Estimating Chicago's Tree Cover and Canopy Height using Multi-Spectral Imagery

The Alan Turing Institute

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Contents

Why this project and why Chicago?

- Investing in urban tree canopies is often identified as one way to help mitigate climate change
  - Trees have been shown to help reduce temperatures, clean the air of some harmful pollutants, while also raising the quality of life for residents
- Urban tree planting initiatives face a lack of up-to-date data about their urban canopies
- The location of trees matters
  - Environmental benefits from trees varies throughout urban areas, so being able to know where trees are can help to identify future planting locations where trees can have largest positive impact
- In 2021, Chicago’s mayor announced a 46 million dollar investment in planting and maintaining 75,000 trees over five years

Data on the Urban Tree Canopy

– Three primary techniques have been previously used to measure tree canopies

- Survey methods sample plots to manually count trees before generating estimates for the entire city
- Image segmentation uses machine learning techniques to identify the outlines of trees from labelled data
- LiDAR (Light Detection and Ranging) is a highly accurate but highly expensive airborne data collection technique which utilizes light beams to create a point cloud of millions of points that can be used to generate a three-dimensional model of the environment

– Urban tree maps tend to rely on only one measure of the canopy, the horizontal coverage of trees, often ignoring the important vertical dimension of the canopy

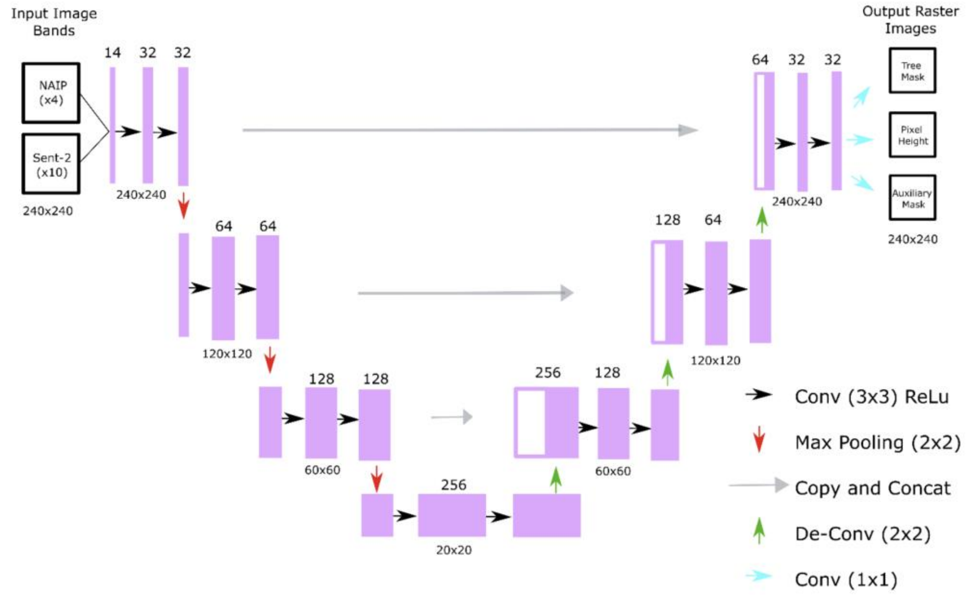
Methodology

- Historical LiDAR data was used to generate a ground truth dataset of tree cover and tree height, both at the pixel level
- A combination of aerial imagery (NAIP) pulled from the US Department of Agriculture and satellite imagery from the Sentinel-2 mission was then used to train a model and generate predictions for timepoints without LiDAR data

Source	Bands	Date	Cloud Coverage %	Usage
U.S. Geological Survey	LiDAR Point Cloud Data	April-May 2017	NA	Ground-truth tree data
NAIP	Red, Green, Blue, NIR (1-m)	September 1-3, 2017 & August 2-9, 2019	<10%	ML prediction, vegetation mask
Sentinel 2	Red, Green, Blue, NIR (10-m); 705nm, 740nm, 783nm, 865nm, 1610nm, 2190nm (20-m)	September 18, 2017 & July 15, 2019	1.16% & 0%	ML prediction

Methodology

- A neural network with the UNet architecture was used in a multi-task framework to predict pixel height and whether or not each pixel is part of a tree
- 9,535 240x240 images were used to train and evaluate the model
- Comparison models with varying components were run to choose the final model

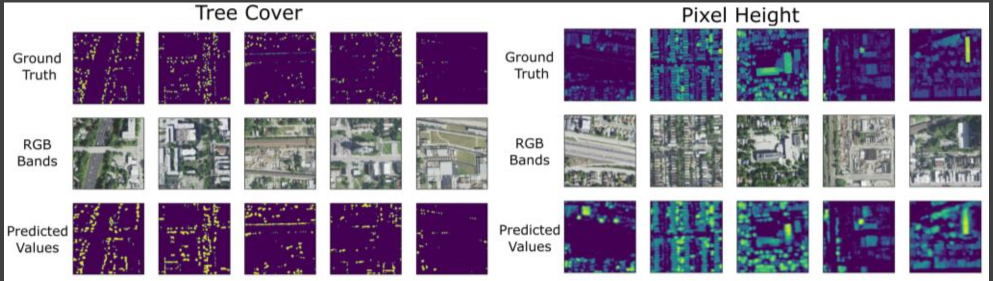


Note: Each pink rectangle corresponds to a multi-channel feature map. The number of z-dimension channels is denoted on top of the rectangle. The x-y dimensions of each feature map are provided at the bottom of the rectangles. White boxes represent copied feature maps.

Results

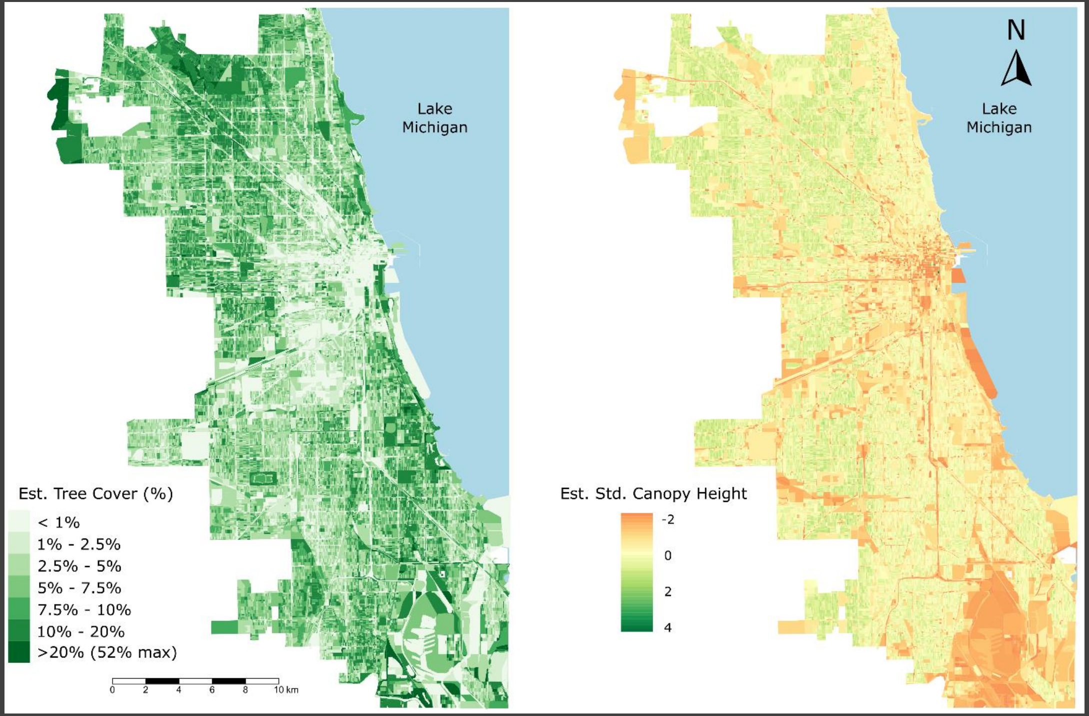
- The model that was best able to identify trees (IoU=.647) was the model with layers fully shared across tasks
- Pixel height was best predicted by the model including only pixel height, estimating height within about five percent of the observed value

Model	Bands Used	Tree Mask IoU	Height MAE	Auxiliary IoU
Tree Mask Alone	RGB Only	.475	-	-
Tree Mask Alone	14 MS Bands	.476	-	-
Pixel Height Alone	RGB Only	-	.063	-
Pixel Height Alone	**14 MS Bands**	-	**.050**	-
Auxiliary Mask	RGB Only	-	-	.131
Auxiliary Mask	14 MS Bands	-	-	.747
MT Fully Shared	RGB Only	.614	.099	.878
MT Fully Shared	**14 MS Bands**	**.647**	.085	**.940**
MT Partially Shared	RGB Only	.621	.070	.884
MT Partially Shared	14 MS Bands	.642	.072	.934



Results

- 2019 tree cover and canopy height were estimated using the UNet model and freely available aerial and satellite imagery
- Estimates were aggregated to US census blocks for mapping
- For Chicago, a total city wide tree cover of ~6% was estimated



Implications and future work

- This work presents a novel pipeline for measuring the urban tree canopy- both horizontally and vertically
- Better data allows for better decision making in tree planting initiatives and for a better understanding of the varying environmental impacts trees have within urban areas
- The addition of relatively low resolution multi-spectral bands added slight predictive capacity to the UNet models, could higher resolution multi-spectral imagery add even more?
- Where LiDAR data has been collected once, this pipeline could be used in the future to help create more robust canopy maps for cities
    - For areas without LiDAR data, canopy maps could potentially be generated using trained model weights from cities with similar geographies and climate

Thanks for viewing this presentation!

For any questions or further information please reach out to jfrancis@turing.ac.uk

Code used for this project can be found at https://github.com/johnfrancis13/where_to_plant_trees

This work would not have been possible without the advice and insight provided by Dr. Mat Disney!