A Lidar-based Method for 3D Urban Forest Evaluation and Microclimate Assessment, a Case Study in Portland, Oregon, USA

Xihan Yao[1] (xyaoaf@berkeley.edu) and Minho Kim[1] (mhk@berkeley.edu)
Department of Landscape Architecture and Environmental Planning, University of California, Berkeley

Introduction

Urban heat islands significantly impact the health and well-being of the urban population. Urban vegetation can help regulate the urban climate by providing shade and evapotranspiration. This study examines the micro perspective of the urban climate and the heterogeneous urban vegetation's role in adjusting the microclimate with an innovative pipeline of workflow integrating **Lidar point statistics**, **Machine Learning classification**, and **microclimate simulation with ENVI-met model**. The method was tested in a comparative study on two socio-demographically distinct communities (Site A: Irvington, West, Site B: Centennial, East) in Portland, Oregon, USA, regarding their different urban tree structures and compositions and resulting differences in air temperature and other microclimate characteristics.

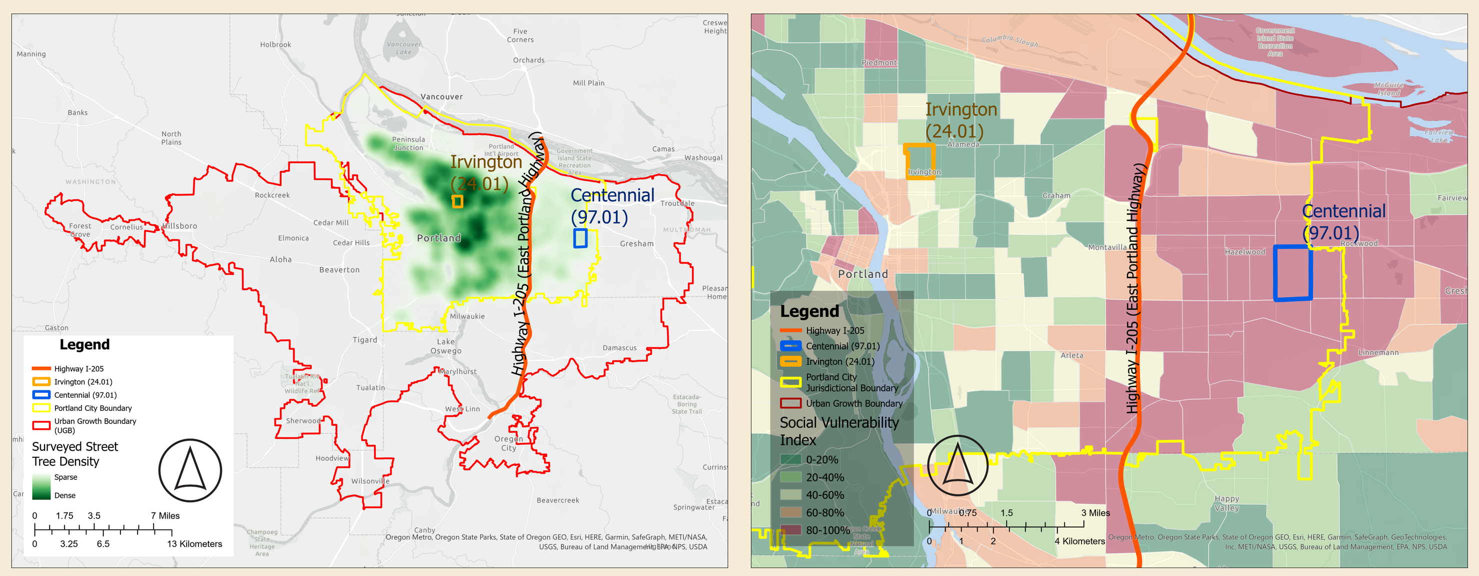


Figure 1: Context. Left: Urban Growth Boundary and clusters of surveyed public trees, Right: Social Vulnerability Index (Source: US CDC) and the two study sites.

Urban Tree Inventory with Lidar Point Cloud Statistics

The Airborne Lidar data was supplied by the City of Portland. The product has over 56 points/pulses per square meter. Lidar point cloud can provide information about the vertical, internal structures of individual trees and be used to distinguish the variations among different trees.

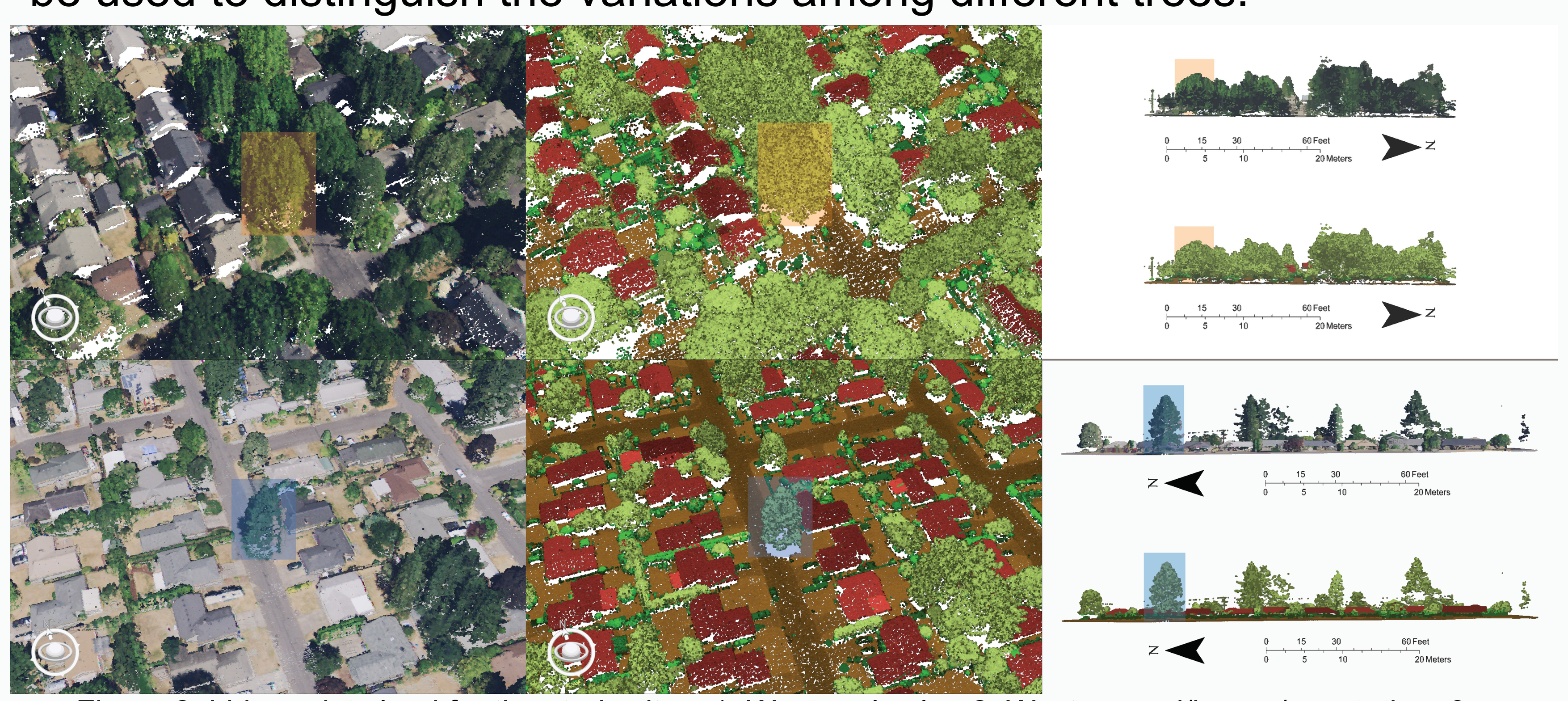


Figure 2: Lidar point cloud for the study sites, 1: West real color, 2: West ground/house/vegetation, 3: West section views, 4: East real color, 5: East ground/house/vegetation, 6: East section views.

1.The Lidar points were classified into vegetation, building, and ground classes using LAStools. Only the vegetation points were retained for further analysis.
2.DEM, DSM, and nDSM were generated. The R programing package "ForestTools" was used for delineating individual tree crown boundaries with the inverse watershed segmentation method.
3. Zonal statistics analysis for individual trees was conducted with LAStools. Metrics were generated with 52 indexes, 43 are from Lidar.

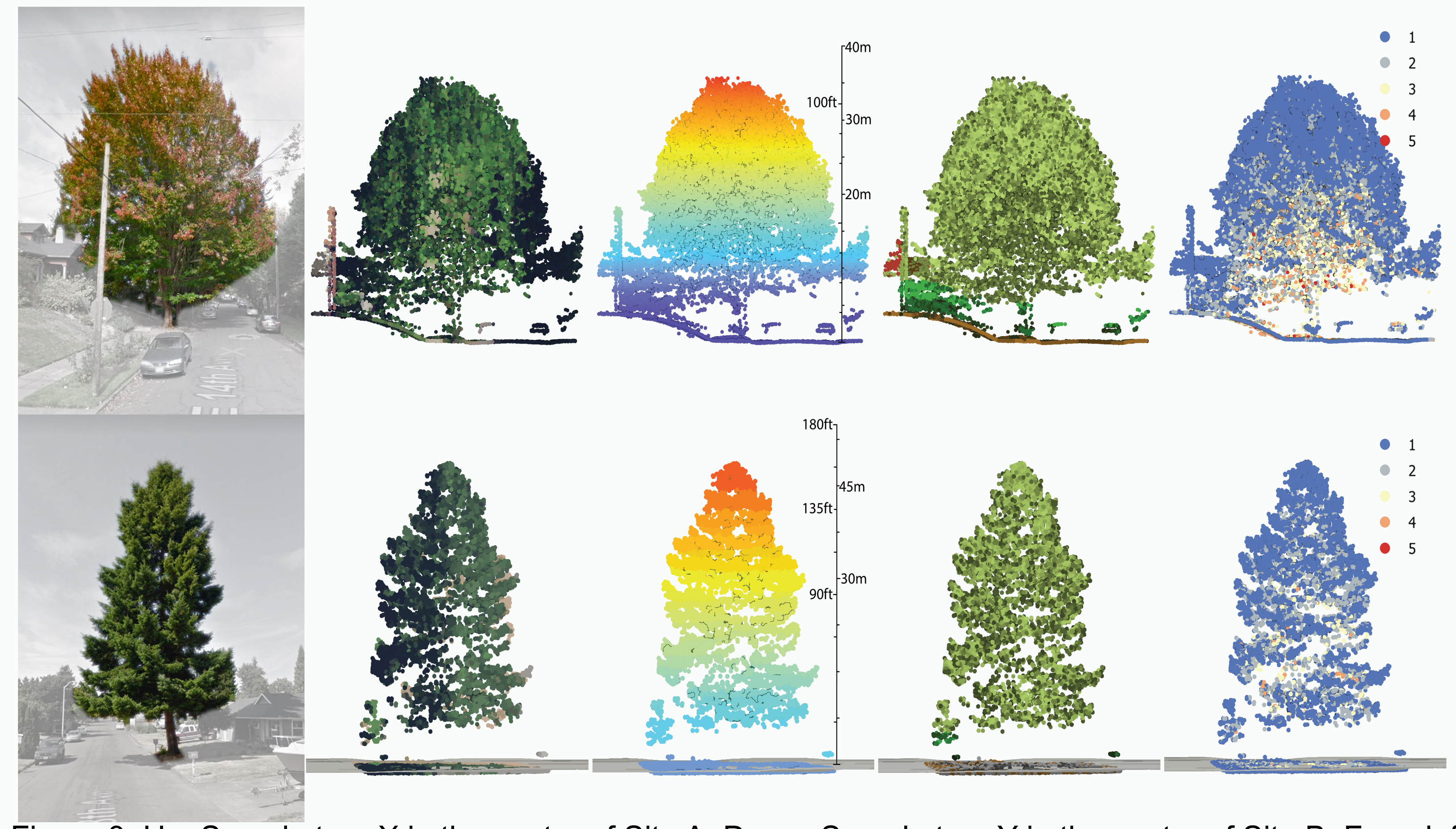
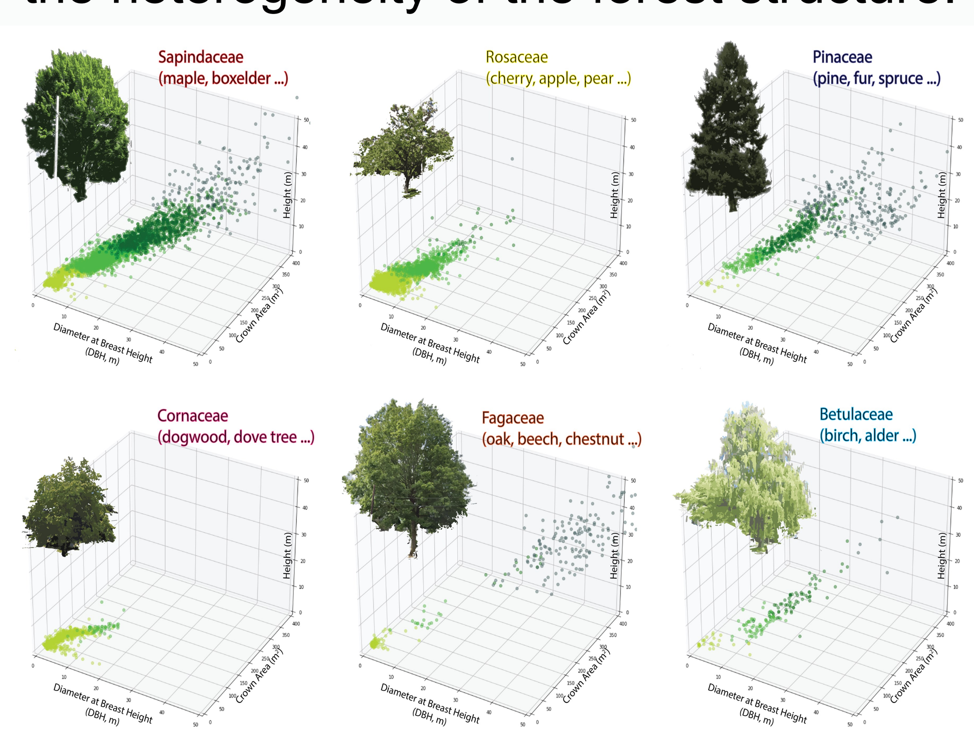


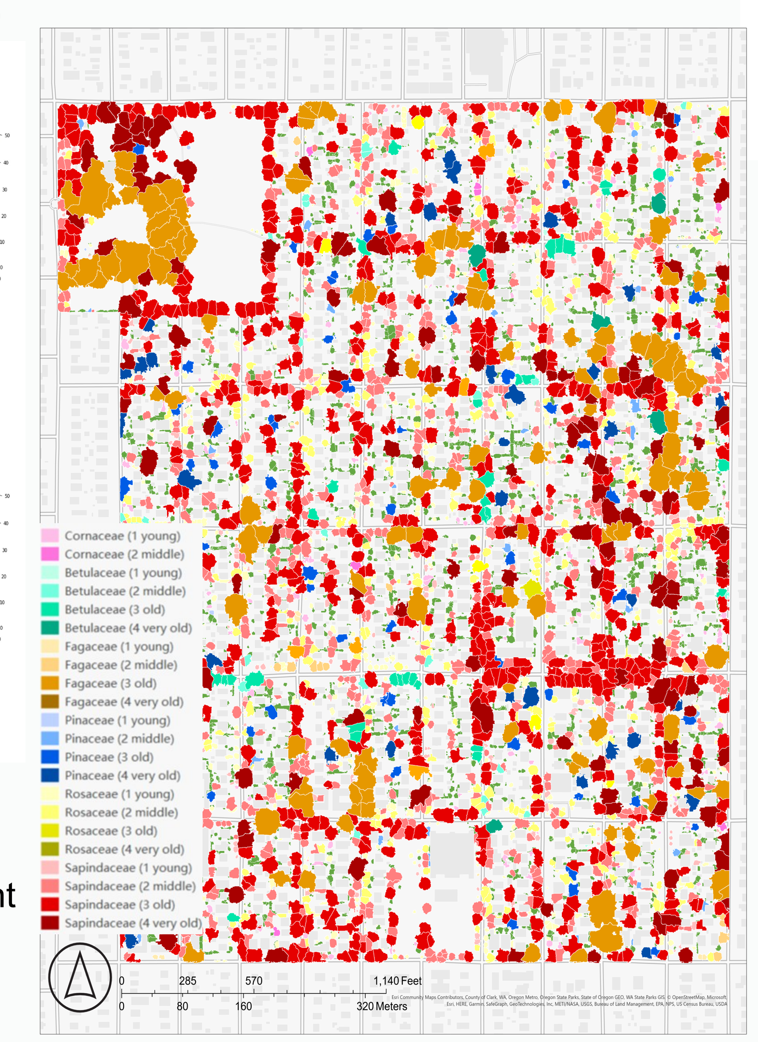
Figure 3: Up: Sample tree X in the center of Site A, Down: Sample tree Y in the center of Site B, From left to right: Google Street View image, Lidar point cloud real color, heigh profile, point intensity, and returns.

Object-based Tree Classification & Microclimate Simulation

The results from the Lidar Point Cloud metrics were combined with the ground-truth **urban street tree and park tree survey data** for training Machine Learning models. The survey recorded the species and family of each tree, and its Diameter at Breast Height (DBH).

1.**Random Forest** ML model was applied for classification, regression, and clustering. For **classification**, tree were classified into six dominant Families (Sapindaceae, Rosaceae, Fagaceae, Betulaceae, Cornaceae, and Pinaceae) plus one extra class for all shrubs. For **regression**, the DBH was predicted for each tree. For **clustering**, every non-shrub tree object was clustered into four sizes (Young, Middle, Old, and Very Old). This helped distinguish different types of trees which suggest differences in their biophysical functionalities and future growth potentials.
2.The results were then used to set up distinct tree models for the ENVI-met simulation. Albero is the vegetation management module which now allows the creation of **distinct individual tree models** to be placed in the explicit 3D microclimate simulation model, accurately representing the heterogeneity of the forest structure.





Up: Figure 4: Distribution of all 6 classified dominant tree families and the clustered sizes of the trees in each Family. Right: Figure 5: Classification results of all trees in Site A (Irvington), color represents the Family, and gradient represent the size.

Simulation Results

In total 16 simulations were conducted. These include real-case scenarios, sensitivity testing (such as deleting the sample trees and compare the difference with the read-case scenarios), and future scenarios assuming the different growth patterns of different classes of trees (such a tree planting scenario where 40 trees were added to Site B).

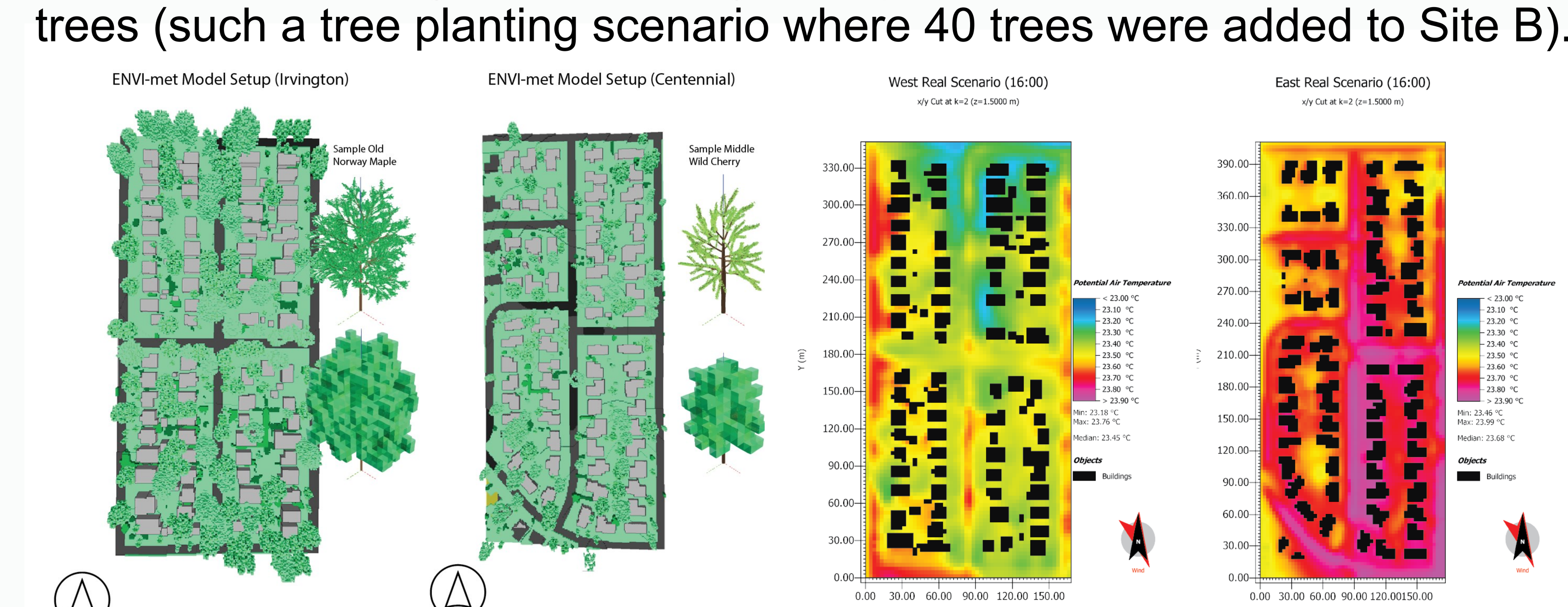


Figure 6: Left: Model set-up for Site A & B, Right: Status quo scenarios simulation results

The simulation results indicate that Site A and B face different levels of urban thermal stresses due to variations in vegetation coverage and quality despite having similar urban architecture forms. Simulations were conducted to compare the benefits of different tree species and verify the significance of testing different tree species. The microclimate benefit gap is expected to get more significant in the future after existing smaller trees have grown up as Site B's trees lack the potential to grow into large trees. Immediate action should be taken to address this issue and ensure the health of the Site B community.

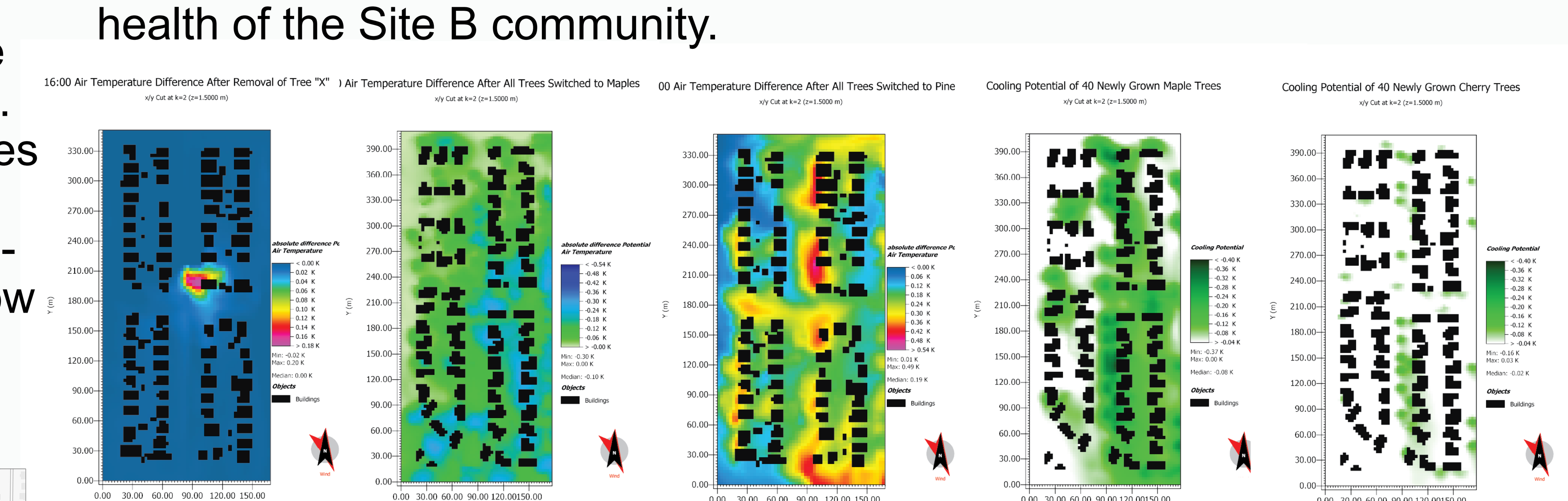


Figure 7: Left 3: Sensitivity tests of the ENVI-met model and different tree species, Right 2: Future scenarios simulations for different species of proposed trees

Conclusion and Discussion

This study developed an innovative method to examine the structure and composition of urban trees using statistics from airborne Lidar point clouds. The study then employed Machine Learning to classify and cluster individual trees, which was integrated into the ENVI-met microclimate simulation model. The method used in the study is reliable, flexible, and scalable.

. **Reliability**: this method tested and was able to distinguish between the density of different types of trees from two different communities and their resultant differences in microclimate.
. **Flexibility**: this object-based model was able to be altered to test different proposed scenarios.
. **Scalability**: the model is able to be applied to a larger area given it automatic nature.