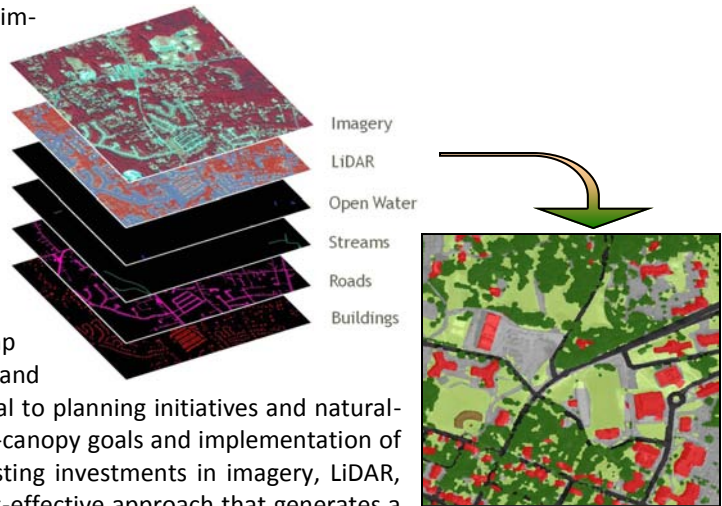


Turning Data Into Information

Leveraging Existing Investments in Remotely Sensed Data to Generate High-Resolution Land Cover Information

Remote sensing datasets like high-resolution satellite imagery and LiDAR are becoming increasingly common in the United States, but they are not always converted into practical, readily-interpretable information. However, the University of Vermont's Spatial Analysis Laboratory (UVM SAL), in conjunction with the USDA Forest Service's Northern Research Station, has developed advanced processing techniques that help fill this information gap. Originally developed to support the Forest Service's urban tree canopy (UTC) assessment program, these techniques are now being used to map land cover across a broad range of urban, suburban, and rural landscapes.



Accurate land cover maps are essential to planning initiatives and natural-resources management, including establishment of tree-canopy goals and implementation of stormwater management programs. By leveraging existing investments in imagery, LiDAR, and GIS datasets, the UVM SAL's techniques offer a cost-effective approach that generates a substantial return on investment from local, state, and Federal geospatial programs.

Source Data

In high-resolution land cover mapping, data drives everything. The National Agricultural Imagery Program (NAIP) regularly acquires high-resolution, leaf-on imagery for each state. Most NAIP imagery is well-suited for land cover mapping, but considerable cost savings can be achieved, particularly over larger areas, by incorporating other datasets (Figure 1). In many cases, state geospatial programs have acquired large volumes of high-resolution remotely sensed data, including LiDAR, which is less sensitive to shadowing and provides structural information. Valued at hundreds of thousands of dollars, these imagery and LiDAR datasets are typically publicly available. In addition, many municipalities have developed planimetric layers and other vector GIS datasets such as building outlines, roads, and surface water features. Incorporating these features into the land cover mapping process reduces cost and ensures consistency.

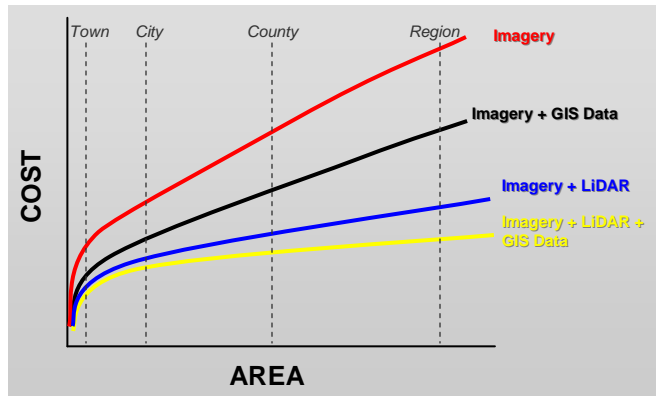


Figure 1. Relative cost of land cover mapping based on area mapped and source data. For larger areas, existing investments in geospatial data can help lower the cost of land cover mapping by a substantial margin.

	DATA DESCRIPTION	PURPOSE
IMAGERY	High-resolution (1 meter or better), preferably leaf-on, multispectral imagery with near-infrared band.	Automated techniques use spectral (color) and spatial (context, size, shape, pattern) information in the imagery to extract land cover features.
GIS DATA	Polygons or lines representing existing mapped features such as building footprints, roads, and hydrography.	These vector datasets reduce the number of features that must be mapped in the automated process and help ensure that the resultant land cover dataset is consistent with existing maps.
LIDAR	Complete point cloud in LAS format with ground returns classified	Surface models are derived from LiDAR and incorporated into the automated process. These surface models are useful for differentiating features based on structural characteristics. LiDAR, unlike imagery, is not sensitive to sunlight and can identify features obscured by shadows.

Table 1. Summary of datasets used for land cover mapping.

High-resolution Land cover Mapping

Moderate-resolution land cover datasets such as the National Land Cover Database (NLCD), derived from 30-meter imagery, have long been available. Unfortunately, these datasets do not accurately represent the landscape at the local scale (Figures 2), resulting in misinformation (Figure 3). Extracting information from high-resolution imagery offers its own set of challenges. Manual image interpretation yields very accurate land cover information, but this approach is time consuming and costly. So-called “pixel-based” techniques such as unsupervised and supervised classifiers have been used for four decades to automate land cover mapping, but they fail to produce land cover datasets that meet acceptable accuracy standards. An additional problem is that many high-resolution datasets are extraordinarily large (e.g., a single county may include billions of data points), slowing processing for large, heterogeneous areas. However, the Cognition Network Lan-

guage® (CNL), developed by Nobel Laureate Dr. Gerd Binnig, permits automatic feature extraction from complex remotely-sensed and GIS datasets. Using CNL to build customized processing systems, the UVM SAL/Forest Service team has mapped land cover for more than 30 municipalities (e.g., cities, counties) in the United and Canada, developing maps whose accuracy approaches that of manual image interpretation. By employing parallel processing, which fully enables the multi-core architecture of modern computer systems, this technology generates accurate land cover datasets in a cost-effective manner for large areas. These high-resolution land cover products are 900 times more detailed than NLCD-derived maps and other moderate-resolution products (Figures 2 and 3), providing decision makers with useful information at the scale of decision making, including parcel level geographies.

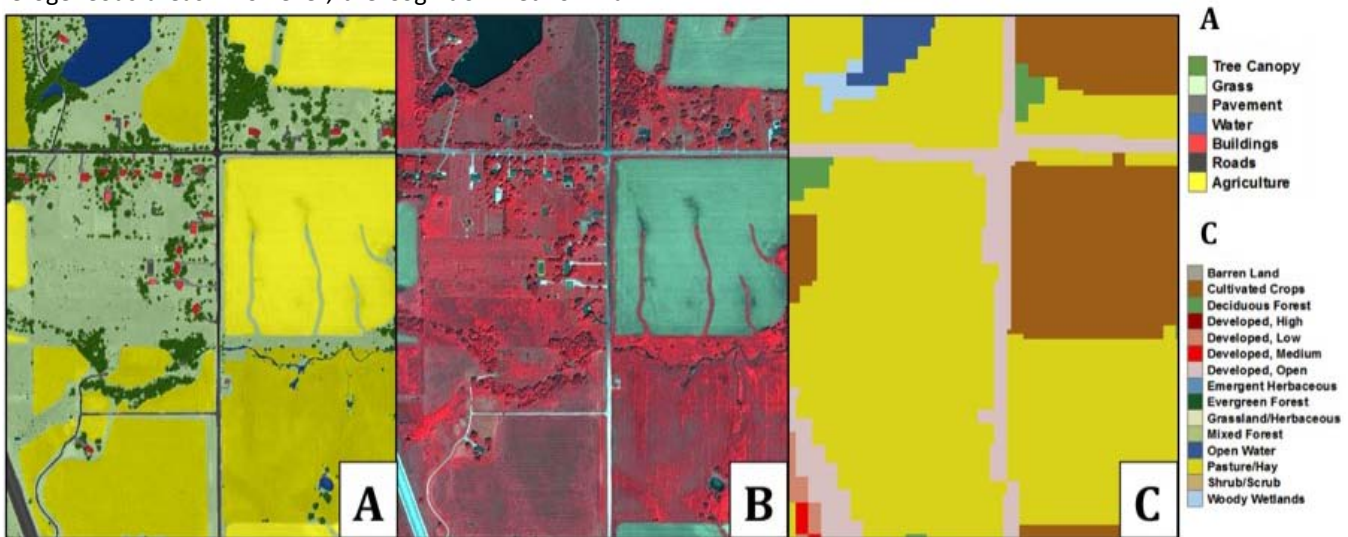


Figure 2. Comparison of land cover dataset (a) derived from high-resolution imagery (b) to 30-meter resolution National Land Cover Database (c) for an area outside of Des Moines, Iowa.



Figure 3. One-meter National Agricultural Imagery Program imagery (a) was used to derive high-resolution land cover data (b) for Hartford, CT. By capturing small, isolated patches of trees, this method estimated that 26% of the city's land area was occupied by tree canopy. In contrast, the 30-meter National Land Cover Dataset (c) estimated tree-canopy coverage of 15%.

Land Cover Metrics and Analyses

The value of high-resolution land cover maps is maximized when they are summarized by user-defined “geographies,” which makes their information content more relevant to a broader range of stakeholders. Geographies typically consist of polygon GIS boundaries such as property parcels, watersheds, census block groups, zoning districts, riparian buffers, and neighborhoods. Following UTC assessment protocols, land cover can be summarized for an entire city (Figure 4a) and then integrated with property land-use data (Figure 4b) to yield tree-canopy (TC) metrics for each land-use type (Figure 4c). Tree-canopy metrics provide the current amount of tree canopy (Existing TC) along with the amount theoretically available for tree canopy (Possible TC). Because high-resolution land cover data are scalable, they can be integrated with other datasets to support multiple programmatic goals (Figures 5 and 6).



Figure 4. Land cover metrics can be summarized for an entire city (a) or integrated with property parcel data (b) to yield tree-canopy metrics by land-use type (c).

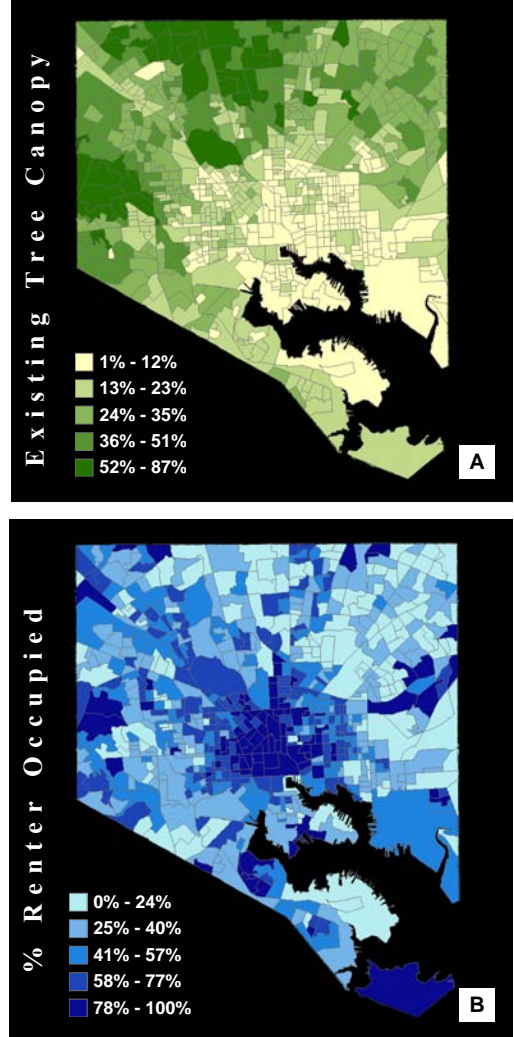


Figure 5. Existing tree canopy from high-resolution land cover data summarized at the census block group (a) and compared to the percentage of homes that are renter occupied (b). This particular combination of land cover and socio-demographic data can help identify tree-stewardship patterns.

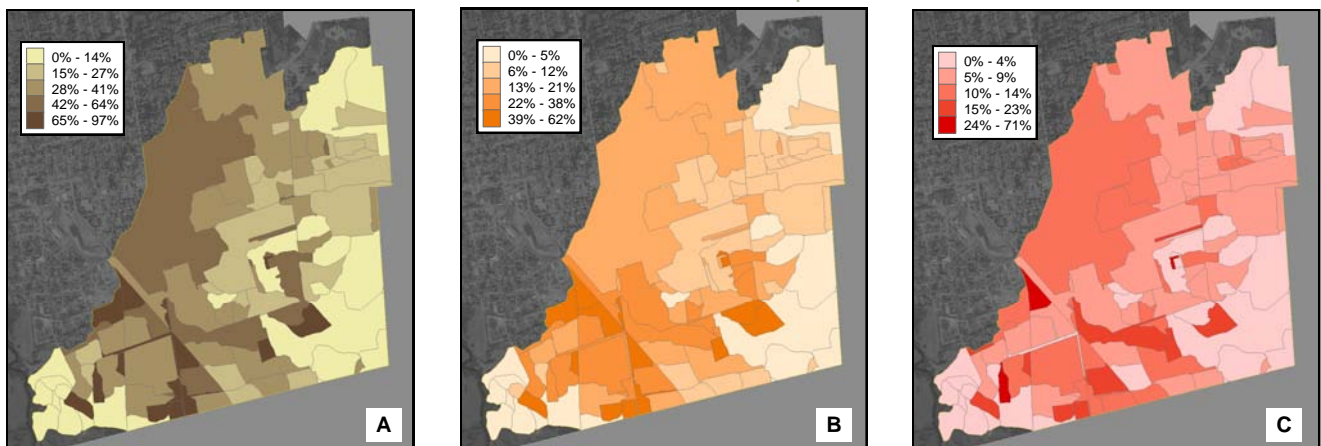


Figure 6. Percentage area of impervious surfaces by subwatershed in an impaired watershed: buildings, roads, and other pavement combined (a); buildings alone (b); and other paved surfaces (c). Because remediation techniques differ according to impervious-surface type (e.g., green roofs for buildings, porous pavement for parking lots), this type of summary mapping permits precision targeting.

Products

Reports, statistics, presentations, and maps ensure that land cover datasets are accessible to the widest possible range of end users. Most importantly, all maps and summary data can be seamlessly integrated into relevant municipal or community GIS databases, providing instant access to land cover and tree-canopy metrics (Figure 7). Intermediate datasets generated to support the land cover mapping processing, such as LiDAR surface models, are also provided.

PRODUCT	DESCRIPTION
Report and Presentation on Existing and Possible Tree Canopy	PDF report and PowerPoint presentation analyzing Existing Tree Canopy and Possible Tree Canopy.
High-Resolution Land Cover	Seven class land cover dataset. Land cover classes include: 1) Tree Canopy; 2) Grass/Shrub; 3) Bare Soil; 4) Water; 5) Buildings; 6) Roads/Railroads; and 7) Other Paved Surfaces.
Tree Canopy Metrics Tables	Tables summarizing Existing Tree Canopy and Possible Tree Canopy by geography (e.g., parcels, watersheds, critical areas, neighborhoods).
Land Cover Metrics Tables	Tables summarizing land cover (seven classes) by geography (e.g. parcels, watersheds, critical areas, neighborhoods).
LiDAR derivatives*	Products derived from the LiDAR dataset, including a digital elevation model (DEM), digital surface model (DSM), and normalized digital surface model (nDSM). The DEM represents the ground surface, the DSM represents the true 3D surface of all features relative to sea level, and the nDSM represents the height of features relative to the ground.

* Provided LiDAR data exist.

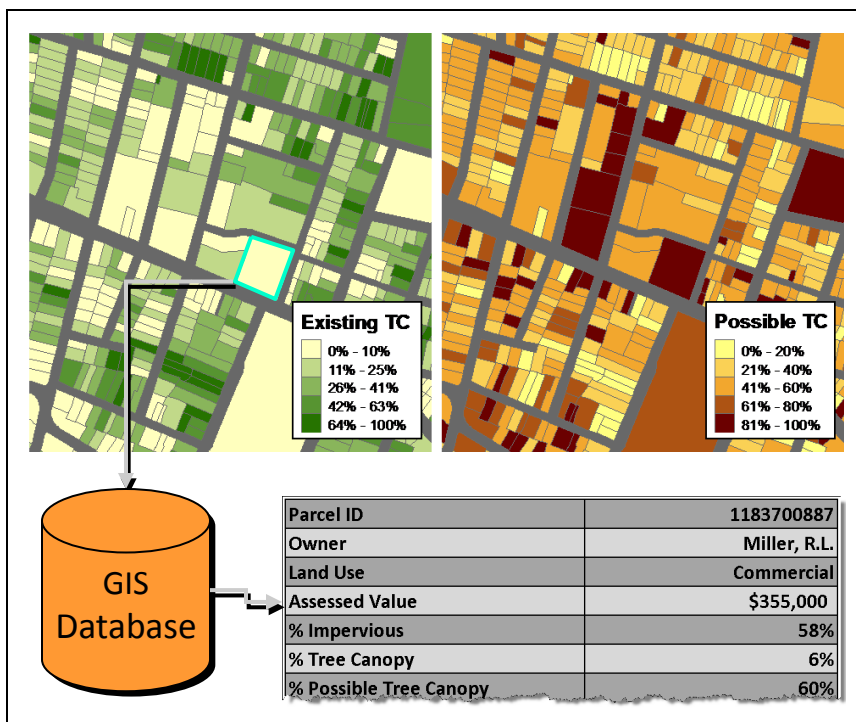


Figure 7: GIS analysis of parcel-based tree canopy metrics for decision support. In this example, GIS is used to select an individual parcel. The attributes for that parcel are displayed in tabular form, providing instant access to relevant tree-canopy information such as existing and possible tree canopy.

For more information:

Urban Tree Canopy Assessment Program website:
<http://nrs.fs.fed.us/urban/utc>

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