Project Report
Tacoma Canopy Cover Assessment

Prepared for:

Ramie Pierce, Urban Forester
ISA Certified Arborist PN-6334A, Certified Tree Risk Assessor #766
City of Tacoma -Public Works
Center for Urban Waters
326 East D Street
Tacoma, WA 98421-1801

Prepared by:

Dr. L. Monika Moskal, Dr. Diane Styers

and

Justin Kirsch
Graduate Research Assistant

UW Remote Sensing and Geospatial Analysis Laboratory (RSGAL)
School of Forest Resources & Precision Forestry Cooperative
College of the Environment
University of Washington
Box 352100
Seattle WA 98195-2100
Office Phone: 206.221.6391

PROJECT BACKGROUND AND SUMMARY

The project was funded by the 2010 DNR Urban and Community Forest Grants through a grant provided to the University of Washington (PIs Dr. L. Monika Moskal and Dr. Dine Styers); the original project proposal is available in Appendix A.

The main purpose of this project was to provide guided analytical training to urban foresters, land managers, and city planners in an innovative technique to quantify tree canopy cover using high-resolution aerial imagery, calculate forest change metrics, and select sampling sites for ground-based tree inventories.

Geospatial Canopy Cover Assessment Workshop

On March 3rd, 2011 a workshop was taught to 2 participants by the project team from the University of Washington Remote Sensing and Geospatial Analysis Laboratory. The workshop materials developed are available in Appendix A and also provided on a website developed specifically for the project at: http://depts.washington.edu/rsgalwrk/canopy/.

The workshop promotes the use of publically available remotely sensed data including the National Agricultural Imagery Program (NAIP) imagery and Puget Sound LiDAR Consortium data. The method of land use land cover (LULC) classification taught was the Object Based Image Analysis (OBIA) approach using the free SPRING software, and described in more detailing Appendix A; as this method is most suitable when using hyperspatial data such as 1m and sub-meter pixel imagery and LiDAR. The method is also suitable for extracting high detailed canopy cover, especially in heterogeneous areas such as urban environments where 30 m pixel data does not capture the fine spatial transitions in LULC. This workshop filled a need for city and county personnel in the state of Washington, who may not otherwise be able to afford training in the use of these new technologies in order to protect natural resources in their communities.

Tacoma 2009 Canopy Cover and LULC Classifications using OBIA

In addition to the workshop the UW RSGAL team worked on producing a canopy cover assessment for the City of Tacoma using 1 m per-pixel resolution. 2009 NAIP imagery (acquired form WAGDA) and 2003 leaf-off LiDAR data acquired from the Puget Sound LiDAR consortium. Ideally the imagery and LiDAR would have been collected during the same year and season, however, that is not always feasible. Studies have shown that inclusion of LiDAR improves LULC classifications, thus, even with the not ideal temporal coverages the two datasets were deployed. Specifically, the normalized height was used from the LiDAR data which accounts for topography and produces a surface above ground height capturing canopy, buildings and other above ground objects. The LiDAR derived layer was at a 1 m raster grid. Ancillary thematic layers provided by the City of Tacoma were also used to increase processing time, although these themes can be derived from OBIA classifications the use of existing data saves processing time and its use has been promoted by others OBIA experts (see letters from SAL blog). The following 2005 thematic layers were used: Roads (polygons not centerlines), Buildings, Sidewalks, Paved Driveways and Water Bodies.

The data were all converted from State Plane to UTM coordinate system using the NAD 83 Zone 10 N projection. Original tiles for NAIP and LiDAR were used through the project and. The Definiens eCognition software was used to refine an algorithm previously used by the UW – RSGAL in Seattle and Olympia. The algorithm was tested and refined for multiple tiles in the Tacoma project to capture the variance of LULC classes; the algorithm incorporated the ancillary thematic layers. Once the algorithm was finalized all NAIP and LiDAR tiles were processed using the Definiens eCognition Batch Processing software.

Figure 1, below shows the results of the 2009 Tacoma LULC classifications, using the OBIA approach. The resulting map is provided as a digital data file and includes 7 classes.

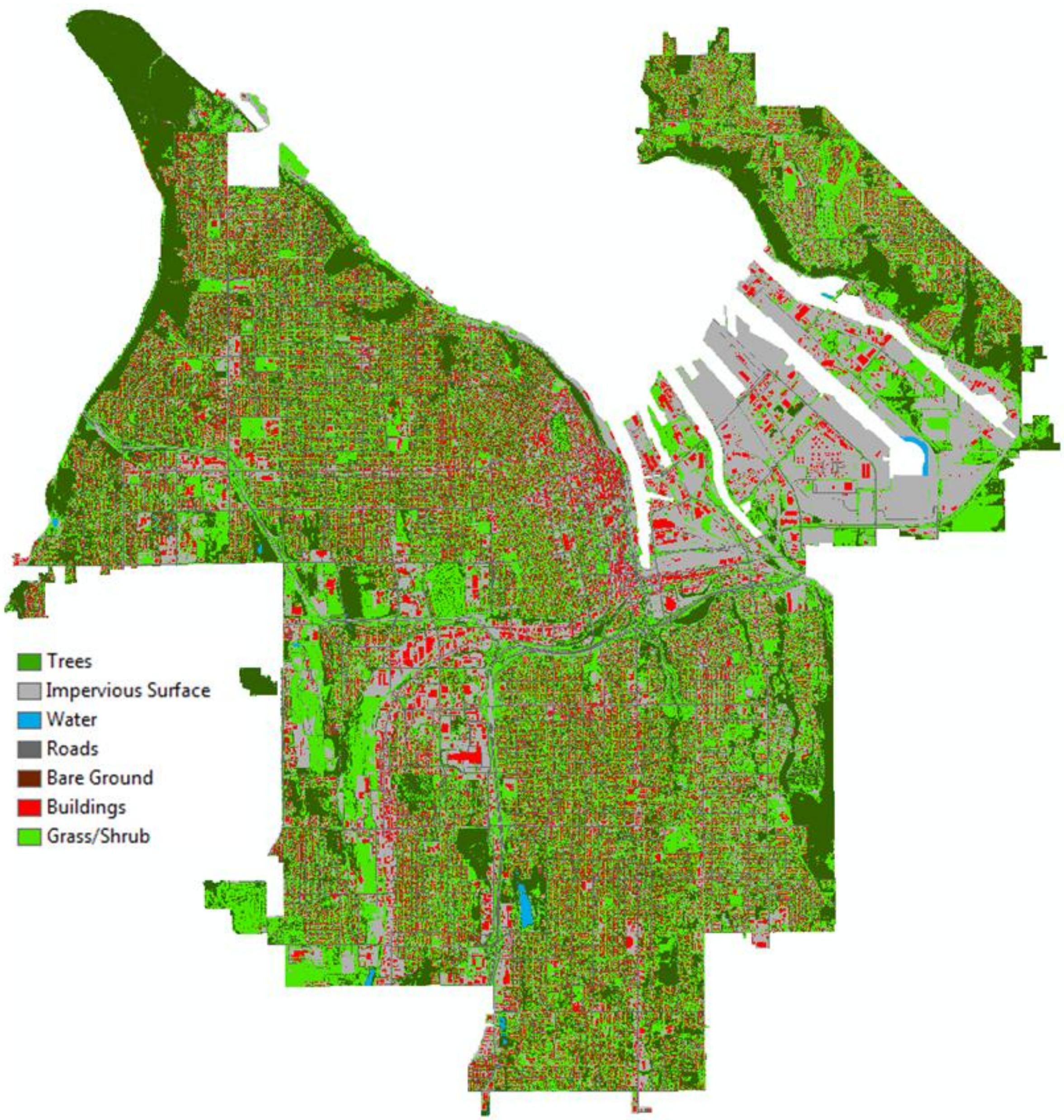


Figure 1. 2009 Tacoma OBIA-based LULC

The accuracy of the map was assessed using accuracy assessment methods introduced in the workshop is Appendix A. This consisted of area weighted number of points per class (points are show in in the digital map) which were visually interpreted by an independent imagery analyst not involved in the development of the classification algorithm. The analyst used the 2009 NAIP imagery as there was no other hyperspatial imagery that the assessment could have been performed with and ground validation was not feasible with the budget of this project. The accuracy assessment results are show in Table 1.

	Trees	Impervious Surface	Buildings	Grass/Shrub	Water	Bare Ground		Users Accuracy *(commission errors)*
Trees	156	10	3	19	3	0	191	81.68%
Impervious Surface	0	268	13	47	0	4	332	80.72%
Buildings	3	8	107	6	0	3	127	84.25%
Grass/Shrub	70	44	7	194	1	1	317	61.20%
Water	0	0	0	0	21	0	21	100.00%
Bare Ground	1	0	0	9	0	2	12	16.67%
	230	330	130	275	25	10		
Producers Accuracy *(omission errors)*	67.83%	81.21%	82.31%	70.55%	84.00%	20.00%	**Overall Accuracy**	**74.80%**

Table 1. Accuracy assessment and the resulting error matrix.

The overall accuracy for the LULC classification was 74.8%. However, it is important to look at the whole error matrix to interpret the classification results. One measure of map accuracy, the User Accuracy (also known as the commission errors) is a good way to evaluate the final map product for individual LULC classes. This is a measure of what somebody looking at a map would call a tree versus what our classification called a tree, more formally the user's accuracy indicates the probability that a sample from a map actually matches what it is from the reference data. The tree canopy class User Accuracy is 81.7%. From this accuracy (81.7%), we are able to calculate the margin of error for the tree canopy class.

The producer's accuracy for the tree canopy class in the 2009 OBIA-based LULC was not as high as the user's accuracy at 67.8%). The producer's accuracy relates to the probability that a classified sample (the trees class in this example) will be correctly mapped and measures the accuracy of the classification. This is a measure of how well the classification performed and can be affected by a variety of factors including the algorithm choice and the data choice used for the classifications. In this case it's the data quality, specifically the older 2003 LiDAR data and the 2005 ancillary data used with 2009 imagery that is impacting the Producers Accuracy; datasets that match closer in date will likely improve this value. This discrepancy in dates of these data means that changes in development, tree removal, and tree growth can have drastic effects on a classification.

The LULC map was used to extract the tree canopy (shown in Figure 2), also provided as a digital layer in the ArcGIS map. This layer is shown on top of the 2003 shaded LiDAR data in Figure 2. The estimated canopy cover for Tacoma based on this 1 m per-pixel resolution map using 2009 NAIP imagery and 2003 LiDAR is 23.3% +/- 4.3%. The 2009 OBIA based map estimates on the low end at **19%,** this conservative number is a good number to use as the

OBIA based classification tends to overestimate canopy which is also confused with grass and shrub; as seen in the error matrix in Table 1.

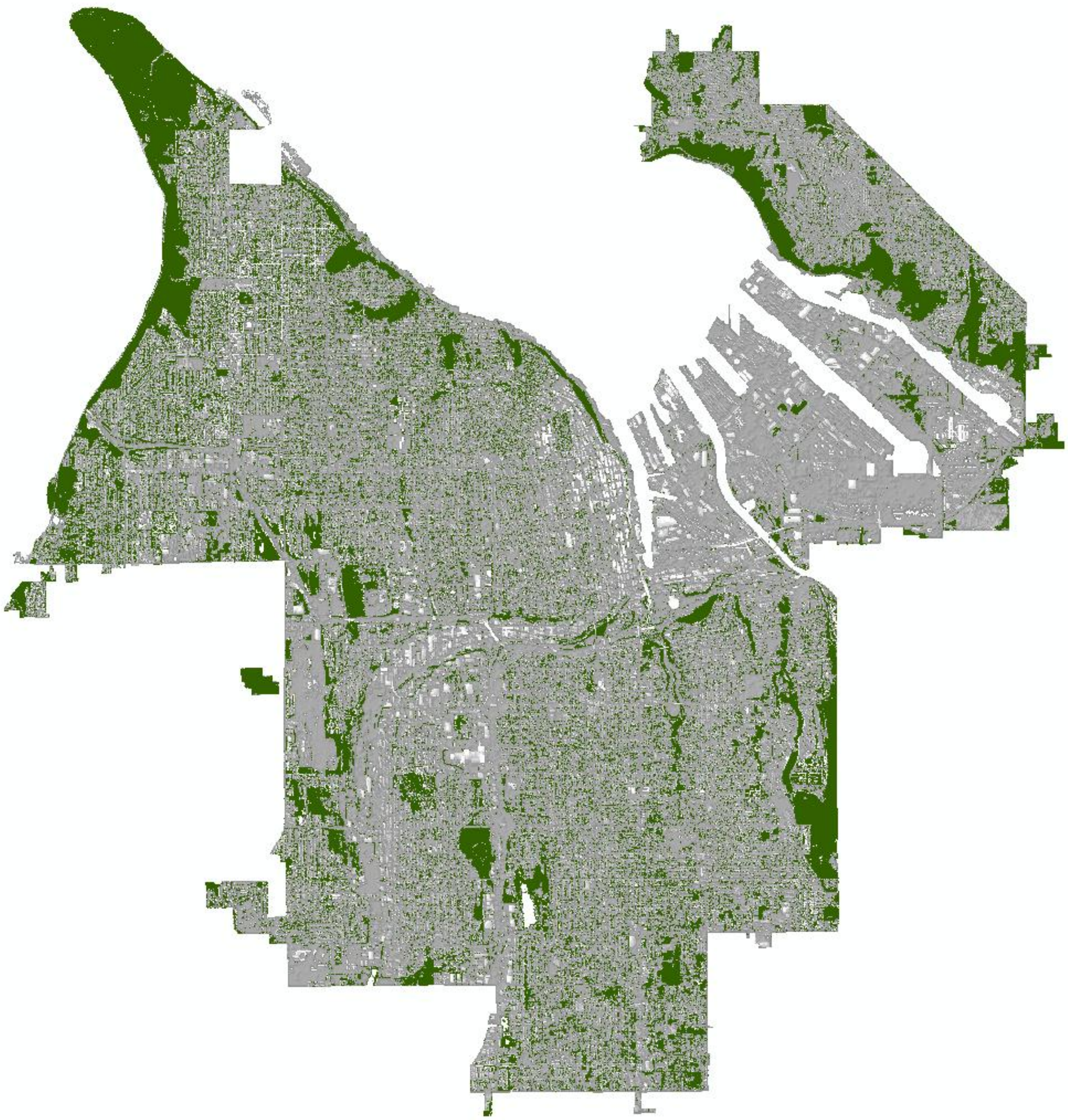
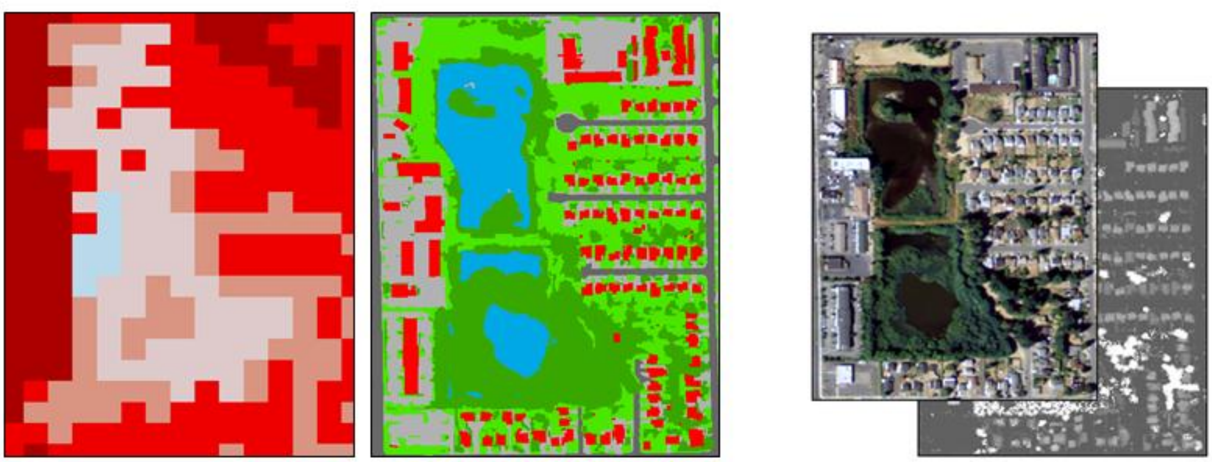


Figure 2. 2009 Tree canopy on top of shaded LiDAR data for the City of Tacoma.

2009 OBIA Versus 2001 NLCD

We compared our results to the 2001 National Land Cover Dataset (NLCD) produced by the USGS and utilized in the USDA Forest Service Urban Canopy Assessment for the City of Tacoma. The 2001 NLCD estimates canopy cover in Tacoma at 12.9%. However, a visual assessment of the 2001 NLCD map and specifically the Canopy Sub-layer and 2009 NAIP imagery shows that there are large forested areas and majority of street trees are not being captured by the 2001 classification. Once can assess the extent of this issue by viewing the digital map with the NAIP imagery provided with this report. However, UW-RSGAL also performed an accuracy assessment of the 2001 NLCD map using some of the Tacoma accuracy assessment points that were classified correctly and double checked by two image analysts to in fact be points associated with tree canopy visible in the 2009 NAIP imagery; total of 156 points. This accuracy is only valid for the canopy sub-layer produced by the NLCD, as other NLCD classes were not assessed using this method. Also, the NLCD canopy-sub player estimates % canopy cover, however in this assessment an NLCD pixel was assessed correctly even without trying to visually estimate % canopy cover using NAIP imagery as this type of assessment would be very time consuming.

Out of the 156 points used in the assessment 115 were correctly identified as canopy by the 2001 NLCD. This assessment shows that the canopy sub layer of the 2001 NLCD is 73.7% accurate. Which means that an error bracket of +/-3.4% can be attributed to the 12.9% canopy cover estimate based on the 2001 NLCD, meaning Tacoma canopy cover based on the 2011 NLCD can be expected to be between 9.5%-**16.3**%. In the case of reporting using the NLCD the higher number is more relevant as the NLCD is known to underestimate land cover classes, specifically those that are heterogeneous. This can be demonstrated by looking at Figure 3, where the 2006 NLCD LULC classification is shown next to the 2009 OBIA LULC classification, not only is the canopy not presented in the classifications (reddish colors indicate built up areas) but the wetlands are severely under estimated in their areas, cover only 7 (30 m) pixels. The 2006 NLCD is shown to minimize the temporal differences in the LULC. Furthermore, when the 156 assessment points were analyzed using the 2001 and the 2006 NLCD LULC maps (not the sub canopy layer) the accuracies of the tree class were 32.7% and 29.5% respectively.



2006 NLCD LULC

2009 OBIA-based LULC classification

2009 NAIP imagery and 2003 LiDAR used to produce the OBIA-based LULC classification

Figure 3. Comparing 2006 NLCD LULC to the 2009 OBIA-based LULC

RECOMMENDATIONS

It is difficult to compare or to track changes with the 2009 NAIP based classification which is hyperspatial in resolution to the 2001 NLCD and even the forthcoming 2005 NLCD canopy cover sub layer which is at a different spatial resolution and produced utilizing algorithms which are optimized for state, county and national assessments. Although these methods are good and appropriate for large scale estimates and perform well in areas of homogenous LULC covering large areas they are currently weaker in heterogeneous landscapes.

In 2011 NAIP will be flow for the State of Washington, the data will match spatially and spectral to the 2009 data. A OBIA based LULC classification using similar methods to those applied here will provide a compatible datasets that can be used to assess change in the canopy from 2009 to 2011 in the City of Tacoma.