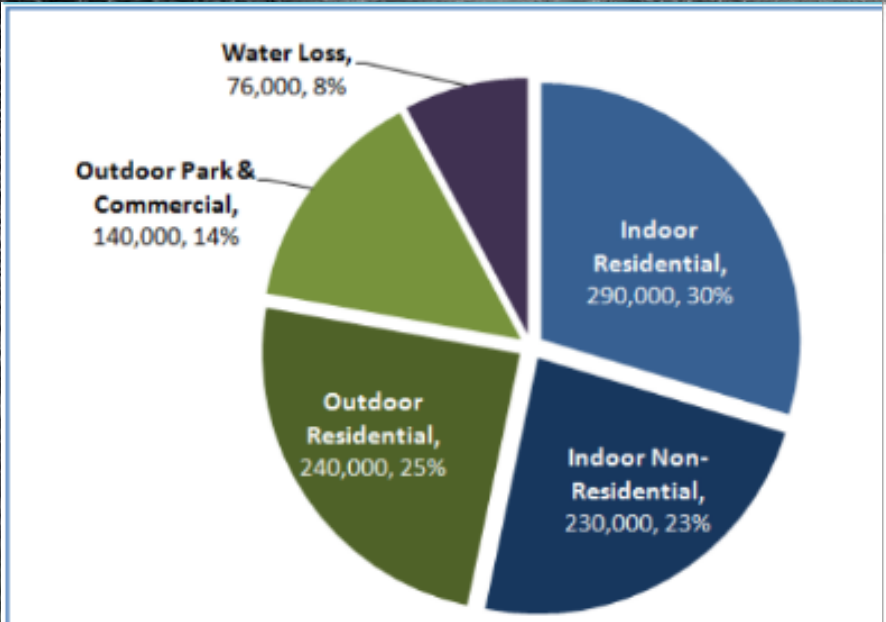
Microscale determinants of residential water use in greater Denver

ASU Urban Water Demand Roundtable, April 2019

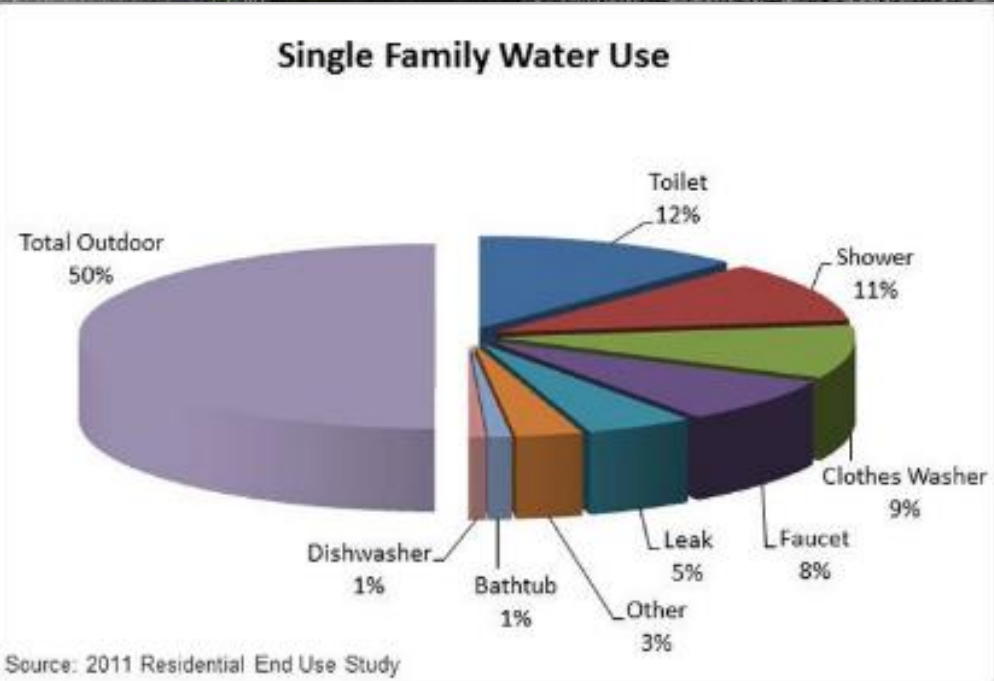
By: Austin Troy, Gretel Folingstad, Bob Taylor, and Mehdi Heris
University of Colorado Denver

University of Colorado **Denver**
CU IN THE CITY

Importance of outdoor irrigation



Total Municipal Water Diversions = 970,000 AF



Source: 2011 Residential End Use Study

Image source: Eric Sonstroem (https://www.flickr.com/photos/sonstroem/), Data: Denver Water and CO state water plan

Yard irrigation is variable

Table ES.10 Summary of annual and outdoor water use for landscape group (n=838)

Site	Sample Size (n)	Average Annual Use (kgal)	Average Outdoor Use (kgal)	% Outdoor
Clayton County	103	62	19.2	31%
Denver Water	95	125	77.0	62%
Ft. Collins	88	111	55.9	50%
Peel	69	87	24.1	28%
San Antonio	98	112	62.0	55%
Scottsdale	111	186	120.4	65%
Tacoma Water	107	73	27.0	37%
Toho	95	93	33.1	36%
Waterloo	72	58	13.0	22%
Total (9 sites)	838	100.8	50.5	50 %

Source: Water Research Foundation 2016

Yard composition variability is key

Denver Water Study of 425 yards

- 18% of pervious area – no irrigation (sidewalks, rock, mulch etc.)
- 29% of pervious area – alternative landscape types (xeriscape, native, low-use) – 9 GPSF
- 53% of pervious area – bluegrass turf – 18 GPSF

Yard characteristics that may predict variability

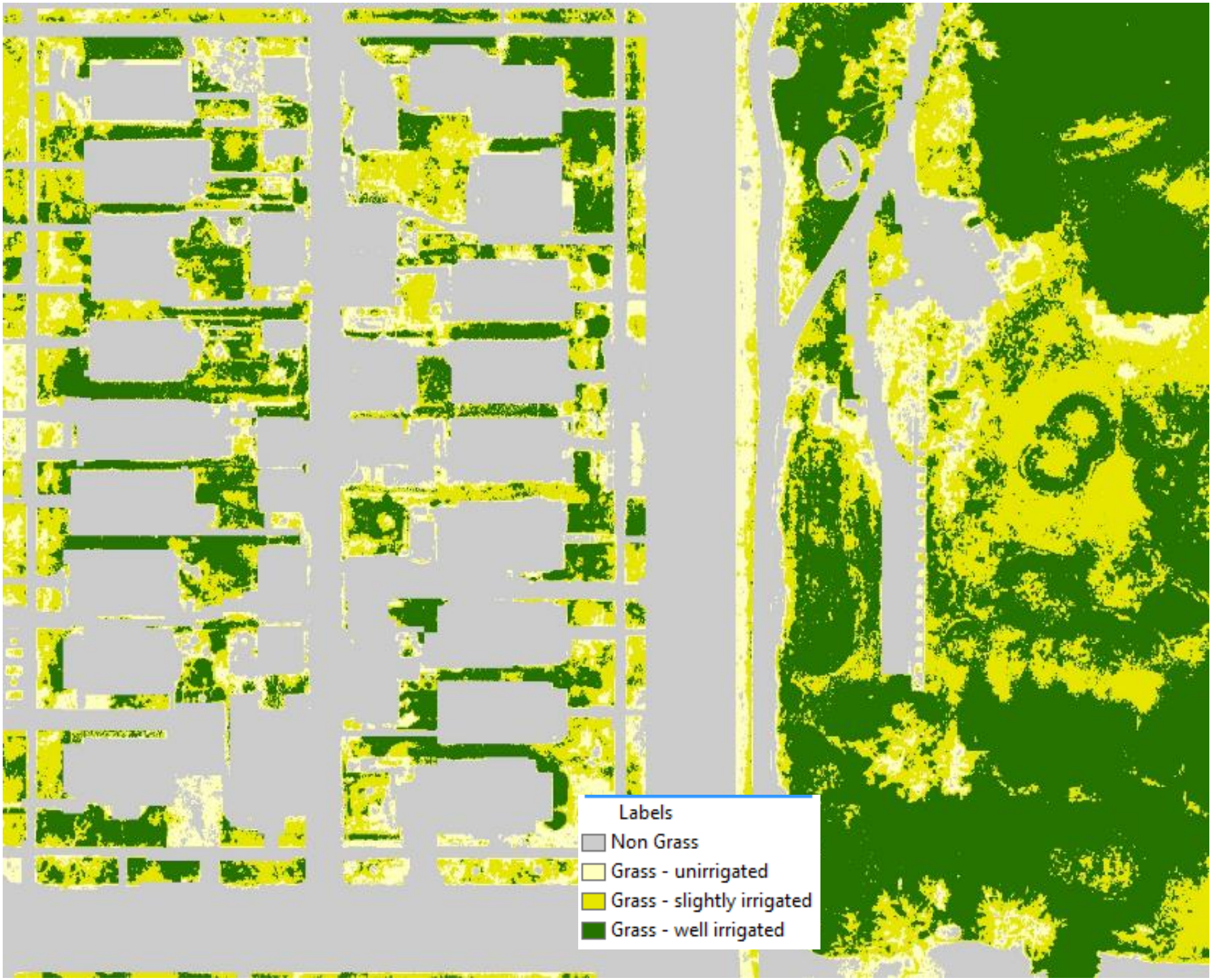
1. Grass area and greenness
2. Tree canopy area
3. Tree size/age
4. Tree and building shade on growing space
5. Species grown

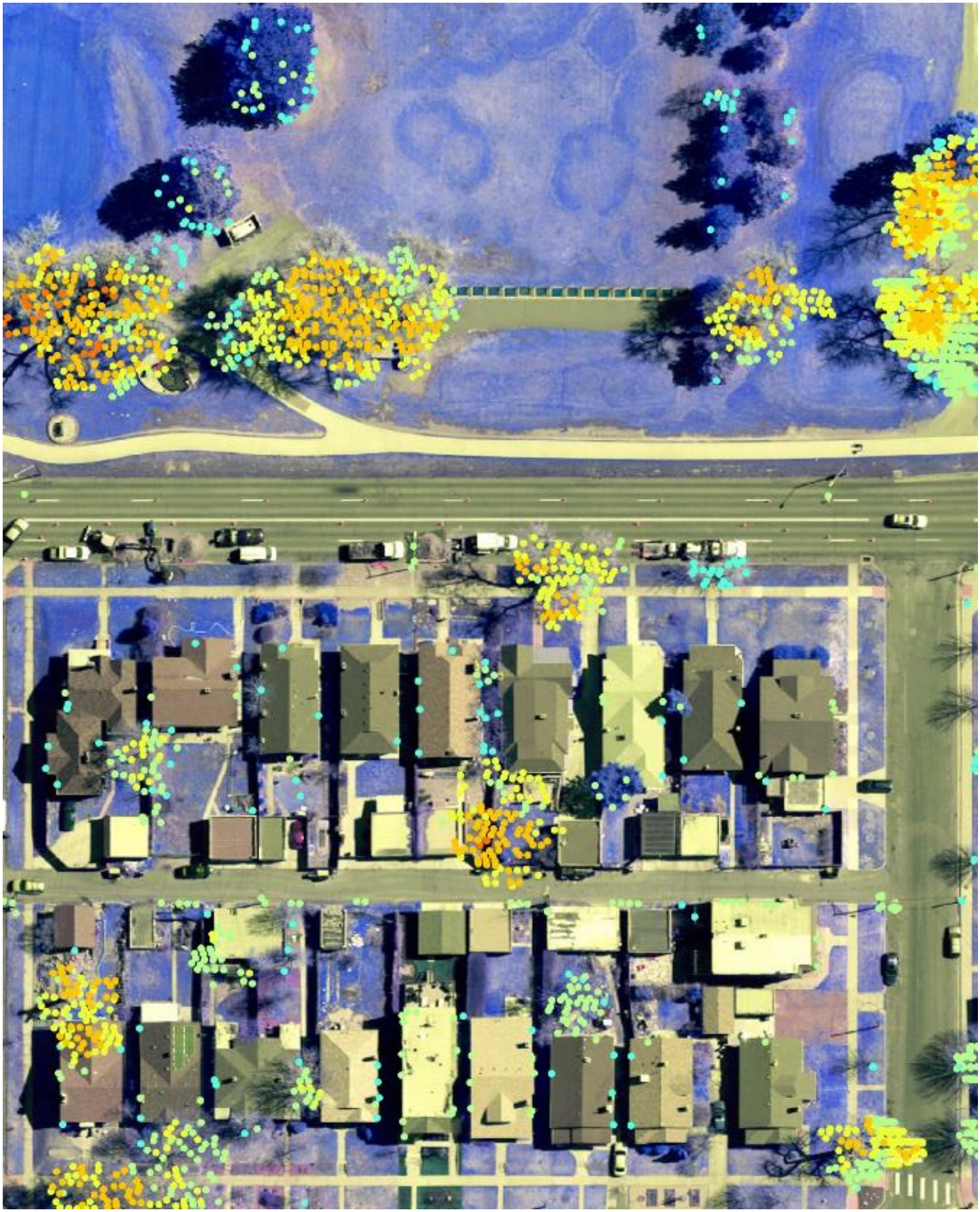
- **HOA rules?**
- **Housing/subdivision age**

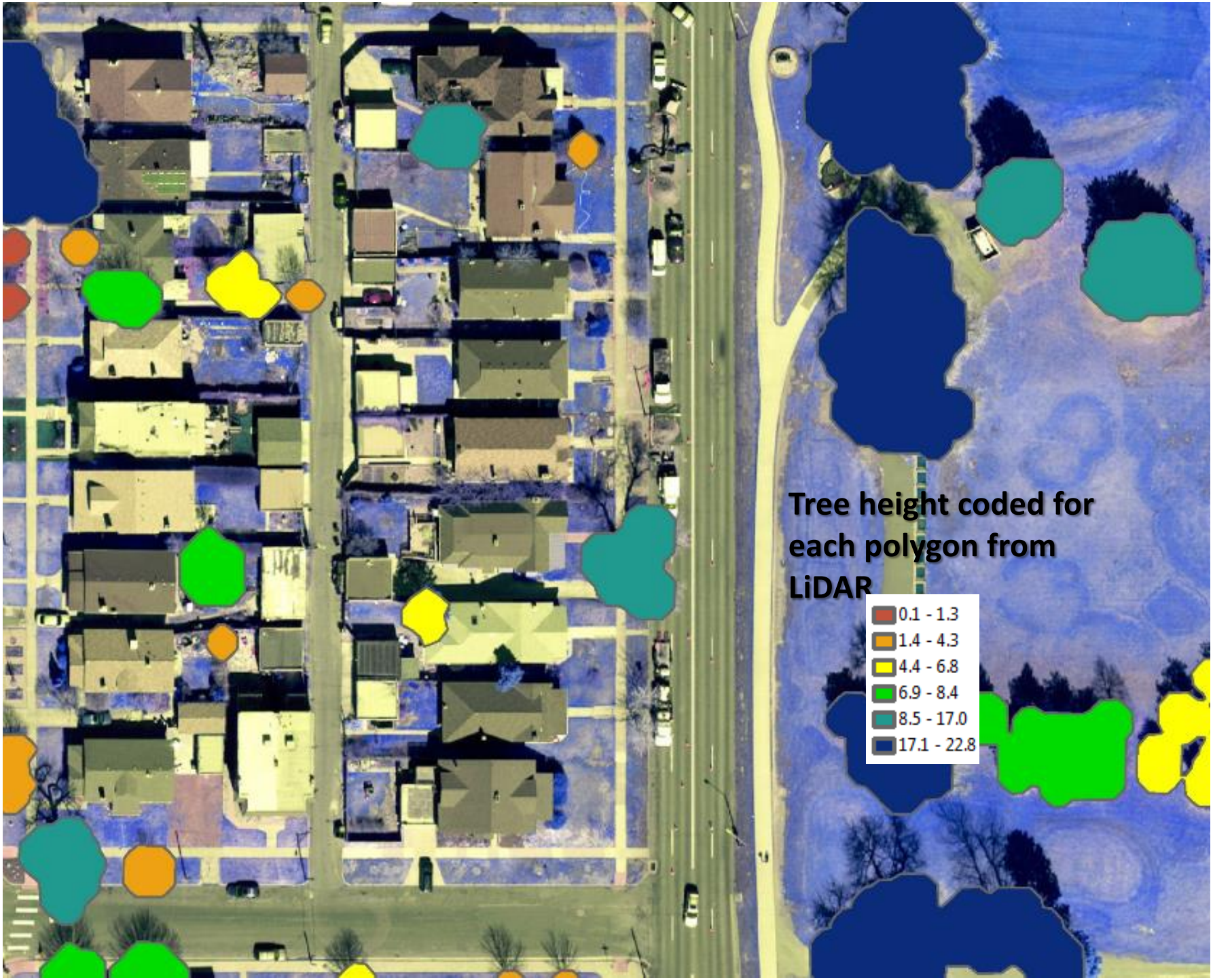
Methods Overview

- Regress **annual water consumption** by parcel for Denver, Engelwood, Littleton against:
  - Total **lawn area**
  - Area of **non-irrigated lawn** (very low greenness)
  - Area of **slightly irrigated lawn** (low-medium greenness)
  - Area of **irrigated lawn** (high greenness)
  - Area of **tree canopy**
  - % of tree canopy accounted for by **low trees** (<6 m)
  - Mean hours of **shade** cast on lawn
  - Whether the property is from a **post-1950** subdivision
  - Whether the property is part of **HOA**
- Did descriptive stats for HOAs
- Quadratic form regression for subdivision age, regression for NVDI

Response data: Denver Water consumption records filtered for private OO-SFH, lot coverage< 30%, July water use> 0, grass area >0= 53,852 observations

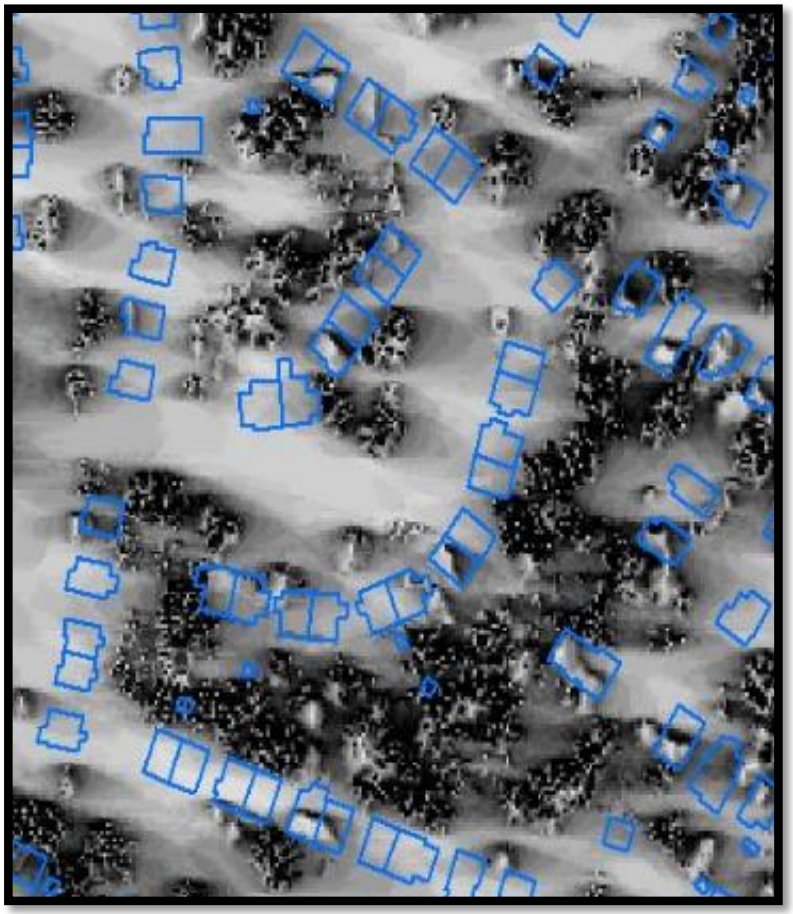

Labels
Non Grass
Grass - unirrigated
Grass - slightly irrigated
Grass - well irrigated

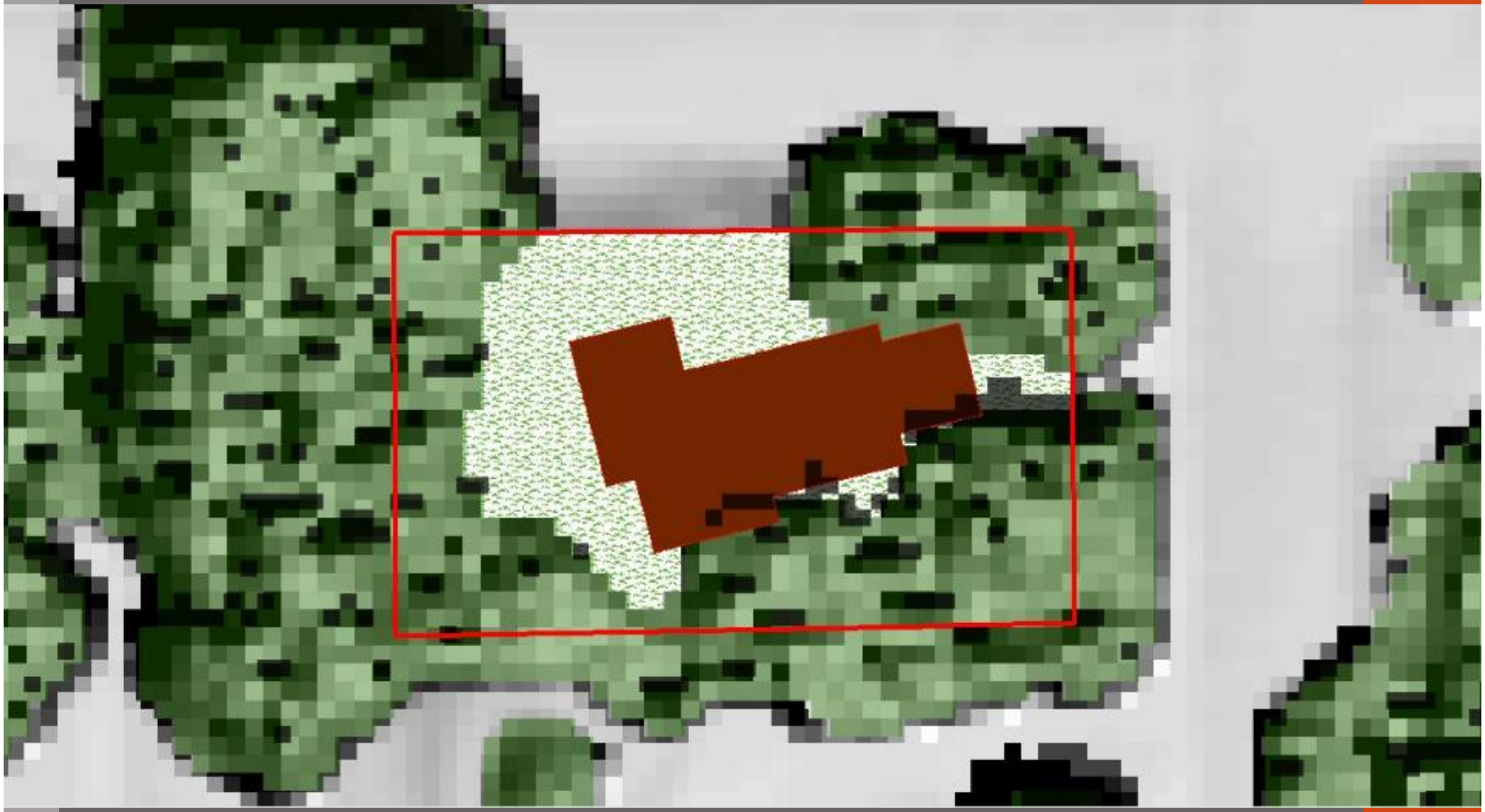



Tree height coded for each polygon from LiDAR
0.1 - 1.3
1.4 - 4.3
4.4 - 6.8
6.9 - 8.4
8.5 - 17.0
17.1 - 22.8

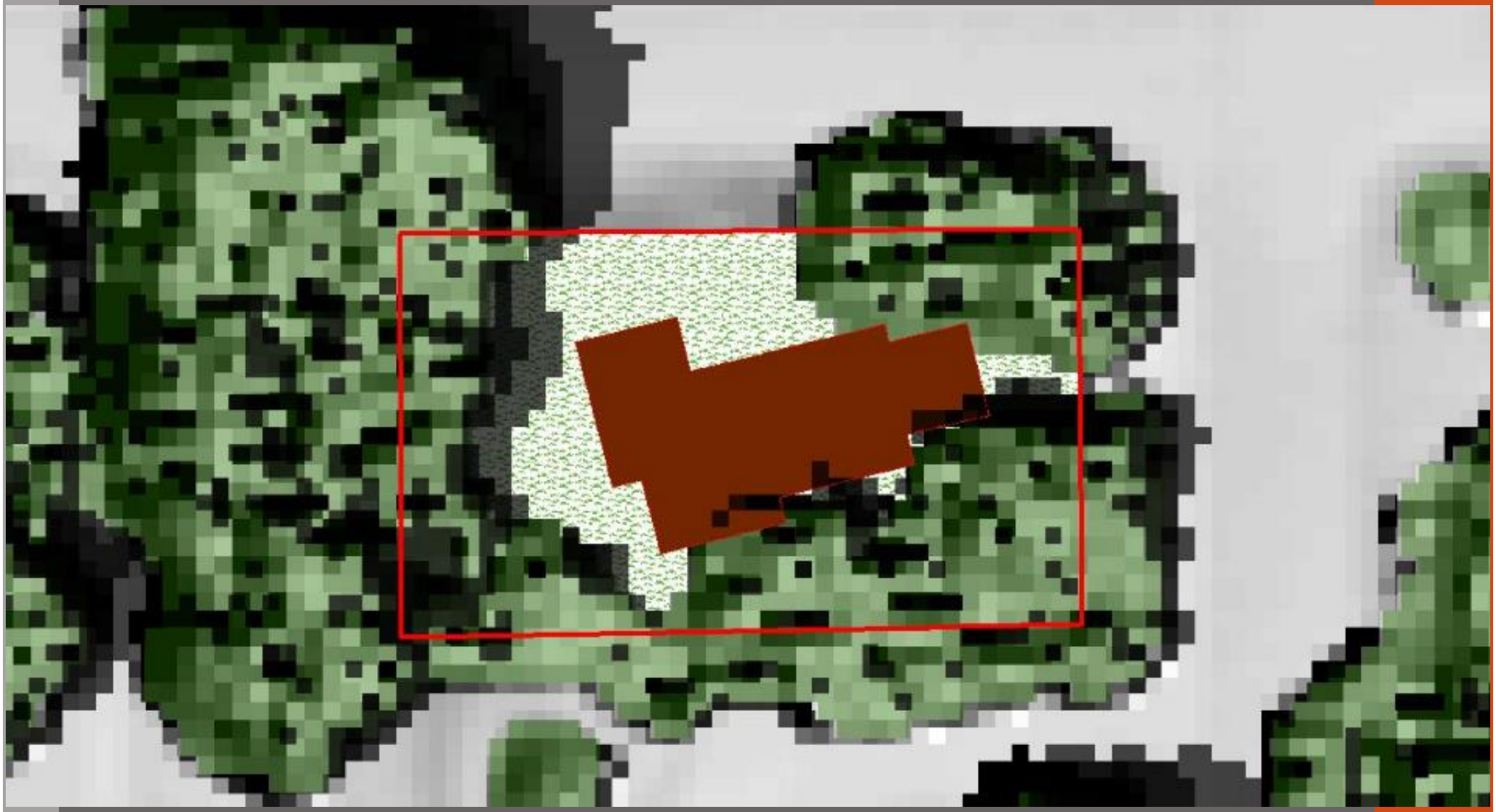
Quantifying yard shade

- Modeled over the course of the day in July using LiDAR for each hour between 11 AM-6PM, then combined
- 3D models of buildings and trees, built in Quick Terrain Modeler
- Path of light relative to 3D objects modeled with ArcGIS hillshade tool, based on Solar Position Algorithm (NREL)
- Overlaid with grass, then average shade hours per grass pixel calculated by parcel

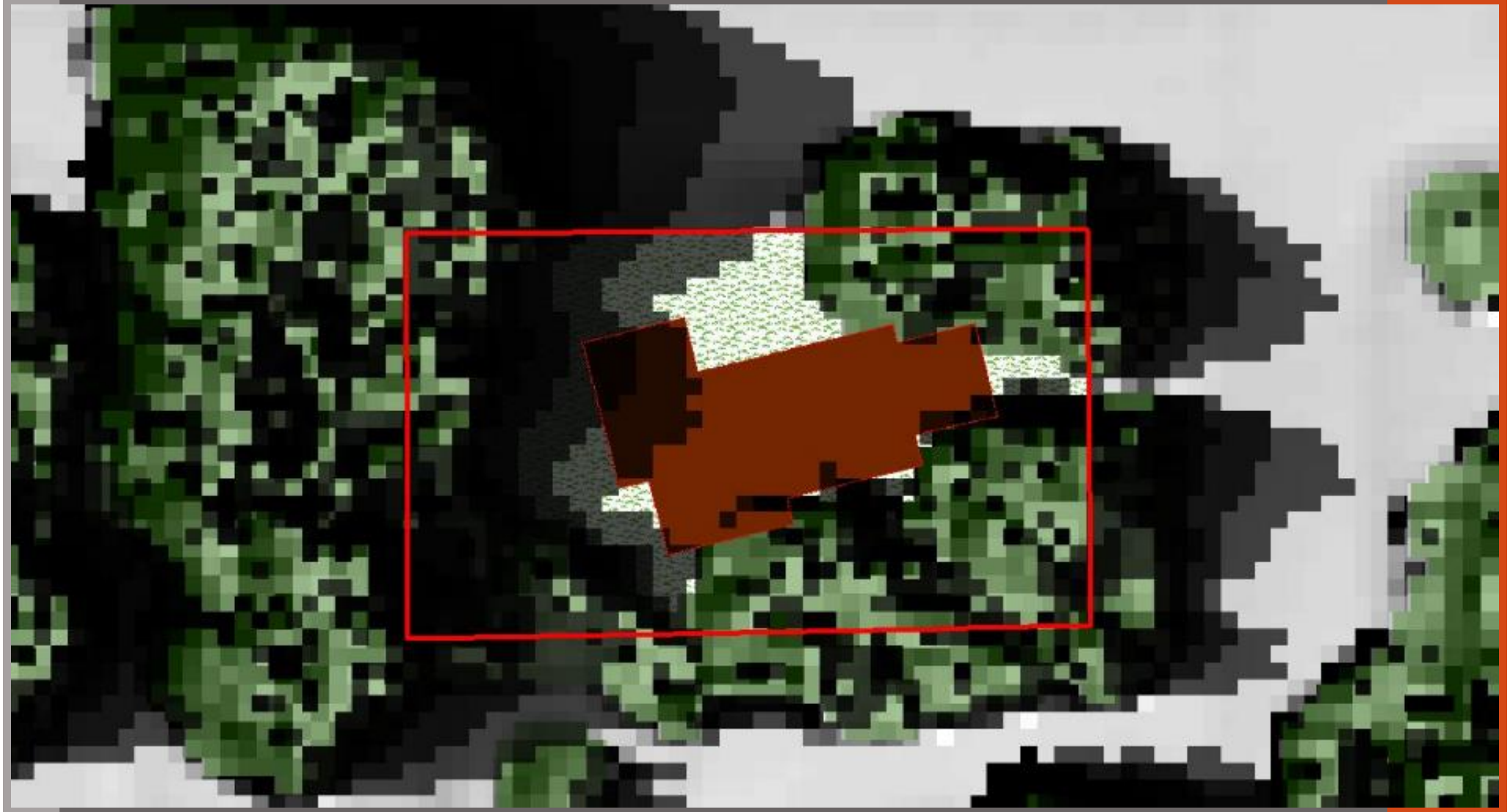




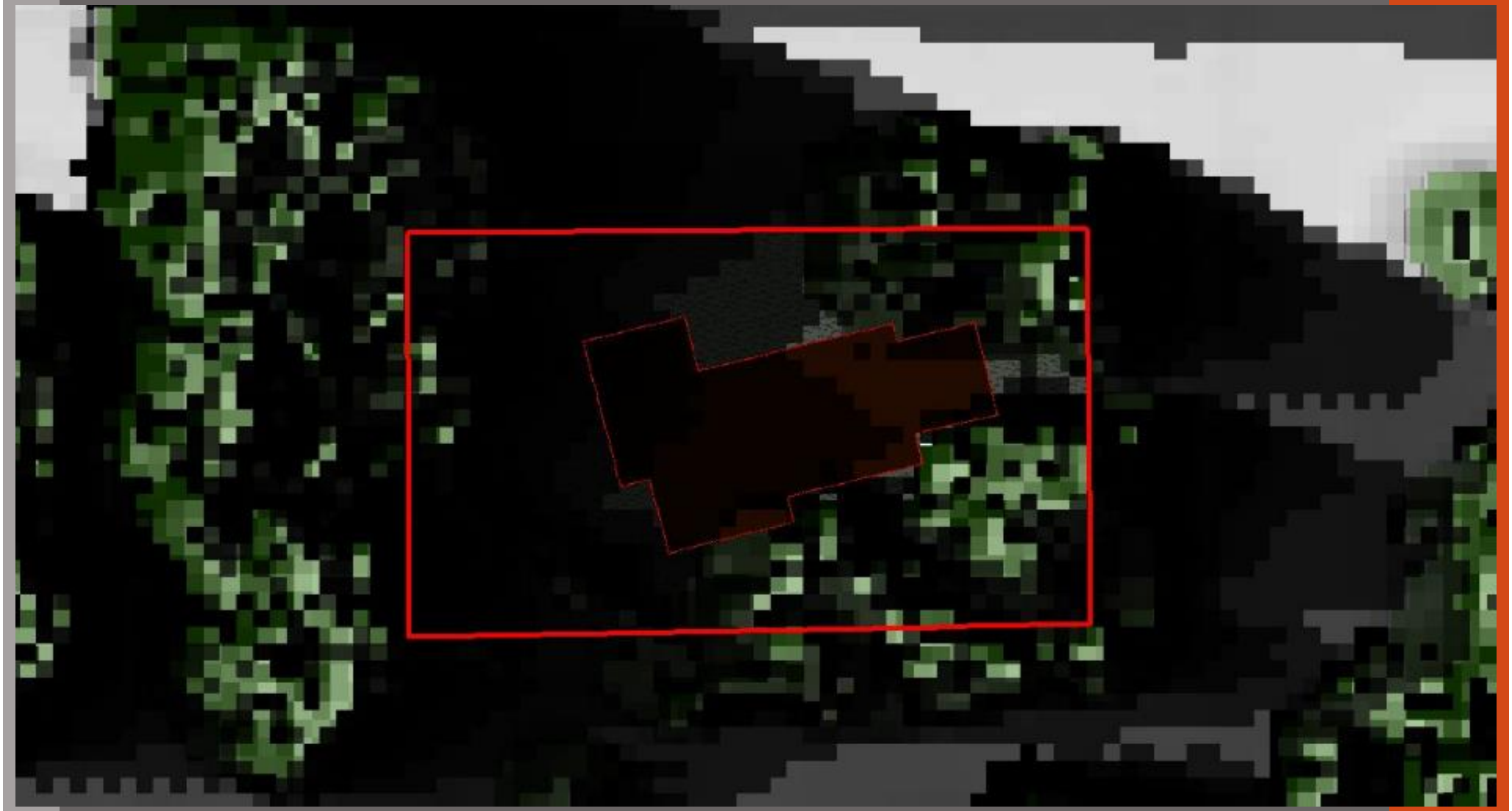
12 PM Shade Area = 728 m^2/1hr



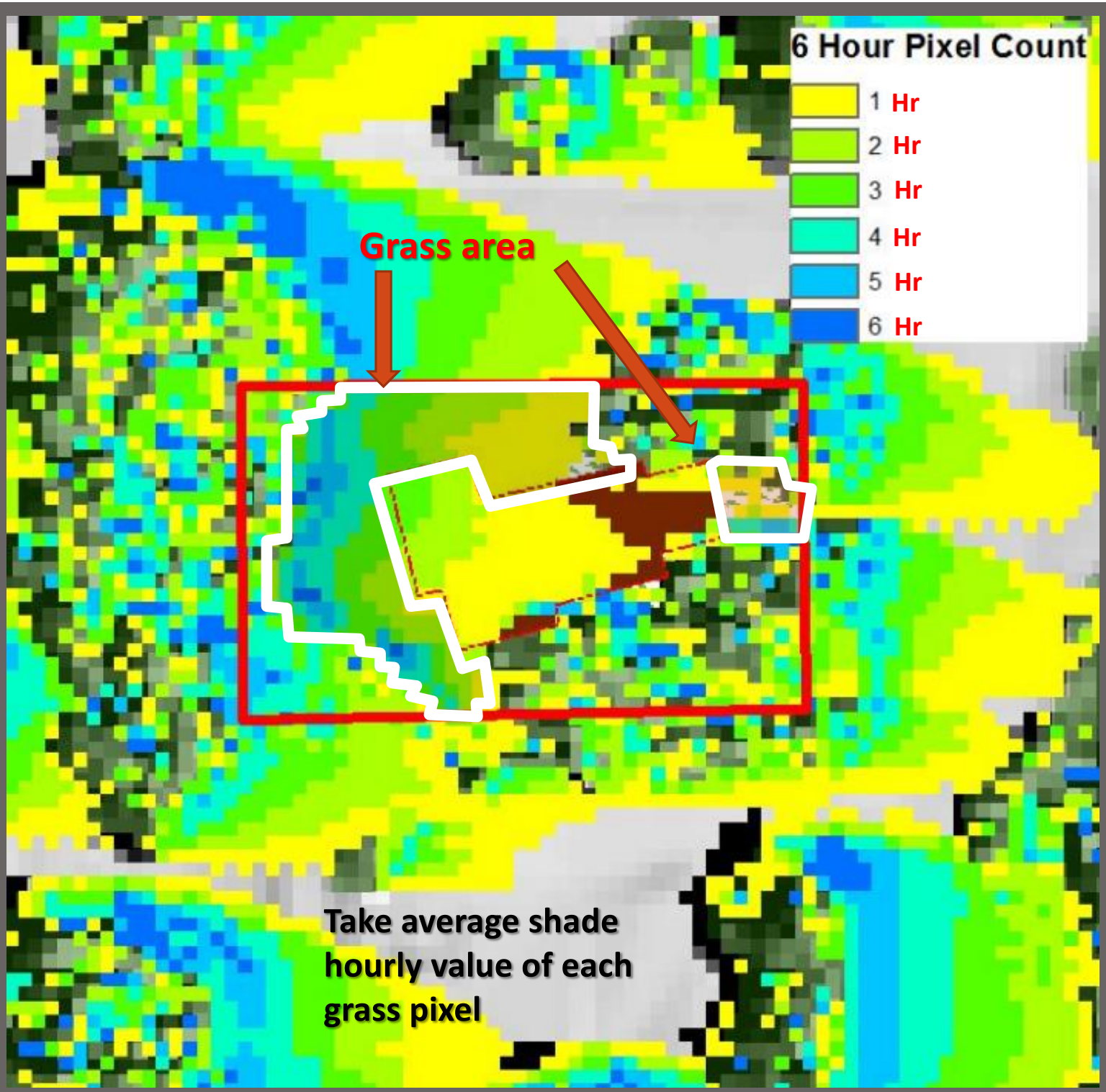
2 PM Shade Area = 3393 m^2/3hr

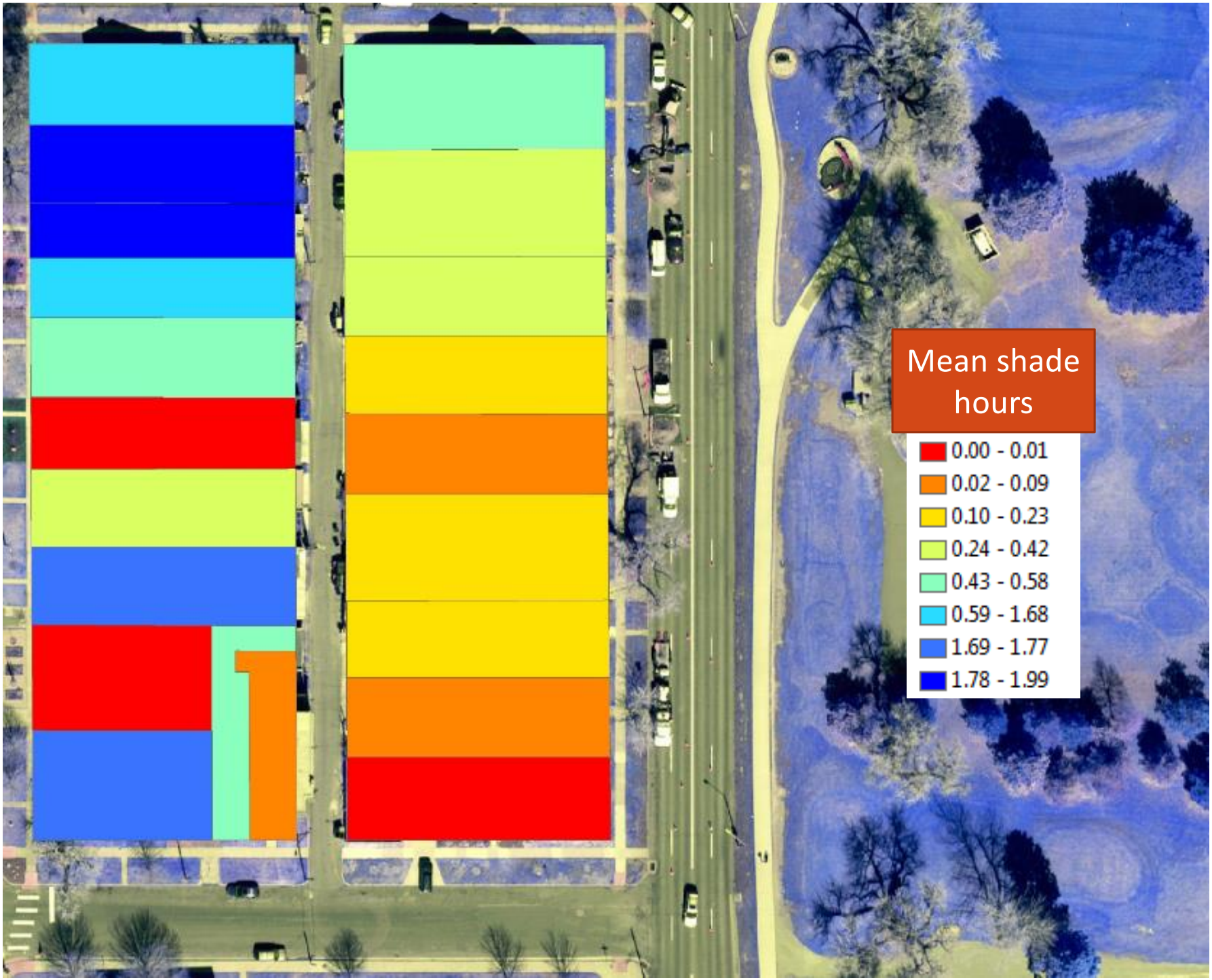


4 PM Shade Area = 13613 m^2/5hr

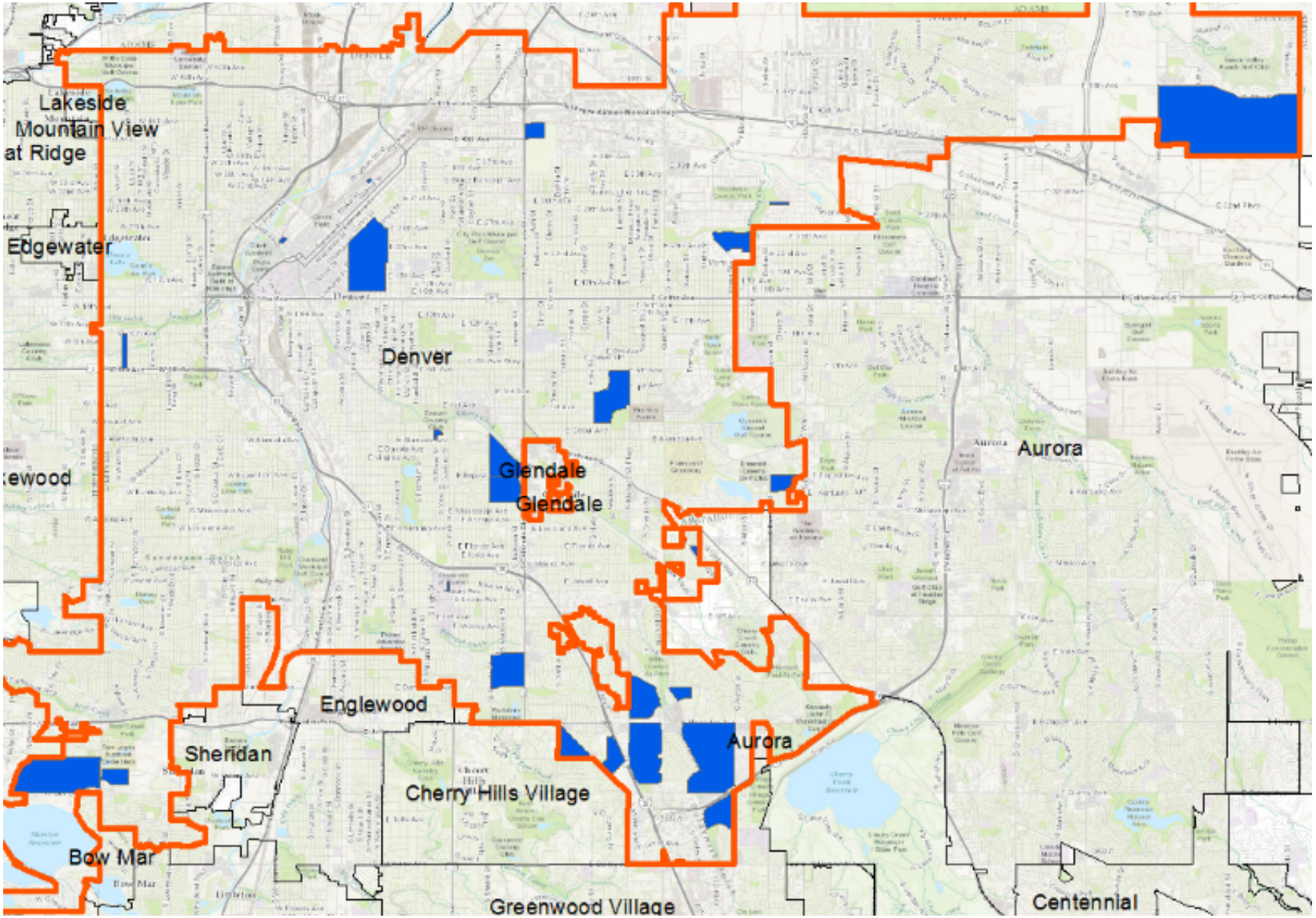


6 PM Shade Area = 25520 m^2/7hr

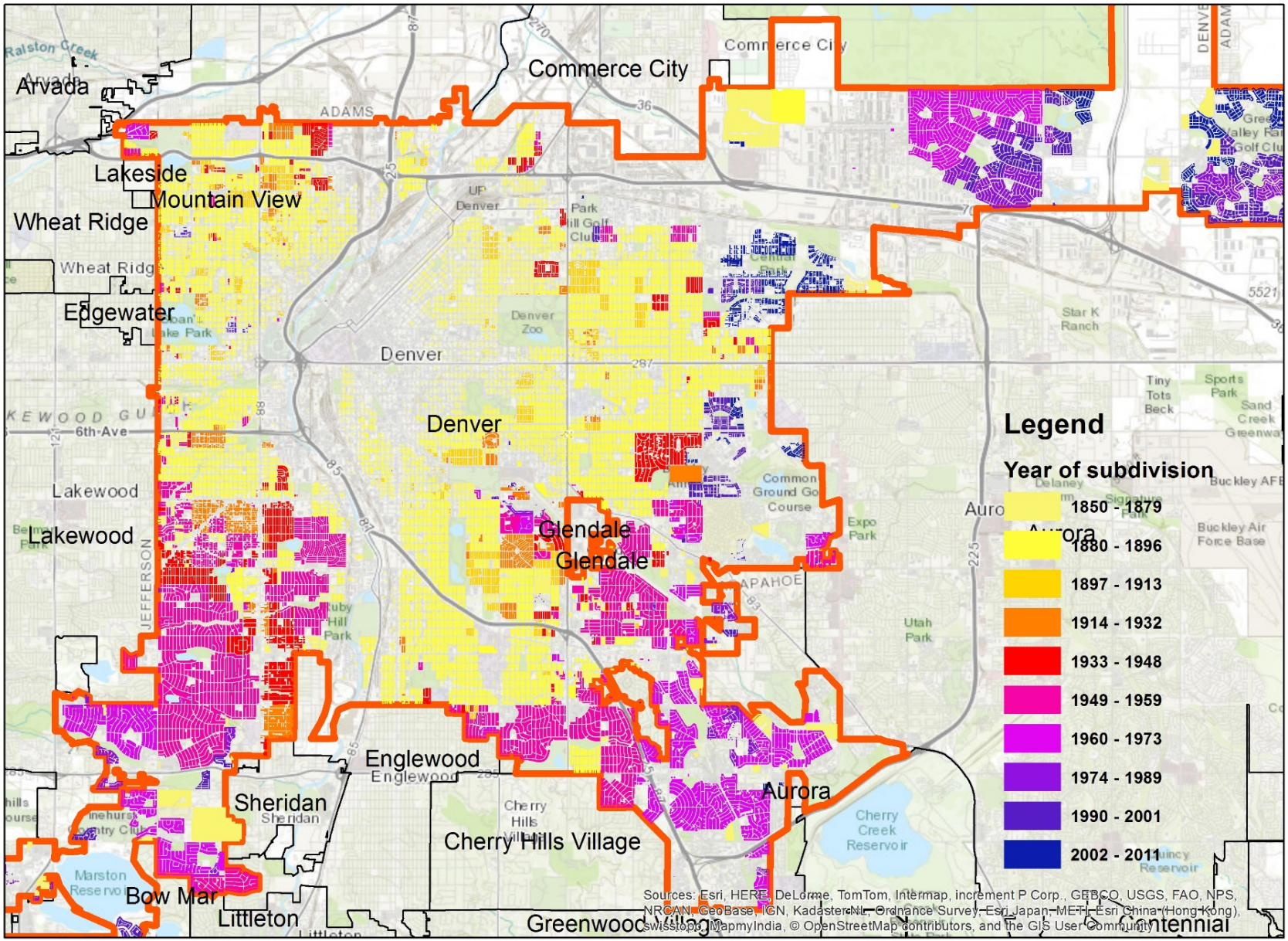

6 Hour Pixel Count
1 Hr
2 Hr
3 Hr
4 Hr
5 Hr
6 Hr
Grass area
Take average shade hourly value of each grass pixel


Mean shade hours
0.00 - 0.01
0.02 - 0.09
0.10 - 0.23
0.24 - 0.42
0.43 - 0.58
0.59 - 1.68
1.69 - 1.77
1.78 - 1.99

HOAs


Lakeside
Mountain View
at Ridge
Edgewater
Denver
Glendale
Glendale
Aurora
Aurora
Englewood
Sheridan
Cherry Hills Village
Aurora
Bow Mar
Greenwood Village
Centennial

Year of subdivision



Results: Water consumption

Variable	Coefficient	T stat
Constant	-.096	-.075
MeanShadeHours*	-1.576[a]	-4.044*
TreeArea *	.022	9.389*
Grass-unirrigated	.000	-.068
Grass—semi-irrigated	-.005	-2.838*
Grass—irrigated	.069	26.713*
BuiltArea*	.316	60.804*
STORIES*	28.359	45.072*
PShortTree*	7.275	4.291*
After1950*	3.769	7.569*
HOA*	10.493	10.435*

Dependent Variable: TOTAL_QTY
R-squared= 0.267
*= significant at the 99% confidence level.
a. MeanShadeHours=-1.136 when only tree shade modeled

Interpretation of results

- Each additional 100 m^2 of **irrigated grass** (Grass3) is associated with 6000 additional gal of irrigation per year
- **Trees** use irrigation, but less than grass. Each additional 100 m^2 of **tree canopy** is associated with 2,200 more gallons or irrigation.
- **Shade** cast by trees and buildings on lawns serves to at least partially offset the water use of trees: for each additional hour of average shade across all grass pixels, 1,576 fewer gallons of water are used (1,136 with only tree shade). Consistent with Litvak et al (2013)
- **Shade** also increases **NDVI**
- If it were possible for a yard with 100 m^2 of tall trees to achieve a mean shading hours of **1.4** for lawn pixels , **water savings from the shade would outweigh water use of trees**
- For each 10% increase in the proportion of **trees that are short**, there is a 726 gal increase in water use. i.e. old, mature trees use less proportionally. Consistent with Bijoor et al (2012)
- HOA status and subdivision year have impact irrigation directly and factors that drive irrigation

HOA differences in Denver

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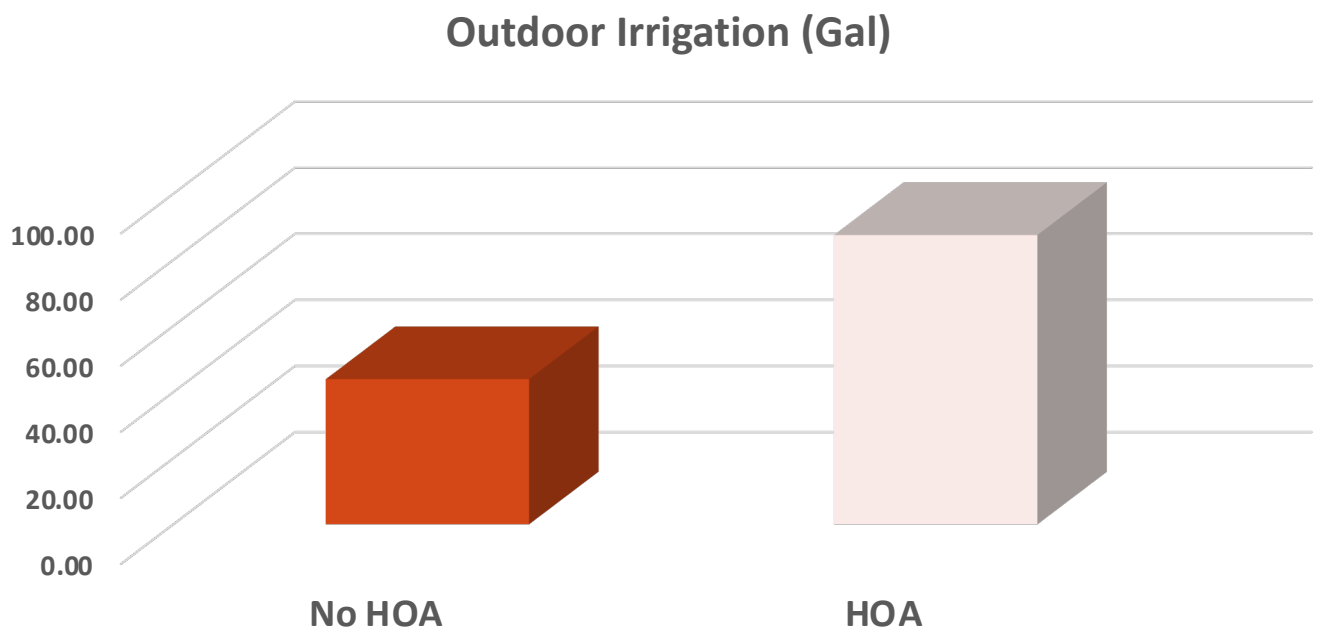
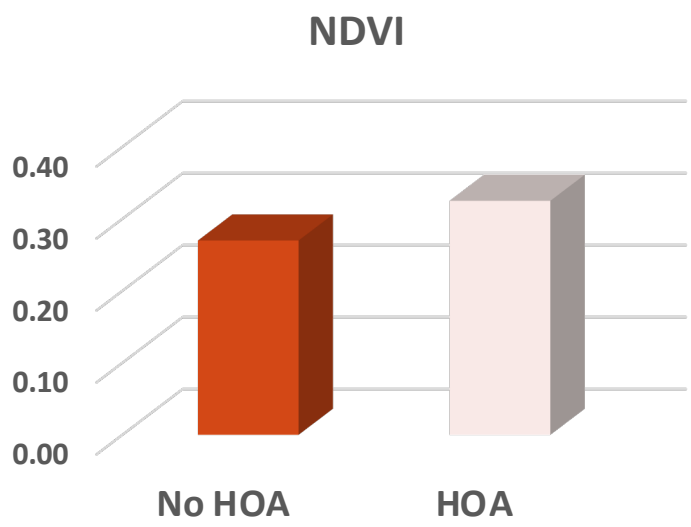
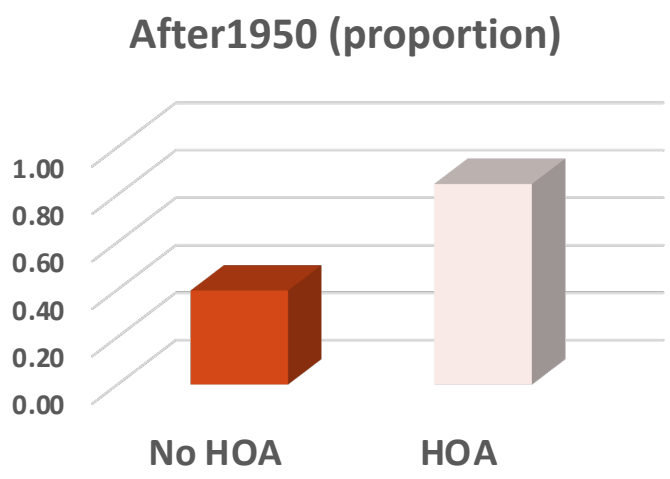
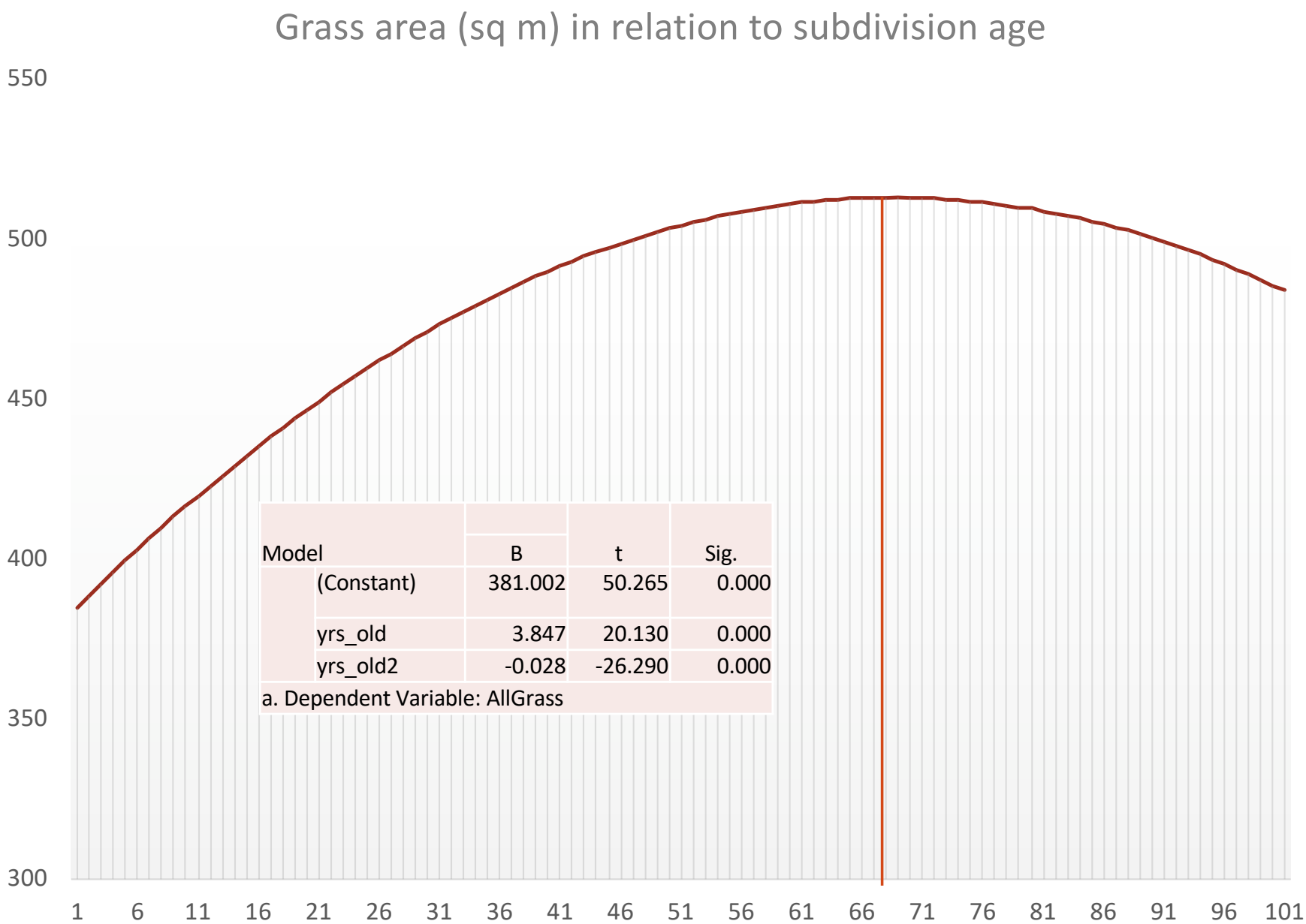






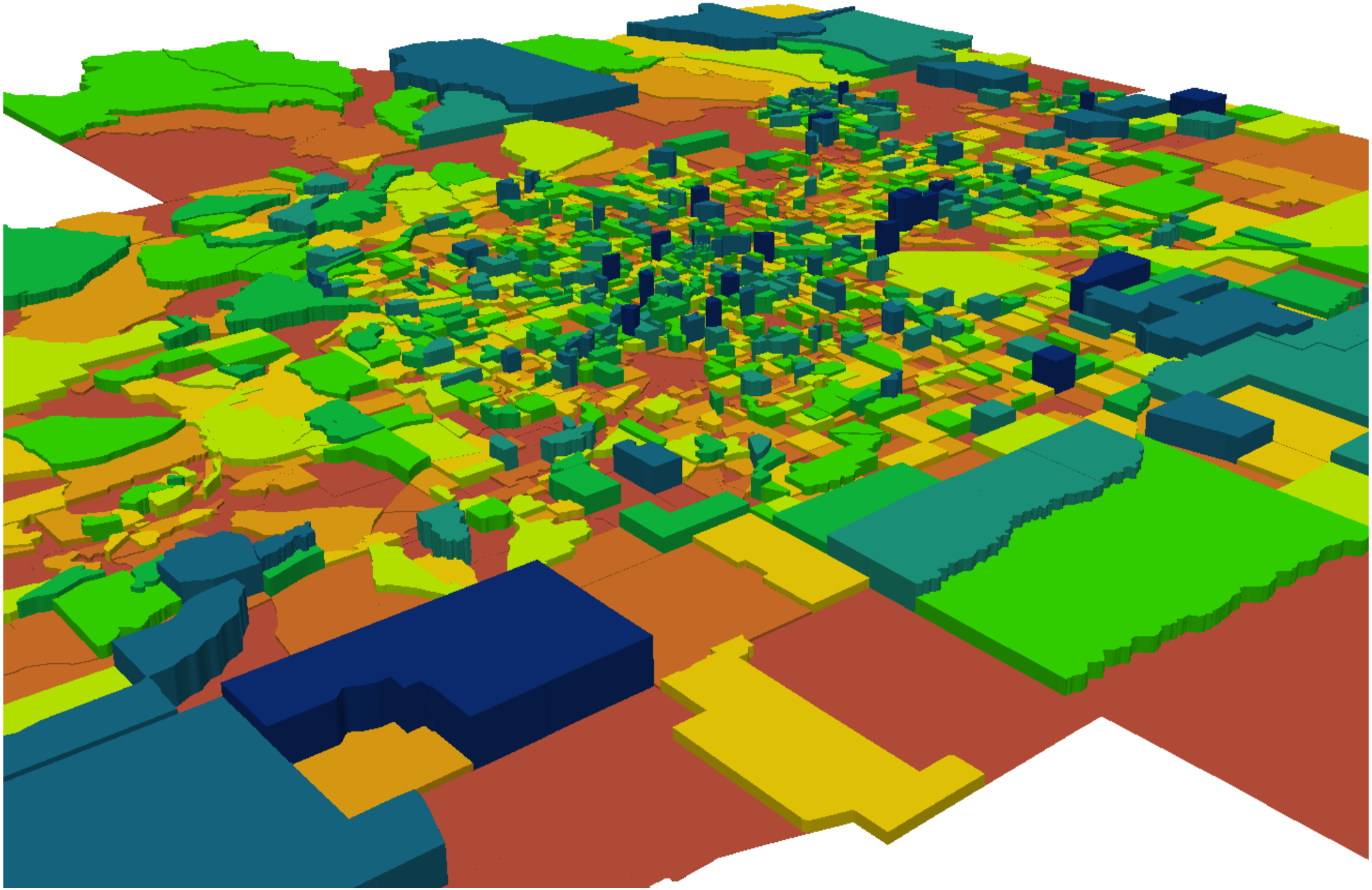
Subdivision age also drives grass area



Model		B	t	Sig.
	(Constant)	381.002	50.265	0.000
	yrs_old	3.847	20.130	0.000
	yrs_old2	-0.028	-26.290	0.000

a. Dependent Variable: AllGrass

Coefficients inform housing typology for UrbanSim-based predictive water consumption model



Thanks/ Questions

Austin.troy@ucdenver.edu

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Source: Eric Sonstroem (https://www.flickr.com/photos/sonstroem/)