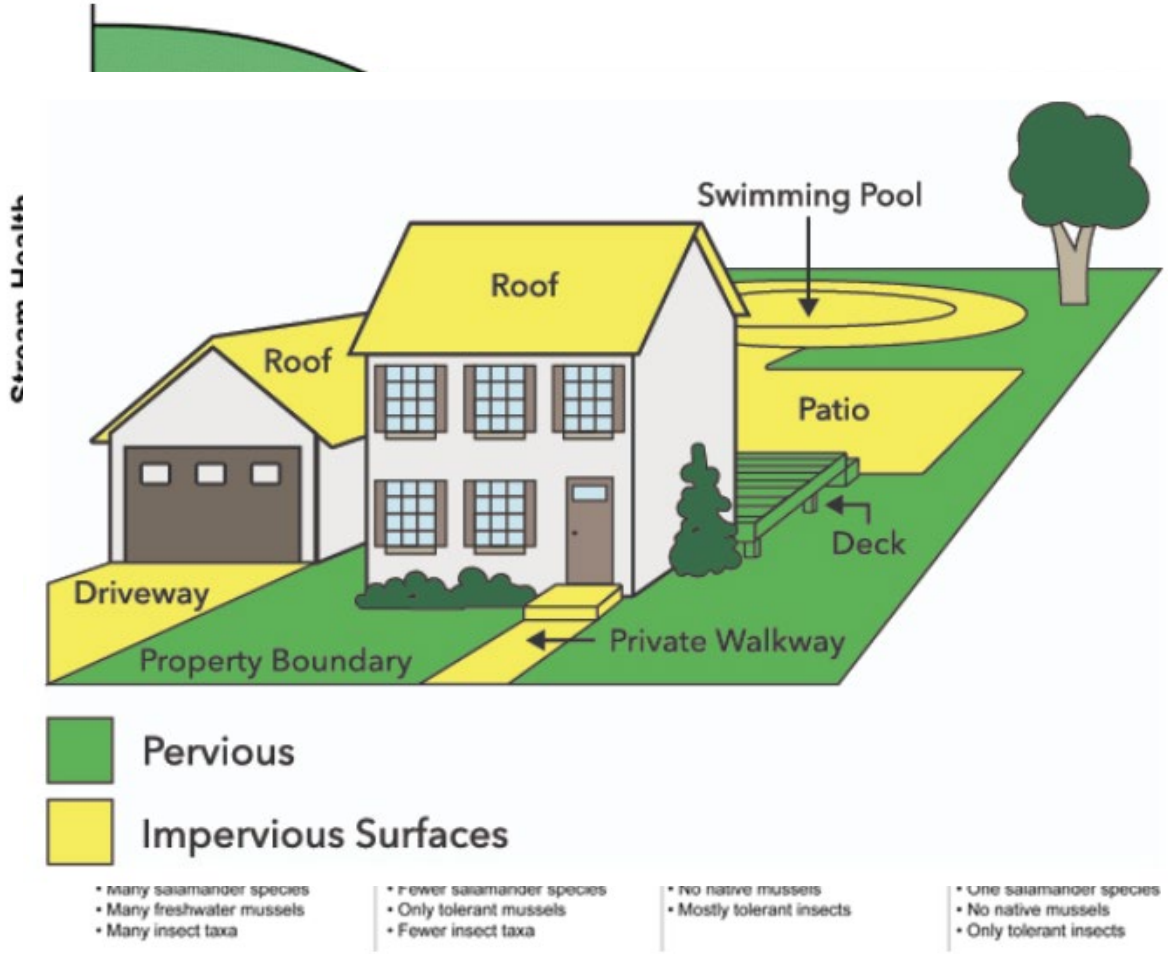
Towards a Fair and Effective Stormwater Management System in Athens, OH: Experimenting with Lidar Intensity to Improve Impervious Surface Classification in areas of Dense Tree Canopy

Impervious Surfaces and Why They Matter

- Impervious surface refers to all hard surfaces such as paved roads, parking lots, roofs, and highly compacted soils, that prevent the natural soaking of rainwater into the ground.
- Impervious Surfaces effect several key environmental factors, including:
  - Flooding and Erosion: “For every percentage point increase in roads, parking lots and other impervious surfaces that prevent water from flowing into the ground, annual floods increase on average by 3.3%” (Blum et al. 2020)
  - Pollution: Heavy metals from roof shingles and motor vehicles, as well as pesticides, bacteria from sewage, and road treatment chemicals are just some of the pollutants that run untreated into the water table.
  - Heat Retention: Urban heat islands and killing of aquatic life



Images courtesy of the Maryland Department of Natural Resources: https://dnr.maryland.gov/streams

A Brief Overview of Stormwater Management Systems

Important Legislation

- 1972 – Creation of the Clean Water Act
- 1987 – Creation of the National Pollutant Discharge Elimination System (NPDES) stormwater program

The NPDES requires municipalities to develop a Stormwater Management Plan to reduce pollutants in the stormwater discharge to the “maximum extent practicable (USEPA, 1999).

The NPDES places responsibility for funding stormwater management policies on local municipalities. As a result, the development of a strong, sustainable stormwater management program is often put on hold in favor more immediate concerns, such as education and law enforcement, with existing stormwater management funds often used to supplement funding to these budgetarily stressed programs.

Stormwater Utility Fees (SUF) are one method to generate revenue for stormwater management.

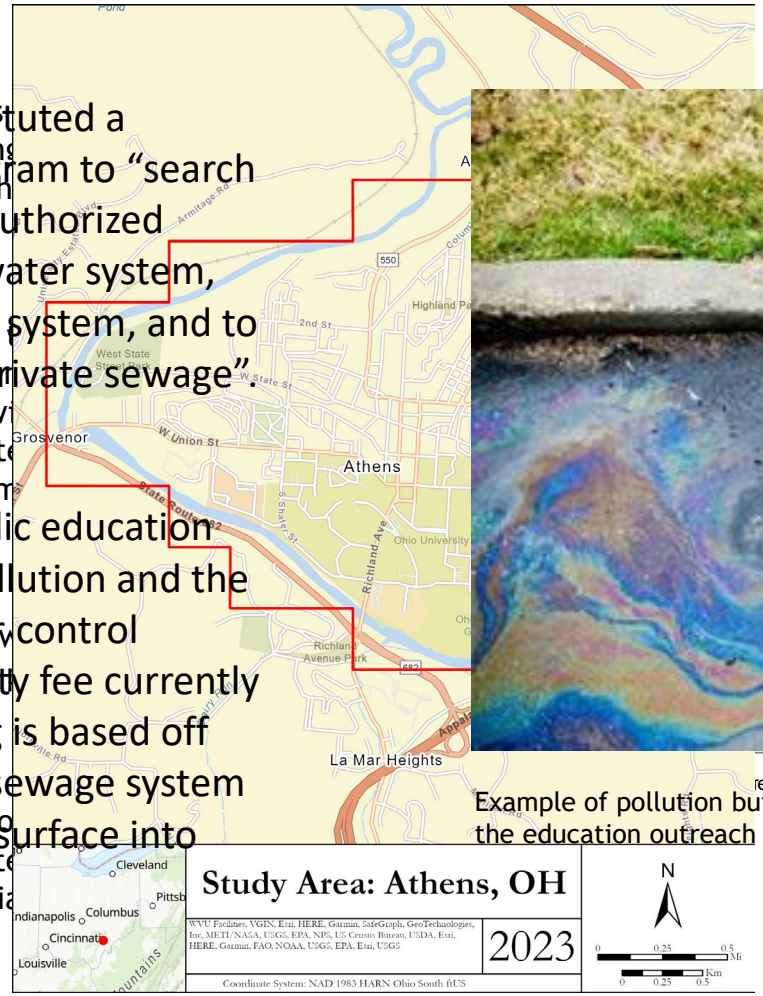
The most common types of SUF – Equivalent Residential Units (ERU), Equivalent Hydraulic Area (EHA), and Intensity of Development (ID) – use the amount of impervious surface per parcel to calculate the amount owed.

In their 2017 case study *The Financial Impact of Different Stormwater Fee Types: A Case Study of Two Municipalities in Virginia*, Fedorchak et al. compare 8 methods of stormwater calculation in two Virginia towns and conclude that methods based on percent impervious surface are often more equitable, as there is a clear correlation between burden contributed and the amount paid to offset the burden. This method also holds large industries more accountable for their contributions to ecological effects of impervious surfaces. **However, many locations chose to implement a flat rate SUF structure, due to the financial cost of providing accurate impervious surface calculations.**

A Clear and Present Need: A look at Stormwater Management in Athens, OH

In 2017 the City of Athens instituted a stormwater management program to "search for, identify and eliminate unauthorized discharges to the city's stormwater system, create a storm sewer mapping system, and to map all residences that have private sewage".

The plan also encourages public education about non-point sources of pollution and the need for increased stormwater control measures. No stormwater utility fee currently exists as such, instead, funding is based off amount of water put into the sewage system and does not take impervious surface into account at all.



Example of pollution build-up from impervious surface used as part of the education outreach by the City of Athens

Benefits of A GIS System for Impervious Surface Calculation

Low Cost

- Object Based Image Extraction (OBIA) reduces cost in time and labor, allowing for an increase of funds being spent on managing storm water
- Uses publicly available data generated from state or national funding

Potential Increased Revenue

- Lower cost of production could allow the SUF to be based on impervious surface per parcel, a method which has been shown to increase total revenue the municipality receives (Fedorchak et. Al 2020). Costs are distributed in correlation with burden provided.

Process is Largely Automated

- Cost of upkeep is lowered and a system for updating is built in

However…

These benefits can only be realized if the impervious surface can be reliably extracted throughout the entire study area, including areas occluded by the tree canopy.

June 2021, Leaf-on NAIP

November 2017 Leaf-off NAIP

lidar
arly
accuracy
action.
a to keep

uture

Methodology

Data Preparation

- Imagery:
  - 1m 2017 NAIP, 60cm 2021 NAIP
  - 6” 2014 CIR, 6” 2014 RGB
  - 6” 2020 RGB
- Lidar: 2021 point cloud
- Vector: Road centerlines, parcels

Create Classification Ruleset in eCognition

- Select Test Area to Develop eCognition Ruleset
- Convert Mr. Sid to .img format
- Develop Lidar Derived Raster Products Based on Ground and Final Returns:
  - nDSM, Slope nDSM, Intensity
- Perform Segmentation
  - Contrast Split (L1)
  - Multi-threshold (L2)
  - Buildings and Roads Classified Separately
- Classify Data
  - Intensity Threshold <= 3450
  - NDVI > 0
  - Area and Region Grow
- Export Data
  - Export to ArcMap to calculate the percent impervious surface per parcel

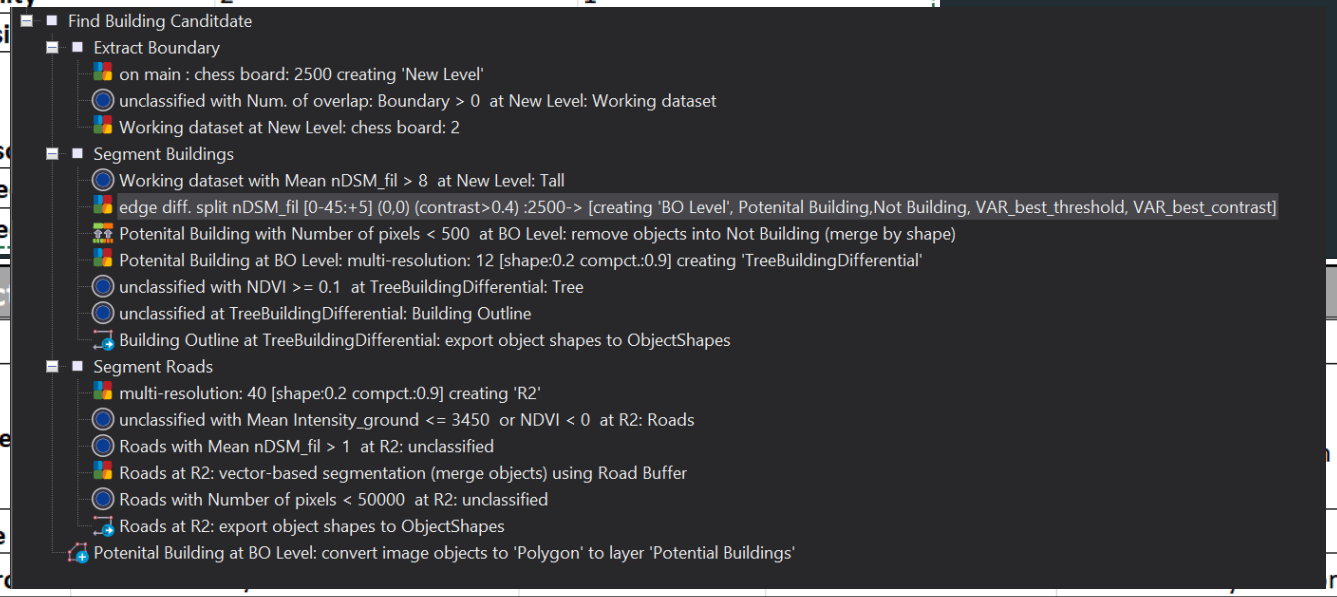
Aerial Imagery

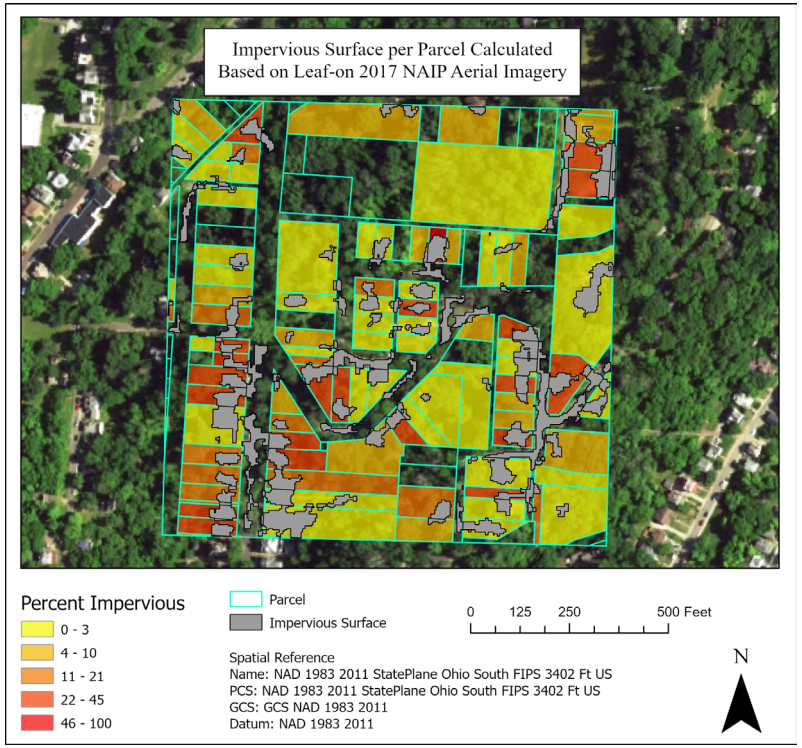
	2017 NAIP	2021 NAIP	2014 CIR (OSIP*[1,2])	2014 RGB (OSIP)	2020 RGB (OSIP)	2007 RBG (OSIP)
Projection	NAD 1983 UTM Zone 17N	NAD 1983 UTM Zone 17N	NAD_1983_HARN_Ohio_South_ftUS	NAD_1983_HARN_Ohio_South_ftUS	NAD 1983 HARN StatePlane Ohio South FIPS 3402 (US Feet)	NAD 1983 HARN StatePlane Ohio South FIPS 3402 (US Feet)
Resolution	1m	.6cm	6inch	6inch	6inch	1ft
Bands/Classes	4 bands	4 bands	3 (NIR-G-R)	3	3	3
Bit Depth	8	8	8	8	8	8
Sensors	CNIR	CNIR	Leica ADS80-SH81/82 Airborne Digital Sensor	Leica ADS80-SH81/82 Airborne Digital Sensor	VisionMap A3 Edge digital camera systems	Leica ADS40/51/52 digital cameras
Collection Date	Jun-17	Nov-21	Spring 2014	Spring 2014	2020 - no month	March-April leaf off

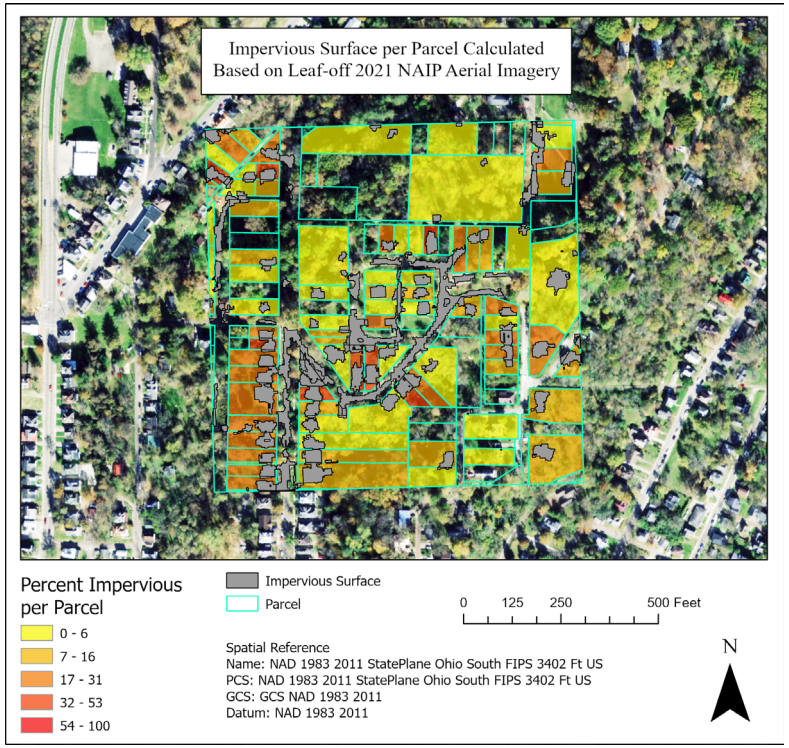
*OSIP = Ohio Statewide Imagery Program

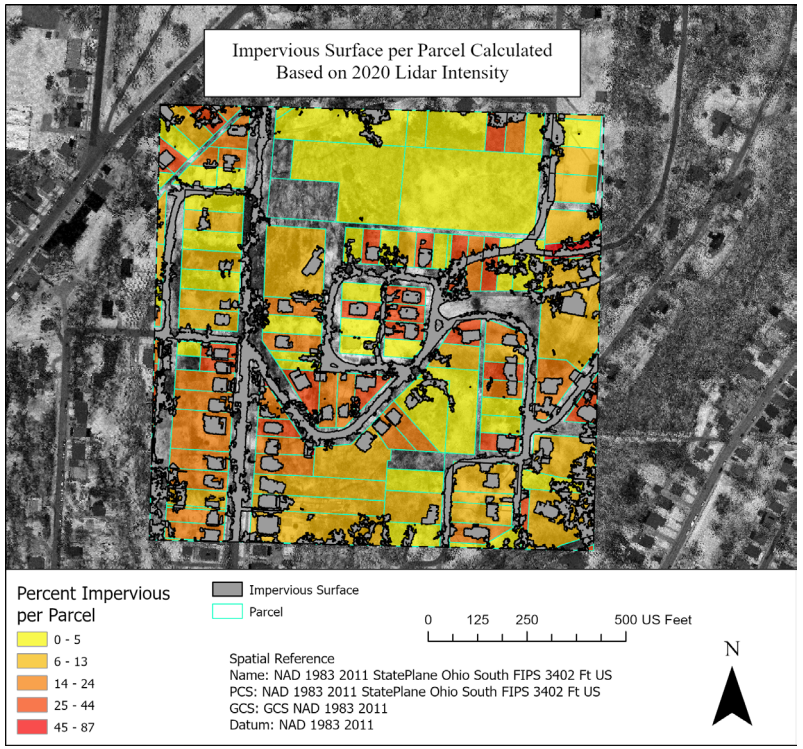
Lidar

	2007 lidar[4]	2021 lidar[1,2]
Projection	NAD 1983 HARN StatePlane Ohio South FIPS 3402 (US Feet)	NAD 1983 (2011) StatePlane Ohio South FIPS 3402 (US Feet)
NPS	1.828 (6ft)	0.35
Quality	2	1









RESULTS

Leaf On Accuracy Assessment

Absolute Producer's Impervious Class Accuracy: 27%
Absolute Overall Accuracy: 85%

Model Producer's Impervious Class Accuracy: 96%
Model Overall Accuracy: 96%

Leaf Off Accuracy Assessment

Absolute Producer's Impervious Class Accuracy: 24%
Absolute Overall Accuracy: 85%

Model Producer's Impervious Class Accuracy: 86%
Model Overall Accuracy: 90%

Intensity Accuracy Assessment

Absolute Producer's Impervious Class Accuracy: 55%
Absolute Overall Accuracy: 86%

Analysis and Future Work

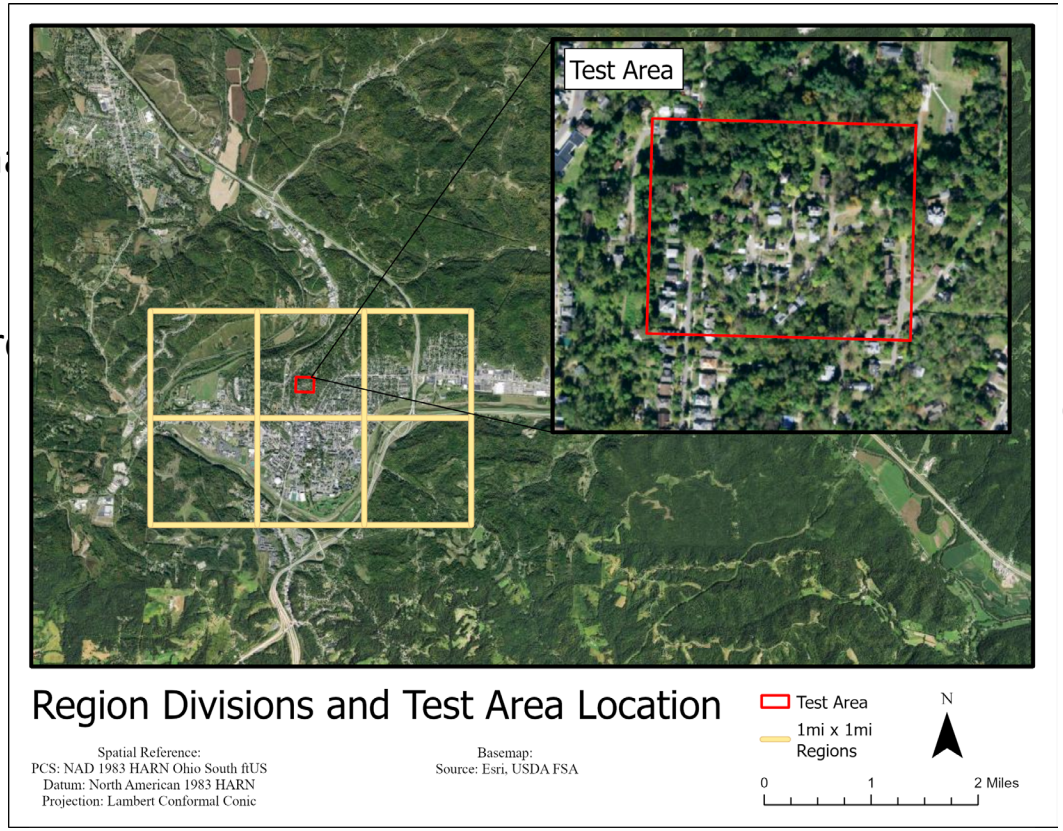
- Primary Strengths
  - Some occluded areas included
  - abnormal wear and tear
- Prima
  -
- Impr
  -
  -

Improve Classification of Test Area

Expand Classification using eCognition Python Interface!

- Allow larger region to be classified without the use of eCognition Server or CPU

class



Finale