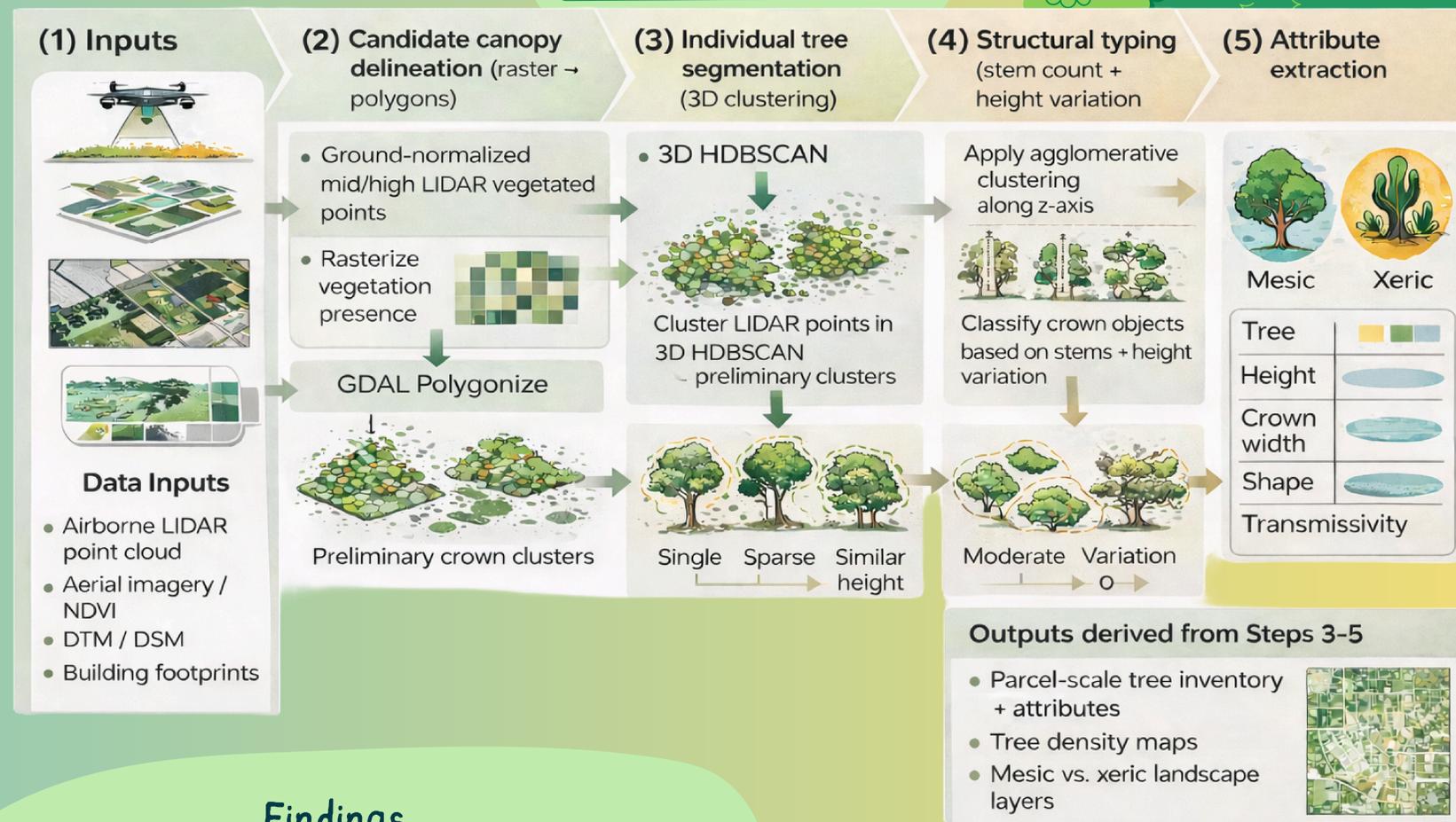# Scalable LiDAR-Based Framework for Automated Tree Inventory and Management

Protik Bose Pranto[1], Isaac Buo[2], Ariane Middel[1,2]
1 School of Computing and Augmented Intelligence (SCAI), Arizona State University, USA
2 The Game School, Arizona State University, USA

Methodology

(1) Inputs

Data Inputs
- Airborne LiDAR point cloud
- Aerial imagery / NDVI
- DTM / DSM
- Building footprints

(2) Candidate canopy delineation (raster → polygons)
- Ground-normalized mid/high LiDAR vegetated points
- Rasterize vegetation presence

GDAL Polygonize

Preliminary crown clusters

(3) Individual tree segmentation (3D clustering)
- 3D HDBSCAN

Cluster LiDAR points in 3D HDBSCAN → preliminary clusters

Single   Sparse   Similar height

(4) Structural typing (stem count + height variation)

Apply agglomerative clustering along z-axis

Classify crown objects based on stems + height variation

Moderate   Variation

(5) Attribute extraction

Mesic   Xeric

Tree		
Height		
Crown width		
Shape		
Transmissivity		

Outputs derived from Steps 3-5
- Parcel-scale tree inventory + attributes
- Tree density maps
- Mesic vs. xeric landscape layers

Introduction

Urban trees provide major benefits, cooling cities, storing carbon, and supporting biodiversity, but most cities still lack a parcel-scale, up-to-date tree inventory. Traditional field surveys are time-consuming, expensive, and often infeasible on private property. This work presents a **scalable LiDAR and imagery framework** that automatically **detects individual trees**, characterizes their structure, and classifies vegetation into **mesic vs. xeric landscape** regimes to support actionable urban forestry decisions in arid cities.

Research Question

How can we build a parcel-scale urban tree inventory automatically and consistently across large cities using airborne LiDAR and imagery?

Objectives

1. Develop a transferable, **end-to-end LiDAR-based pipeline** to detect and delineate individual urban trees at the city scale.
2. For individual trees, **estimate key attributes** (e.g., height, canopy width, crown shape, transmissivity, etc.) relevant to **shade and management**.
3. **Train ML models** to classify trees as **mesic vs. xeric**, enabling evaluation of how landscape regimes affect tree performance, longevity, and resources.

Findings

- Trees were categorized into four structural types: **1) single trees, 2) multiple trees with similar heights, 3) multiple trees with moderate height variation, and 4) structurally diverse canopies.**
- The proposed LiDAR-based framework reliably maps individual urban trees at the parcel scale, detecting approximately **270,000 trees across Tempe, Arizona.**
- Manual validation of **100 randomly selected trees** across different urban zones demonstrates strong classification performance, with accuracies of **72%, 93%, 77%, and 96%** for the four structural categories, respectively.

Limitations

Closely spaced or overlapping tree crowns in very dense urban canopies can still be partially merged, leading to uncertainty in individual tree delineation.

Future Work

- Apply **ML models** to detected trees using canopy **transmissivity** and **NDVI** to classify mesic and xeric vegetation
- Scale the framework by applying the workflow to all major cities across the CAPLTER area.

Conclusion

This study presents a scalable LiDAR-based tree inventory framework to support data-driven planning for heat mitigation, water efficiency, and long-term urban forest sustainability.