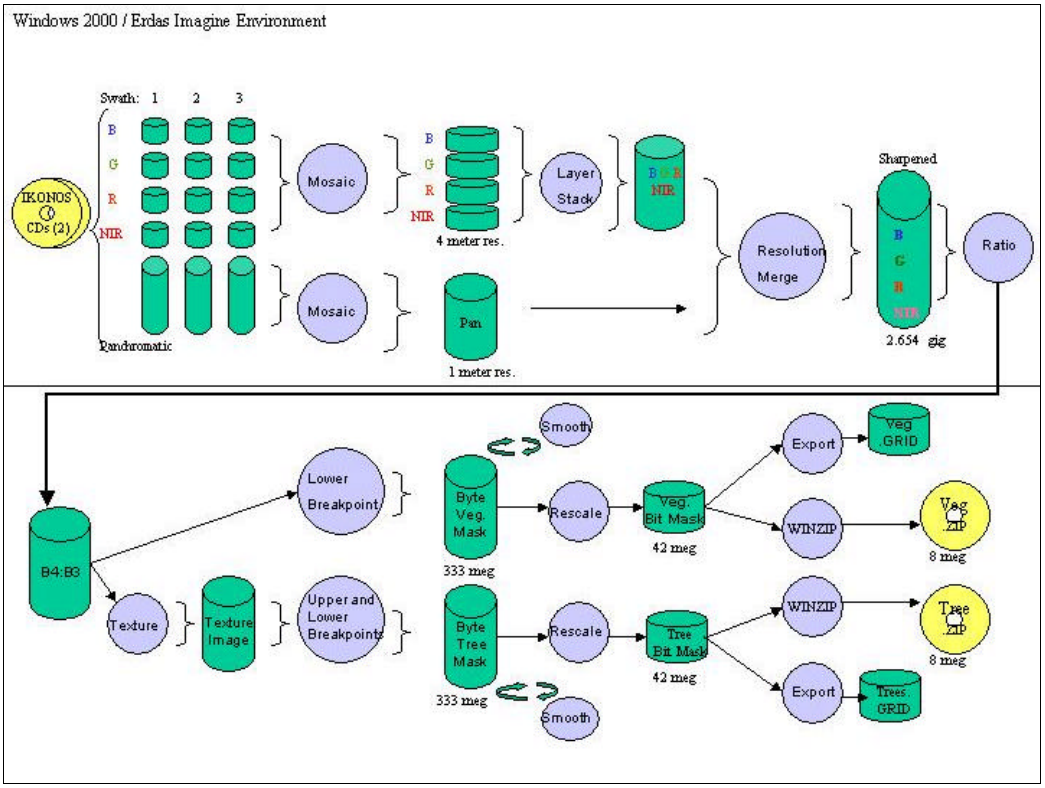


Figure 3. Procedure used to convert IKONOS bundled product to vegetation and tree mask grid files. Braces and arrows both represent direction of work flow. Circles represent ERDAS Imagine application programs or models.

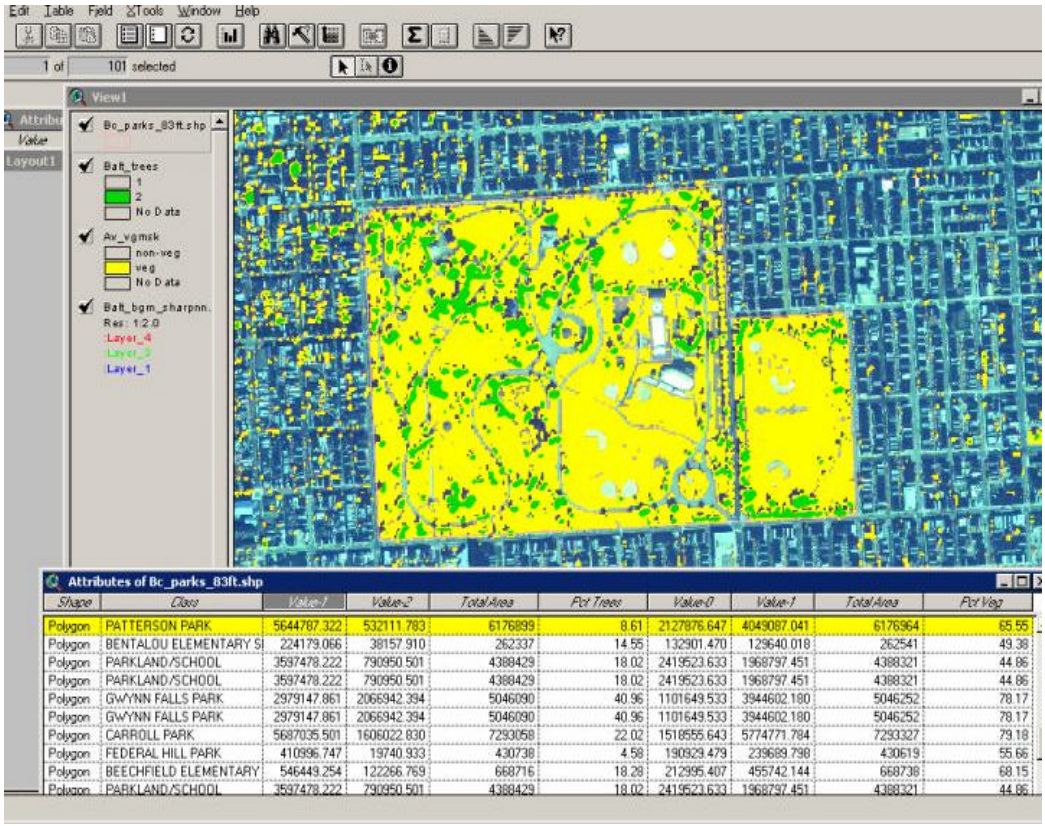
The Baltimore City Department of Planning will overlay in-house GIS layers of site types (parks, hiker-biker trails, street tree corridors, etc.) to establish baseline canopy cover on different site types and set targets for tree cover enhancement creating a template for future City and partner tree plantings. The Baltimore City Dept. of Recreation and Parks, Forestry Division and the volunteer Baltimore City Forestry Board cooperated on the first two plantings which took place at Thomas Jefferson Elementary School on April 17th, and at Cherry Hill Elementary School on April 24th, 2002. On the following May 4th, 175 sophomores came from all across Maryland for a four-day leadership workshop when they planted 80 trees at Cherry Hill Park as a community service project. In June of 2002, representatives of the Parks & People

Foundation met with Mayor O'Malley and shared the IKONOS image and information related to the US Forest Service grant. The Mayor viewed it favorably and declared a 3 month long "Paint the Town Green with Mayor O'Malley" tree planting event to support the grant and mobilize volunteers needed to accomplish the plantings – 24 plantings to plant 2002 new trees around Baltimore. The SUFA: Baltimore effort will serve as a long-term green infrastructure and planning template for Baltimore City and partners.

The Baltimore Neighborhood Indicators Alliance (BNIA) is "an alliance of organizations committed to promoting, supporting and making better decisions using accurate, reliable, and accessible data and information for improving the quality of life in Baltimore City neighborhoods." BNIA developed criteria and indicators which mirror those in other cities across the country involved in the National Neighborhood Indicators Partnership, related them to neighborhood priorities, and produced a series of Vital Signs, reported by Community Statistical Area (CSA). Combination of the vegetation mask with the CSA layer provided for reporting of tree canopy by CSA, which directly addresses one of BNIA's Urban Environment and Transit goals and indicators (BNIA, 2002).

SUMMARY

The priorities set by the US Forest Service for this grant were met by demonstrating the inventory and monitoring capabilities that could be achieved through partnership efforts at the federal, state and local government levels. Technology transfer and public outreach were combined to produce an unprecedented spatial inventory of tree canopy within the Baltimore City limits. This project employed technical capabilities present at the MD DNR to greatly foster collaboration among state, city, and public groups to plant, protect, restore and manage urban trees and forests.



Shape	Class	Value-1	Value-2	Total Area	Pct Trees	Value-0	Value-1	Total Area	Pct Veg
Polygon	PATTERSON PARK	5644787.322	532111.783	6176899	8.61	2127876.647	4049087.041	6176964	65.55
Polygon	BENTALOU ELEMENTARY SI	224179.066	38157.910	262337	14.55	132901.470	129640.018	262541	49.38
Polygon	PARKLAND/SCHOOL	3597478.222	790950.501	4388429	18.02	2419523.633	1968797.451	4388321	44.86
Polygon	PARKLAND/SCHOOL	3597478.222	790950.501	4388429	18.02	2419523.633	1968797.451	4388321	44.86
Polygon	GWYNN FALLS PARK	2979147.861	2066942.394	5046090	40.96	1101649.533	3944602.180	5046252	78.17
Polygon	GWYNN FALLS PARK	2979147.861	2066942.394	5046090	40.96	1101649.533	3944602.180	5046252	78.17
Polygon	CARROLL PARK	5687035.501	1606022.830	7293058	22.02	1518555.643	5774771.784	7293327	79.18
Polygon	FEDERAL HILL PARK	410996.747	19740.933	430738	4.58	190929.479	239689.798	430619	55.66
Polygon	BEECHFIELD ELEMENTARY	546449.254	122266.769	668716	18.28	212995.407	455742.144	668738	68.15
Polygon	PARKLAND/SCHOOL	3597478.222	790950.501	4388429	18.02	2419523.633	1968797.451	4388321	44.86

Figure 4. Public lands analysis of IKONOS derived vegetation and canopy masks.

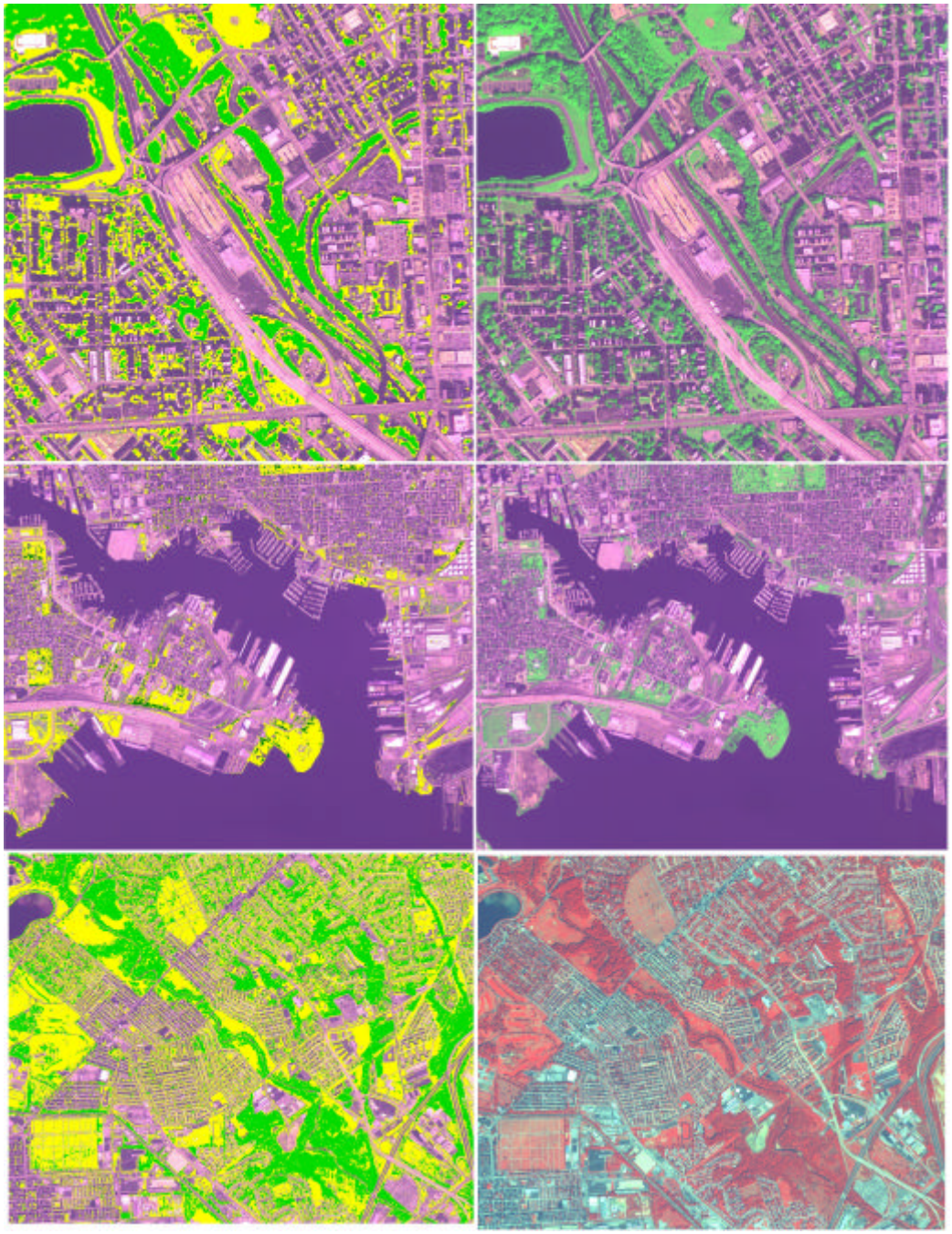


Figure 5. Vegetation and Tree Canopy Masks (left) vs. unclassified imagery (right). Left: Vegetation mask is shown in yellow and Tree Canopy is displayed as green.

REFERENCES

American Forests, 2002. *City Green: Calculating the Value of Nature V5.0 User Manual*, American Forests, PO Box 2000, Washington DC 20013.

BNIA, 2002. Baltimore Neighborhood Indicators Alliance, URL: http://www.bnia.org

Cumming, Anne Buckelew, M. F. Galvin, R. J. Rabaglia, J. R. Cumming, and D.B. Twardus, 2001. *Forest Health Monitoring Protocol Applied to Roadside Trees in Maryland.* Journal of Arboriculture. 27(3): 126-137.

Ferro, C.J.S., and Warner, T.A., 2002. Scale and Texture in Digital Image Classification, *Photogrammetric Engineering& Remote Sensing*, 68(1):51-63.

Nowak, David J.; Crane, Daniel E.; Stevens, Jack C., 2002. Baltimore's Urban Forest. Gen. Tech. Rep. (in publication). Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 131 p.

Parks and People Foundation , 2002. URL: http://www.parksandpeople.org

Riemann, Rachel, 2001. Pilot inventory of FIA plots traditionally called "nonforest". Unpublished.

Space Imaging, 2002. URL: http://www.spaceimaging.com

Wolf, J.C., 2002. Strategic Forest Lands Assessment, 2002. URL: http://www.dnr.state.md.us/forests/conferences/sfla

Zhang, Y., 2001. Texture-Integrated Classification of Urban Treed Areas in High Resolution Color-Infrared Imagery, *Photogrammetric Engineering and Remote Sensing*, 67(12):1359-1365.