Final Report

Cuyahoga County
2019 Tree Canopy Assessment

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September 13, 2019

Overview

Cuyahoga County's urban forest provides numerous ecosystem benefits to its citizens and businesses: air and water pollution reduction, stormwater control, moderation of high summer temperatures, aesthetic urban viewsheds, and community sense of place. These benefits ensure not only the daily well-being of its residents but also contribute to making the county a desirable place to live and work. The county's trees face a multitude of known and potential environmental threats, including invasive species, storm damage, development pressure, and climate change. It is thus imperative for the county to understand the nature and extent of recent changes to its tree canopy, and also to gauge the contributions of its ongoing tree-planting initiatives.

The University of Vermont Spatial Analysis Lab was part of the team that performed the urban tree canopy (UTC) assessment for Cuyahoga County in 2013 using circa 2011 data. The 2013 assessment products consisted of both a 7-class and 10-class land cover datasets suitable for use with the USDA Forest Service's UTC assessment protocols. Geoprocessing workflows to compute UTC metrics were also provided to the county. Newly available remotely sensed data in the form of LiDAR and imagery provide a unique opportunity to update the tree canopy assessment to reflect 2017 conditions and map the change in tree canopy from 2011 to 2017.

Estimating tree canopy change over time from remotely sensed data (imagery and LiDAR) requires that the amount of change measured fall outside of the margin of error. For example, if the two tree canopy estimates, produced at differing times, have a margin of error of +/- 2%, one cannot conclude that there is a 2% increase. It is thus imperative that the approach to tree canopy change mapping reduces the amount of error associated with mapping tree canopy from two separate time periods using different source data. The various imagery and LiDAR datasets for this project were not collected with slightly different specifications. To accommodate the challenges inherent in tree canopy change detection the University of Vermont Spatial Analysis Laboratory (SAL), in collaboration with the USDA Forest Service, has developed mapping protocols that minimize the errors associated with mapping tree canopy change over time. These techniques have become the standard for tree canopy change detection by ensuring that the change that is mapped is due to actual change in the canopy not due to slight differences in the source data collection or processing specifications. These techniques were employed in this study to ensure the highest standard of quality.

Objectives

1. **Developed updated land cover datasets**. 7-class and 10-class land cover datasets based on the best available 2017/2018 remotely sensed data.
2. **Map tree canopy change.** This project provided a complete, comprehensive, and accurate accounting of tree canopy change over the 2011-2017 time period.
3. **Produced geospatial datasets suitable for distribution**. The geospatial products developed as part of this project contain the appropriate data and thus are suitable for distribution on the county's open data portal.
4. **Assisted with UTC maps and metrics.** Provided access to the geoprocessing tools and offered technical assistance on developing UTC metrics and maps using the USDA Forest Service protocols.

Source Data

The source datasets required to complete the project are presented in Table 1.

Table 1. List of source datasets.

Description	Currentness	Format	Source
National Agricultural Imagery Program (NAIP) leaf-on imagery	2011/2017	Raster GeoTIFF	USDA
County orthophotos	2017	Raster GeoTIFF	County Planning
LiDAR point cloud	2006/2017/2018	LAS	County Planning
LiDAR surface models (e.g. DEM)	2006/2018	GeoTIFF	County Planning
Supporting vector data	Various	Vector	County Planning

Methods

This project employed land cover mapping and tree canopy assessment techniques that have been developed in collaboration with the USDA Forest Service. The workflow is illustrated in Figure 1. The 2017 mapping effort was similar to the workflow used in 2011, however, new datasets and improvements to algorithm development were incorporated.

Before being able to utilize LiDAR to its greatest potential, a substantial amount of preprocessing of raw point clouds is done to create derivative datasets (raster surface models and normalized, classified point clouds). The SAL has developed an automated pipeline in Python that strings together a variety of software packages, including LAStools, FME, and ArcGIS Pro to create these derivative products. This LiDAR data prep pipeline also has quality assurance algorithms built in to identify and diagnose challenges with the input point clouds, such as a handful of tiles with the wrong coordinate system attribution or a different point classification schema that could throw off processing. The LiDAR derivates produced include the Digital Surface Model (first returns), Digital Terrain Model (last returns), Digital Elevation Model (bare earth), Intensity (strength of pulse return) and normalized, classified point clouds (ground height = 0, buildings and tree points classified).

Mapping tree canopy and land cover using an object-based approach has two distinctive automated steps: segmentation of an image into image objects (groups of pixels with similar values) and classification of those image objects mimicking human cognition, considering the image object's spectral, topographic and contextual properties (Figure 2). These automated steps iterate in conjunction with manual corrections for each feature of interest to create a cascading effect, increasing the ability to identify subsequent features more accurately. Further, by leveraging the strengths of imagery, LiDAR and existing ancillary vector datasets in both the automated and manual processes, known weaknesses in each respective dataset can be circumvented to improve feature extraction outcomes.

Tree canopy and land cover change detection, as previously described, has a slew of nuances that are imperative to address. There are inherent differences between datasets from multiple time periods that require reconciliation, including resolution and horizontal alignment of the respective datasets to confirm the verifiable change is indeed occurring. The SAL has developed techniques to address these challenges, for example, by utilizing the highly accurate horizontal spatial fidelity of the LiDAR surface models to account for lean in the imagery. This approach ensures that despite spectral value shifts between the two time periods, analysis of the difference in height maximizes the extraction of legitimate change and minimizes the false change inherent in varying input datasets. Often LiDAR collects are flown during varying times of year or are processed with different algorithms, causing what may look like actual variation within a forest between two time periods in the surface models. In these cases, the imagery can be used to confirm in which contextual scenarios tree gain/loss is occurring and when there is no change.

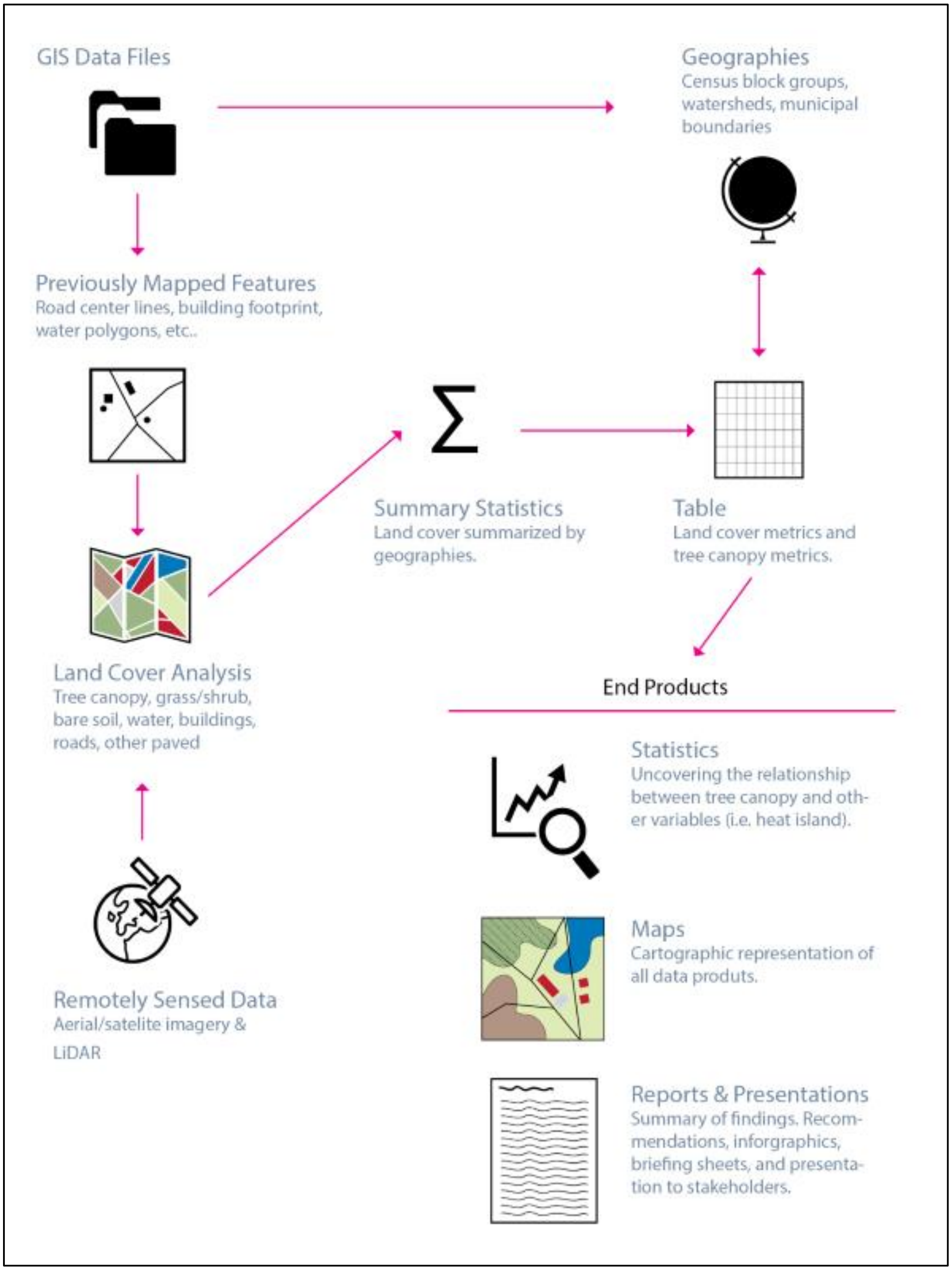

Figure 1. Tree canopy assessment workflow.

The change mapping provided a unique opportunity to also make improvements to the 2011 datasets. Advances in algorithm development, better data, and data from multiple time periods all contributed to the improvements to the 2011 datasets. While these modifications do not have a significant impact on the overall land cover summaries the changes are noticeable at a fine scale in some areas.

Figure 2. Image segmentation, grouping pixels into image objects based on similar height values (left), image object classification of tree canopy using spectral, topographic and contextual properties (right).

Deliverables

There are five deliverables for this project. Sample deliverables are presented below. The minimum mapping unit was set at 30 square feet. Raster products have a cell size of 1 foot. The coordinate system for all geospatial deliverables was set to NAD1983 StatePlane Ohio North.

1. **High-resolution 7-class land cover dataset**. This dataset represented land cover based on 2017 ground conditions. The land cover classes included: (1) tree canopy, (2) grass/shrub, (3) bare soil, (4) water, (5) buildings, (6) roads/railroads, (7) other paved. This is a raster geospatial dataset.
2. **High-resolution 10-class land cover dataset**. This dataset is a modified version of the 7-class land cover dataset that addresses features underneath tree canopy. The classes include: (2) grass/shrub, (3) bare earth, (4) water, (5) buildings, (6) roads/railroads, (7) other paved surfaces, (8) tree canopy over vegetation or soil, (9) tree canopy over building, (10) tree canopy over road/railroad, and (11) tree canopy over other paved surfaces.
3. **High-resolution tree canopy change dataset**. This dataset will represent the change in tree canopy over the 2011-2017 time period. Three change classes were mapped: (1) no change, (2) gain, and (3) loss. This is a vector geospatial dataset.

4. **Land cover inter-comparison dataset**. Comparisons of the 2011 and 2017 7-class land cover datasets showing between class change. This is a raster geospatial dataset.
5. **UTC metrics geoprocessing tools**. These tools, developed in collaboration with the USDA Forest Service, derive land cover metrics, tree canopy metrics, and tree canopy change metrics from the deliverables listed above. The land cover metrics summarize the area and percent area for all seven land cover classes for the various geographies of interest (e.g. land use, parks, watersheds). This is a tabular dataset that can be joined to the appropriate geospatial geography layer. The tree canopy metrics compute the existing tree canopy and possible tree canopy area and percent area for the various geographies of interest (e.g. land use, parks, watersheds). This is a tabular dataset that can be joined to the appropriate geospatial geography layer. The tree canopy change metrics summarize total change, percent change, and relative change for tree canopy no change, gain, and loss for the various geographies of interest (e.g. land use, parks, watersheds).
6. **LiDAR Surface Models**. Raster surface models derived from the LiDAR data. The digital elevation model (DEM) represents the bare earth topographic surface. It was derived from the LiDAR points assigned to the ground class. The digital surface model (DSM) represents the true 3D surface of all features. It was derived from all non-noise, non-withheld points in the LiDAR dataset using a customized "pit-free" routine developed by for UTC assessments. The normalized digital surface model (nDSM) will represent the height above ground for all features. It was derived by subtracting the DEM from the DSM.
7. **Classification routines**. The expert system used for automated feature extraction. Delivered in a text format, the routines include information such as the spectral and height thresholds used to extract land cover features and map change.
8. **Reports**. Two progress reports and a final report. This document is the final report.
9. **Presentation**. The final presentation was delivered via webinar. The webinar was recorded.

Figure 3. High-resolution 7-class land cover 2017 products (left), 2017 NAIP imagery displayed using a color infrared composite (right).

Figure 4. High-resolution 10-class land cover 2017 products (left), 2017 NAIP imagery displayed using a color infrared composite (right).

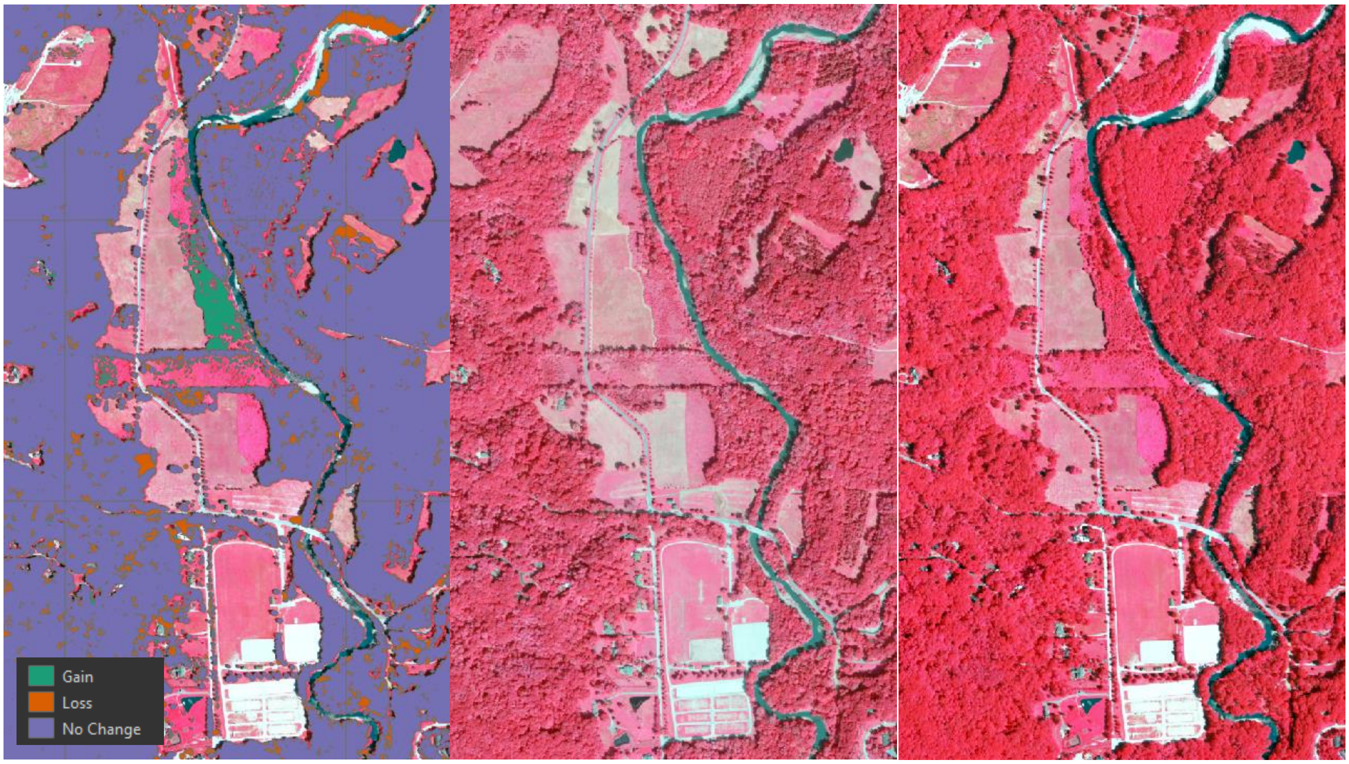

Figure 5. High-resolution tree canopy change (left) compared to 2011 NAIP (center) and 2017 NAIP (right).

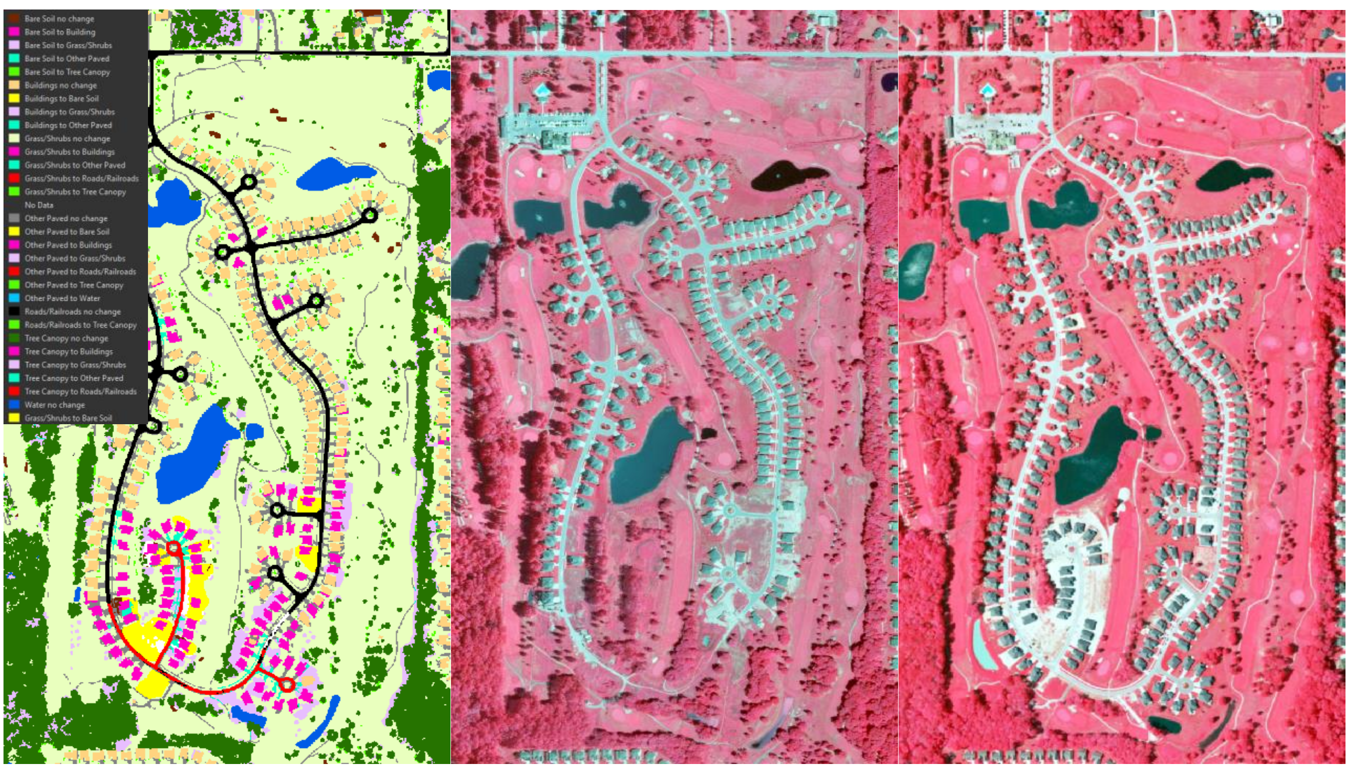

Figure 6. High-resolution 2011 – 2017 Land Cover Change products (left), 2011 NAIP imagery displayed using a color infrared composite (middle), 2017 NAIP imagery (right).

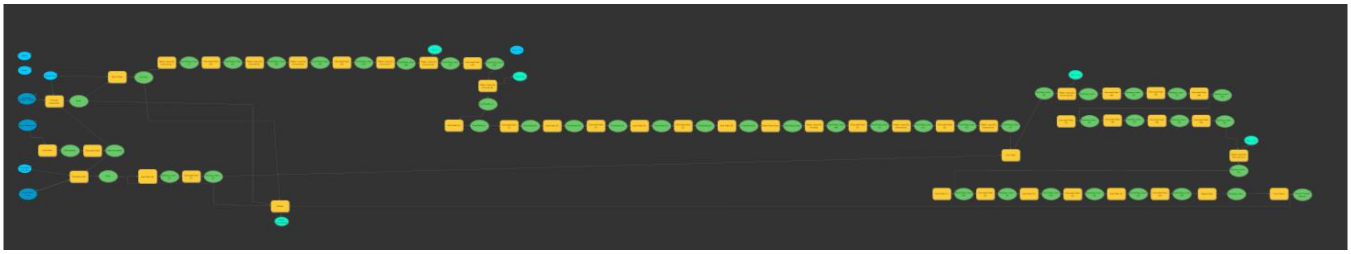

Figure 7. Metrics model.

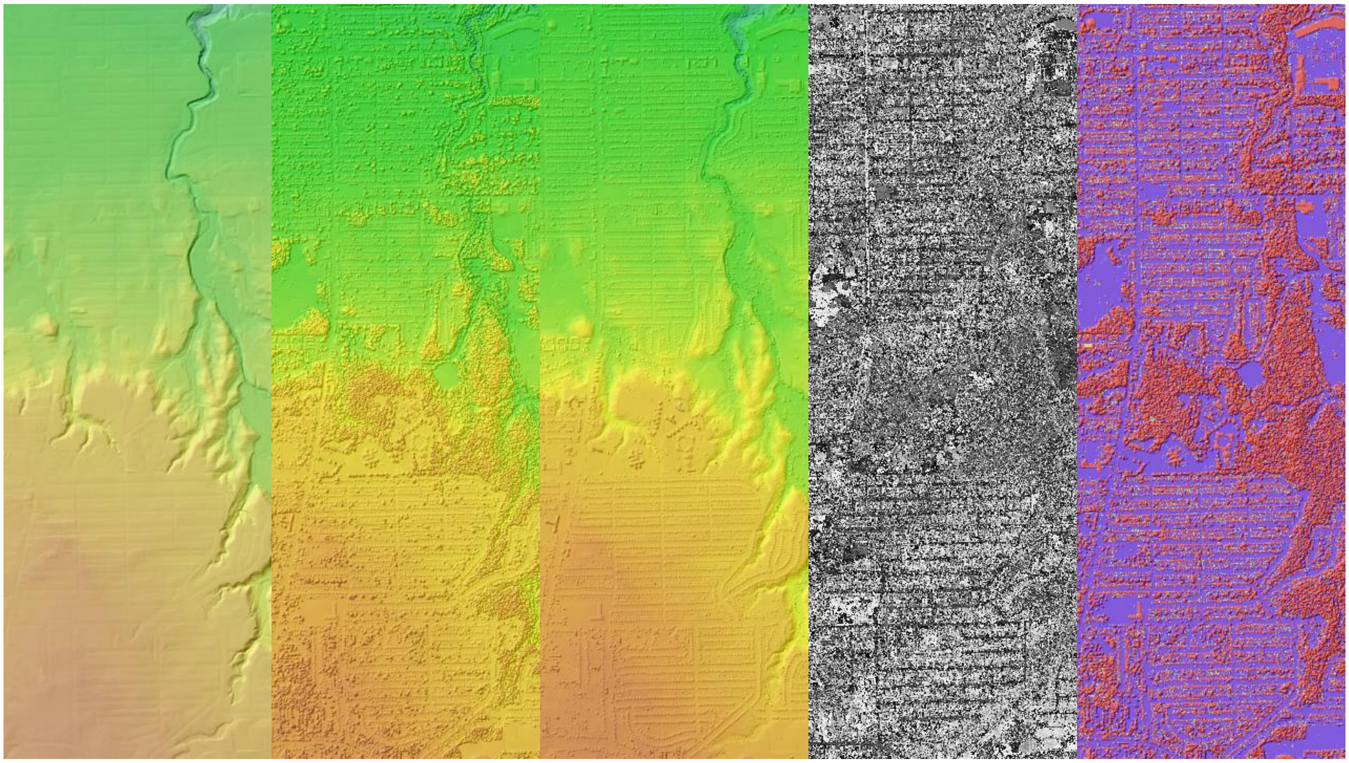

Figure** 8**. LiDAR surface models from left to right: DEM (bare earth), DSM (first returns), DTM (last returns), intensity (strength of return), and nDSM (normalized DSM).