



Datamining Imaginary Maps

A Mathematical Investigation of Cellular Artwork

Christopher Hanusa
Queens College, CUNY

qc.edu/~chanusa
christopherhanusa.com

Emily Garfield
New York City

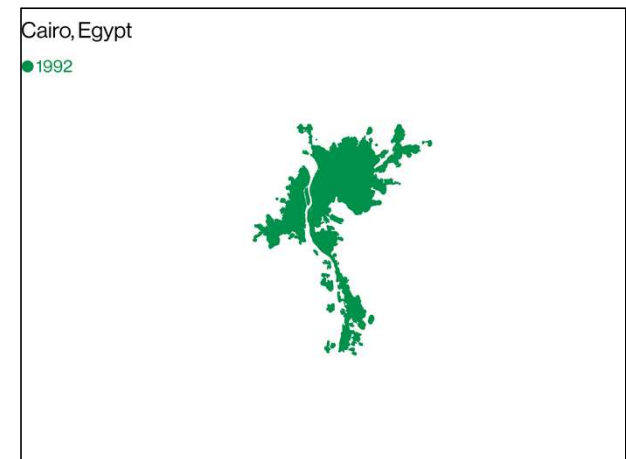
emilygarfield.com

Emily Garfield

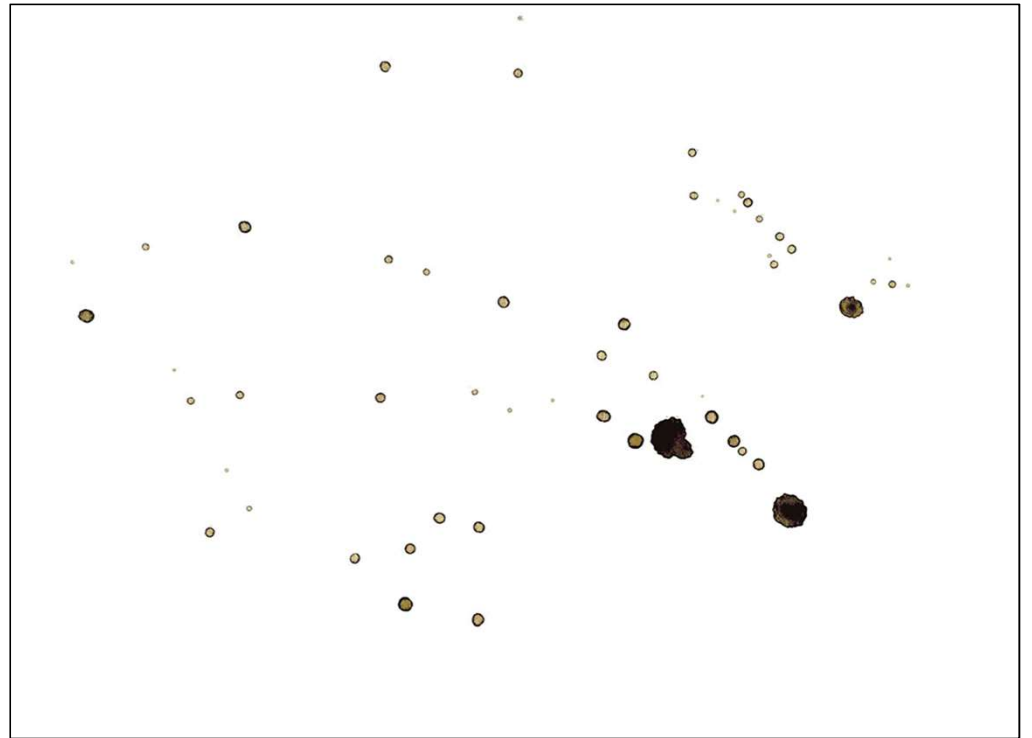
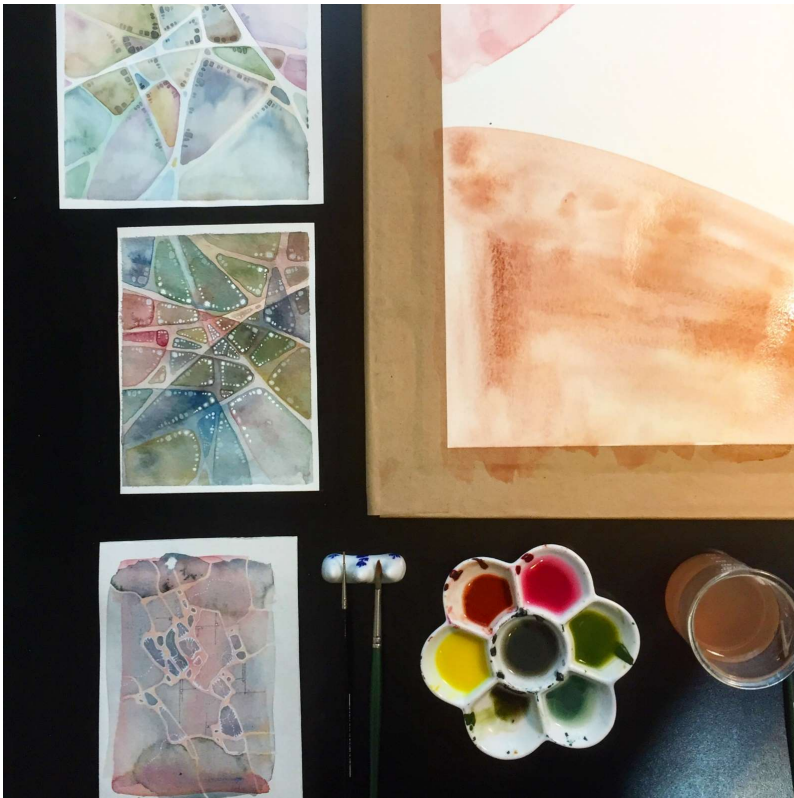
- Full-time artist working on studio art and commissions
- Abstract, procedurally-drawn maplike artwork
- Inspired by networks in the natural/human world



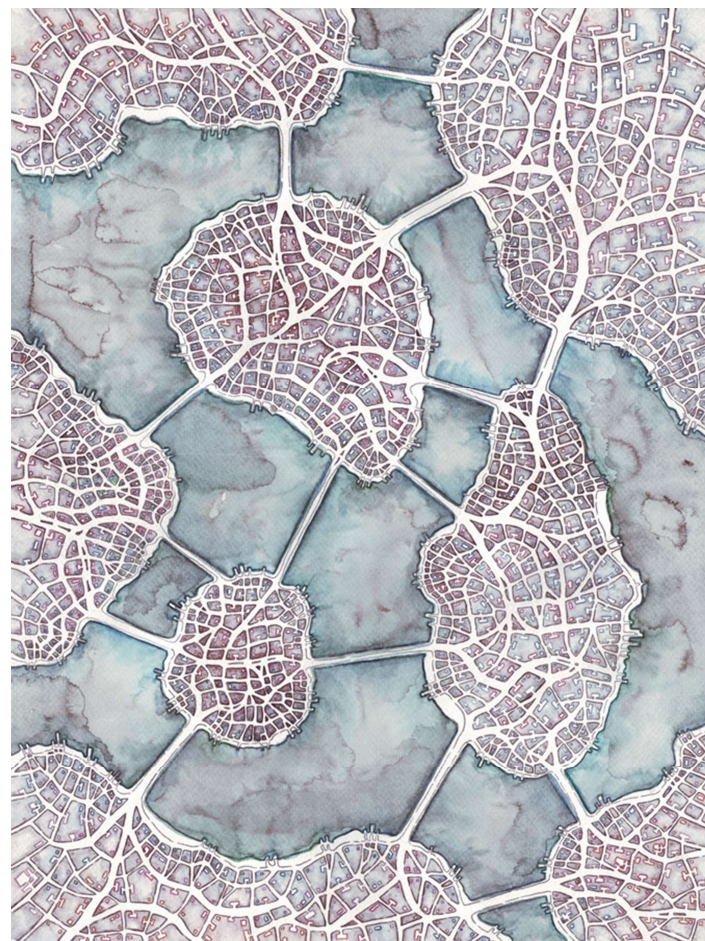
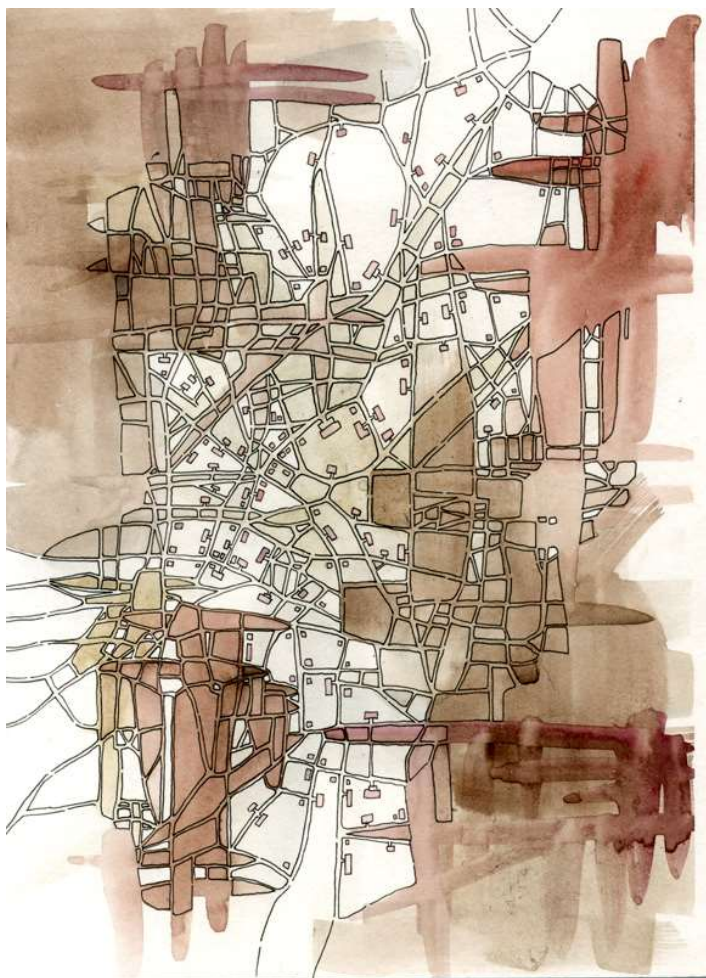
Inspiration



Materials and Process



Datamining Imaginary Maps - Christopher Hanusa and Emily Garfield – Twitter: @mathzorro @EmilyGarfield #ImaginaryMaps #MOVES2019

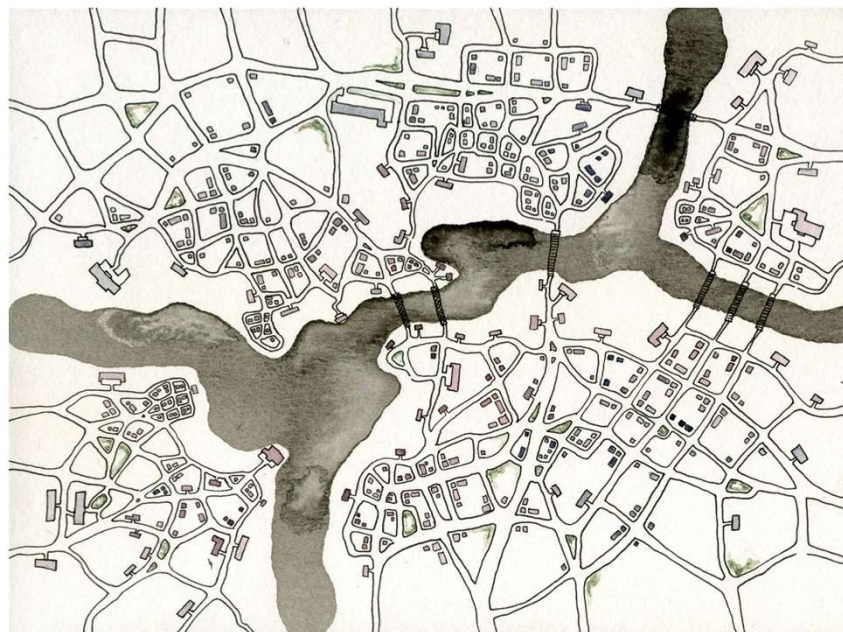


Datamining Imaginary Maps - Christopher Hanusa and Emily Garfield – Twitter: @mathzorro @EmilyGarfield #ImaginaryMaps #MOVES2019

Traveling into Garfield's World

Motivation

- What makes these “mappy”?
- What is life like there?



Emily Garfield – Cityspace #267

Traveling into Garfield's World

Motivation

- What makes these “mappy”?
- What is life like there?
- Fractal analysis of artwork



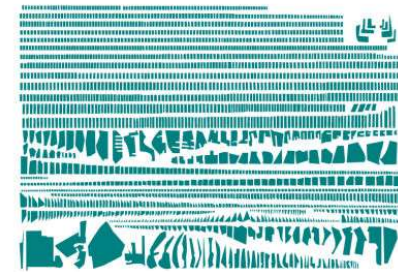
Jackson Pollock 1952

Taylor et al., Authenticating Pollock
Painting using Fractal Geometry, 2006

Traveling into Garfield's World

Motivation

- What makes these “mappy”?
- What is life like there?

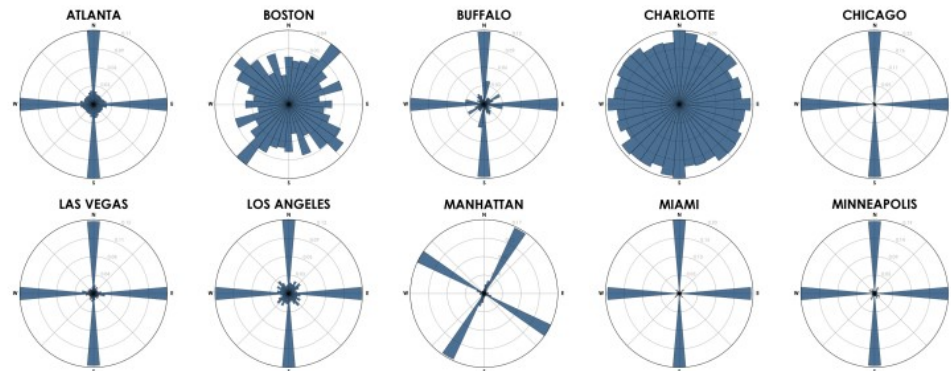


Armelle
Caron
2005/8

New York Deconstructed

City Street Network Orientation

- Fractal analysis of artwork
- Data visualization of cities



Geoff
Boeing
2018



Traveling into Garfield's World

Motivation

- What makes these “mappy”?
- What is life like there?
- Fractal analysis of artwork
- Data visualization of cities

Questions

- Color Palette
- Block and Road Structure
- Neighborhood analysis
- Fractal qualities
- Generative map

What makes a map?

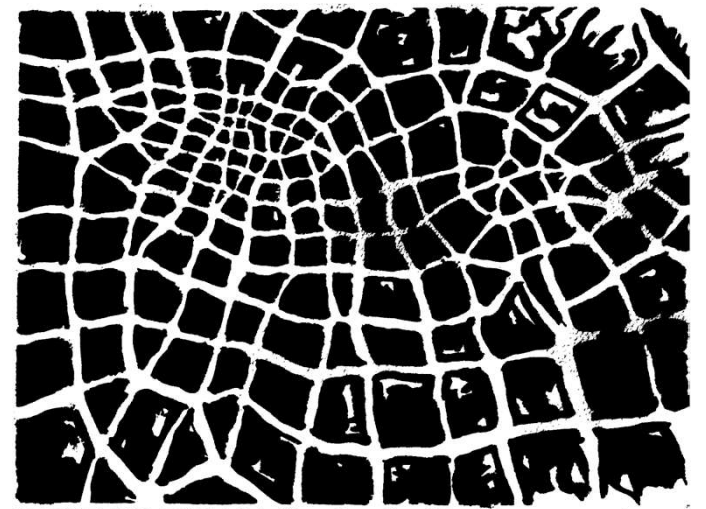
Importing into Mathematica

- Convert image to Black and White



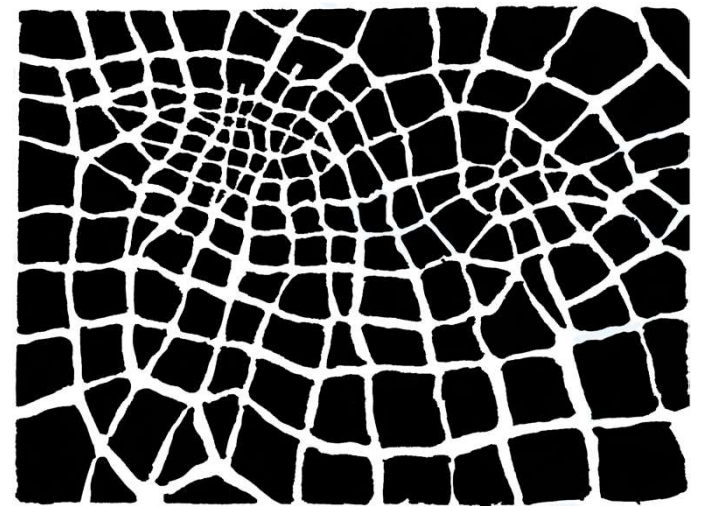
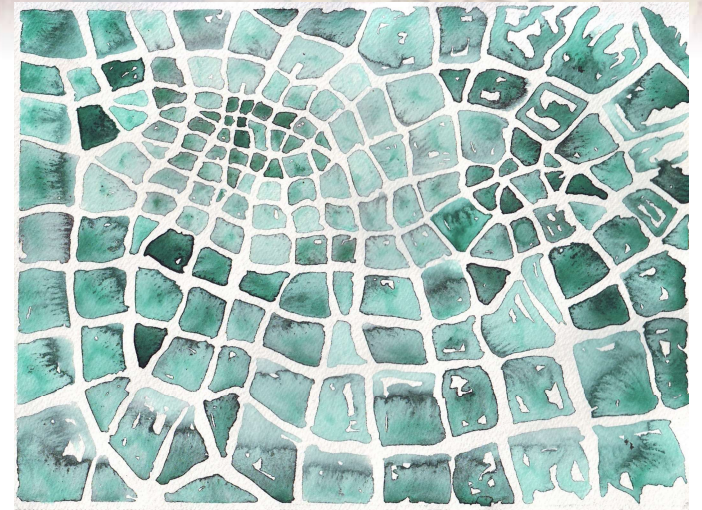
Importing into Mathematica

- Convert image to Black and White



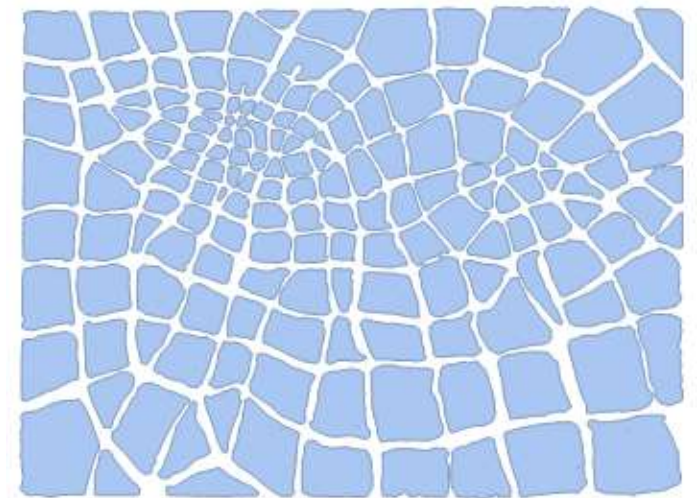
Importing into Mathematica

- Convert image to Black and White



Importing into Mathematica

- Convert image to Black and White
- Compute the block boundaries (ImageMesh)
 - Block size and shape



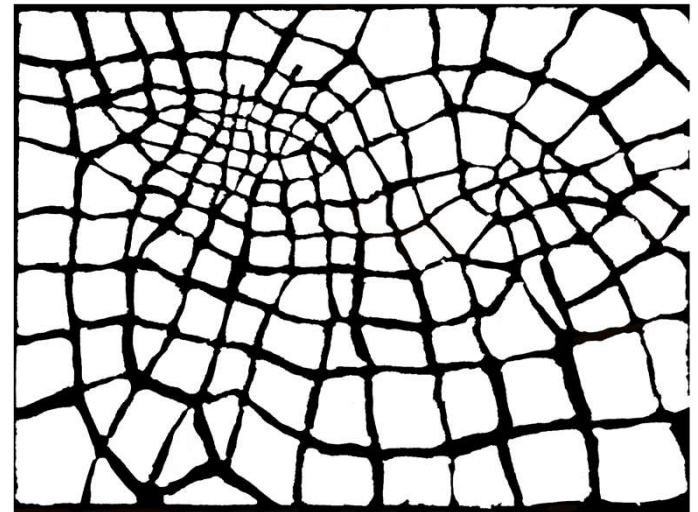
Importing into Mathematica

- Convert image to Black and White
- Compute the block boundaries (ImageMesh)
 - Block size and shape
 - Average color of each block



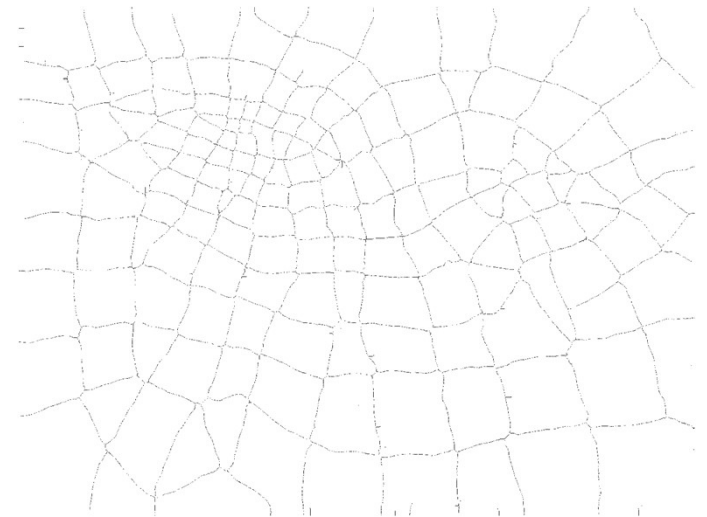
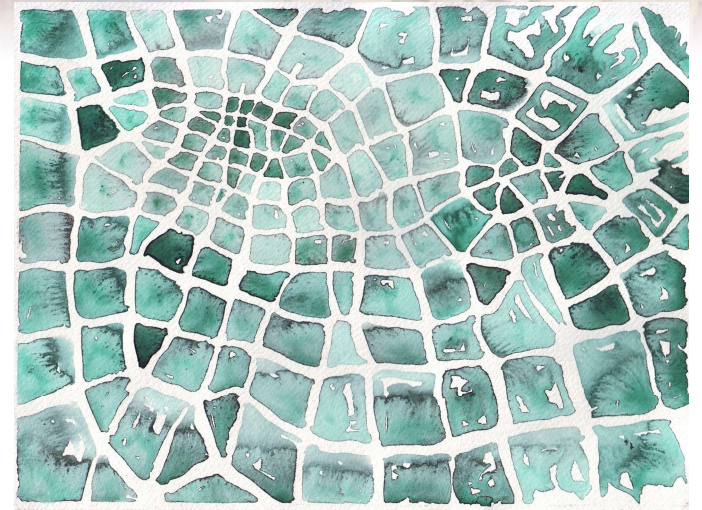
Importing into Mathematica

- Convert image to Black and White
- Compute the block boundaries (ImageMesh)
 - Block size and shape
 - Average color of each block
- Infer the road network – *** INTENSIVE**



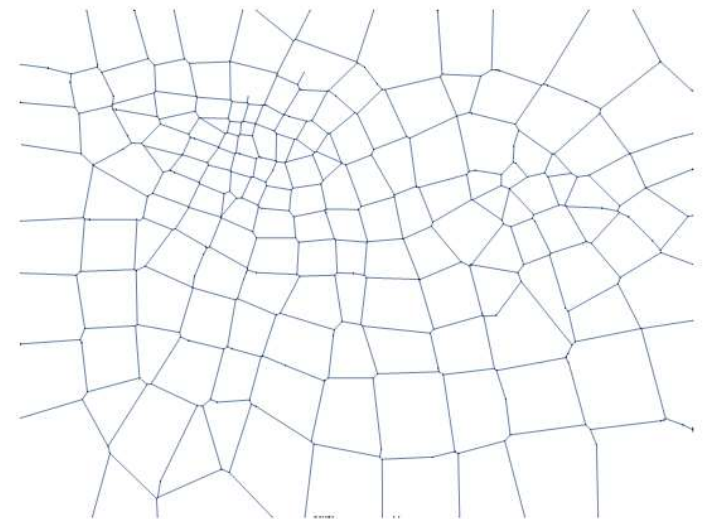
Importing into Mathematica

- Convert image to Black and White
- Compute the block boundaries (ImageMesh)
 - Block size and shape
 - Average color of each block
- Infer the road network



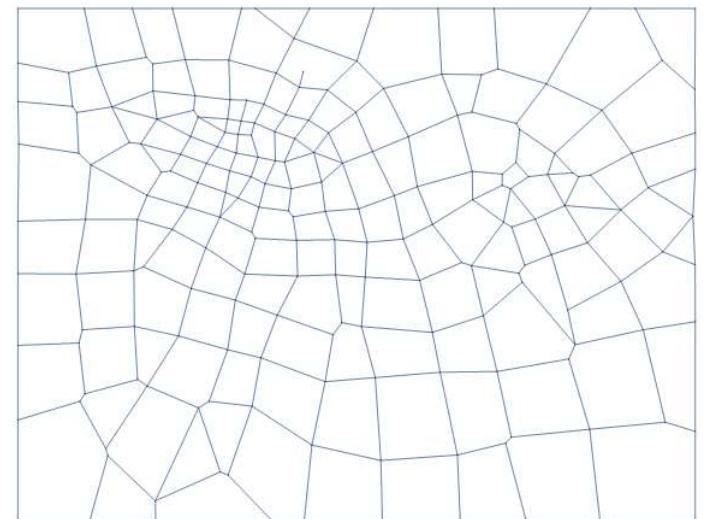
Importing into Mathematica

- Convert image to Black and White
- Compute the block boundaries (ImageMesh)
 - Block size and shape
 - Average color of each block
- Infer the road network (MorphologicalGraph)



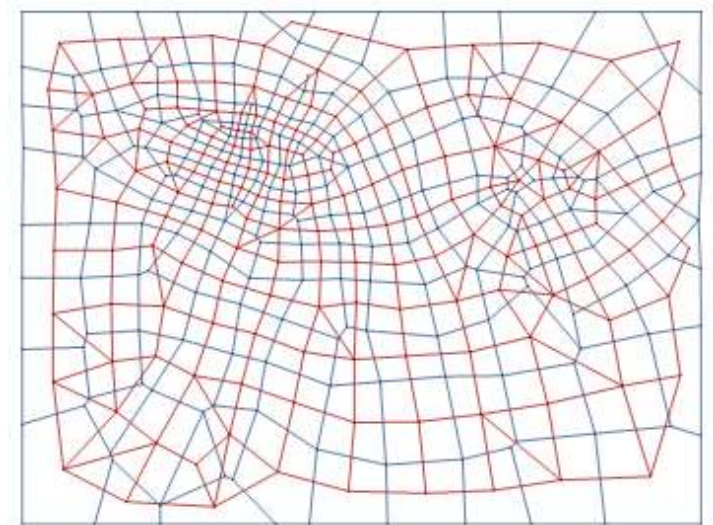
Importing into Mathematica

- Convert image to Black and White
- Compute the block boundaries (ImageMesh)
 - Block size and shape
 - Average color of each block
- Infer the road network (MorphologicalGraph)



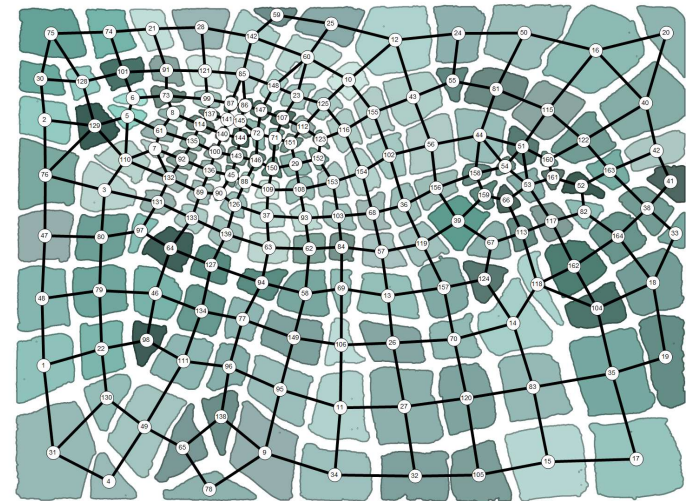
Importing into Mathematica

- Convert image to Black and White
- Compute the block boundaries (ImageMesh)
 - Block size and shape
 - Average color of each block
- Infer the road network (MorphologicalGraph)
 - Dual graph (IGraph/M)



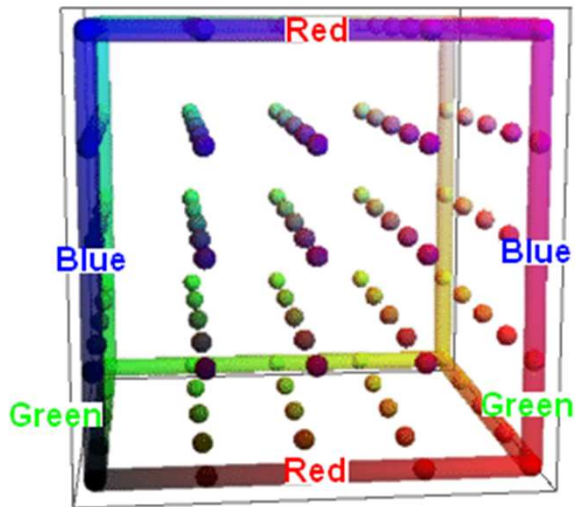
Importing into Mathematica

- Convert image to Black and White
- Compute the block boundaries (ImageMesh)
 - Block size and shape
 - Average color of each block
- Infer the road network (MorphologicalGraph)
 - Dual graph (IGraph/M)
 - Block adjacencies

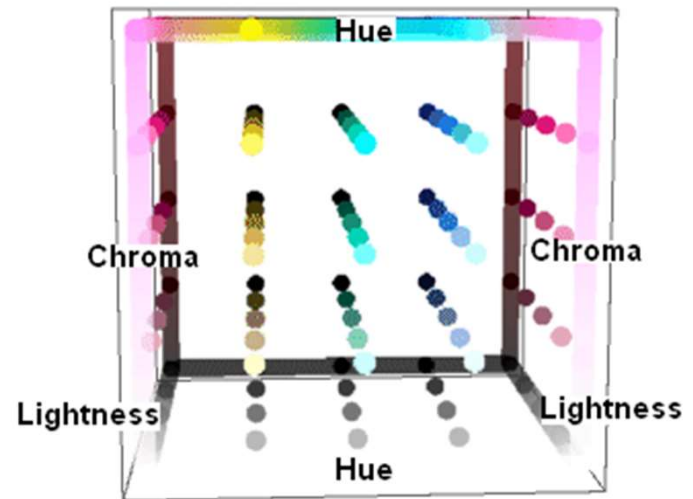


Color Analysis

RGB Colors



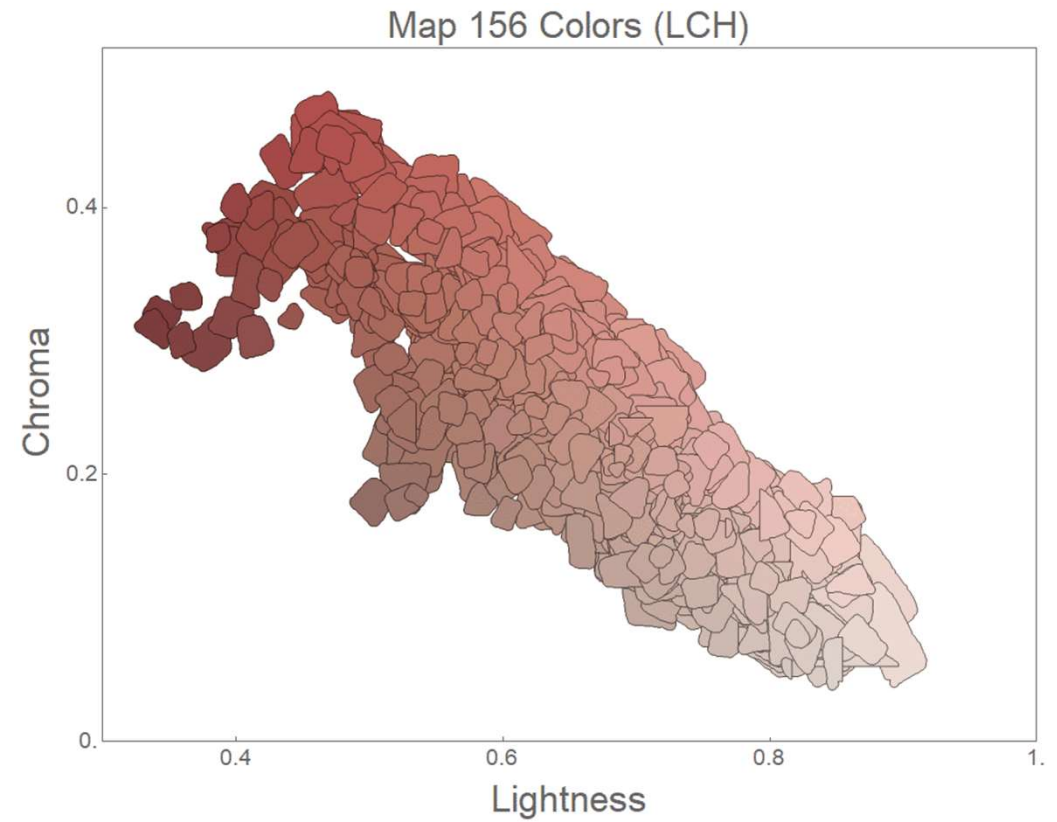
LCH Colors



Color Analysis – Cityspace #156

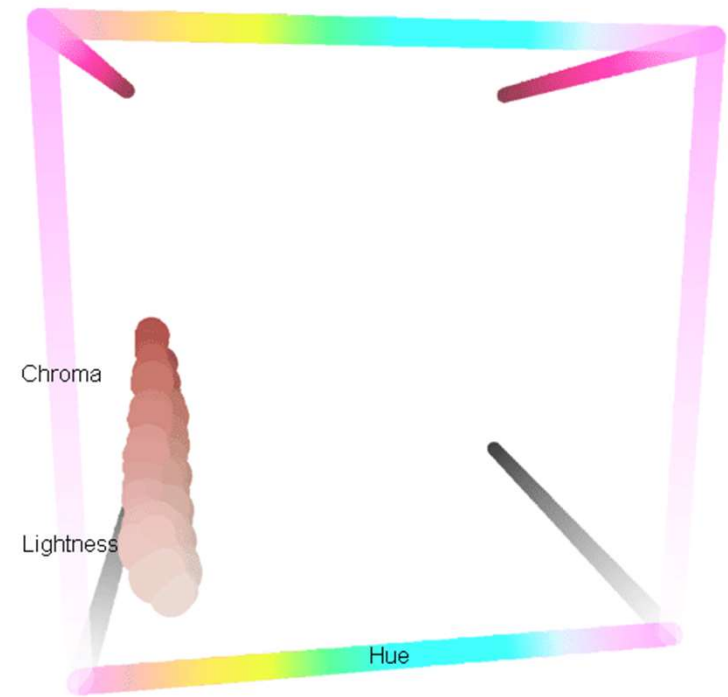
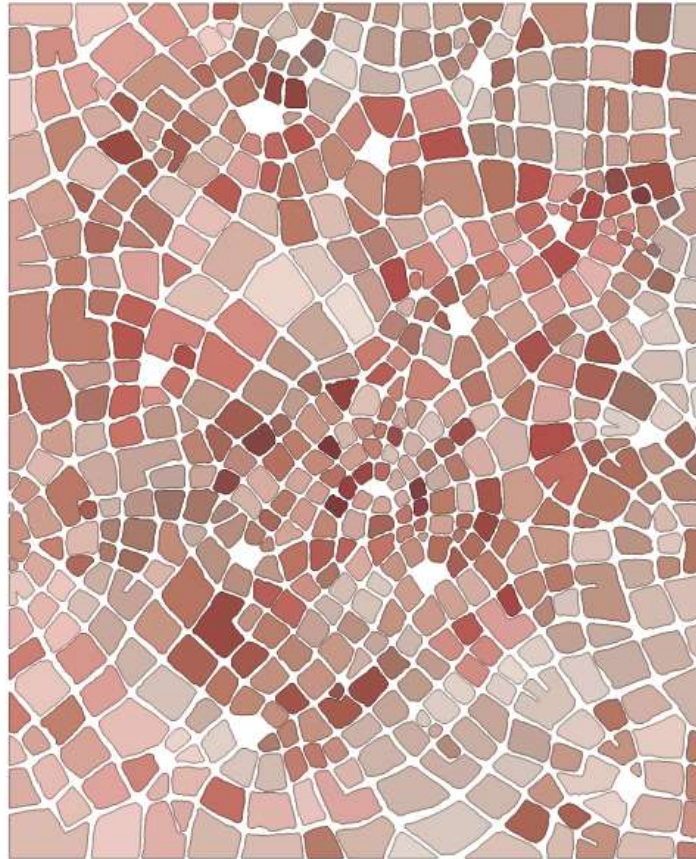


Color Analysis



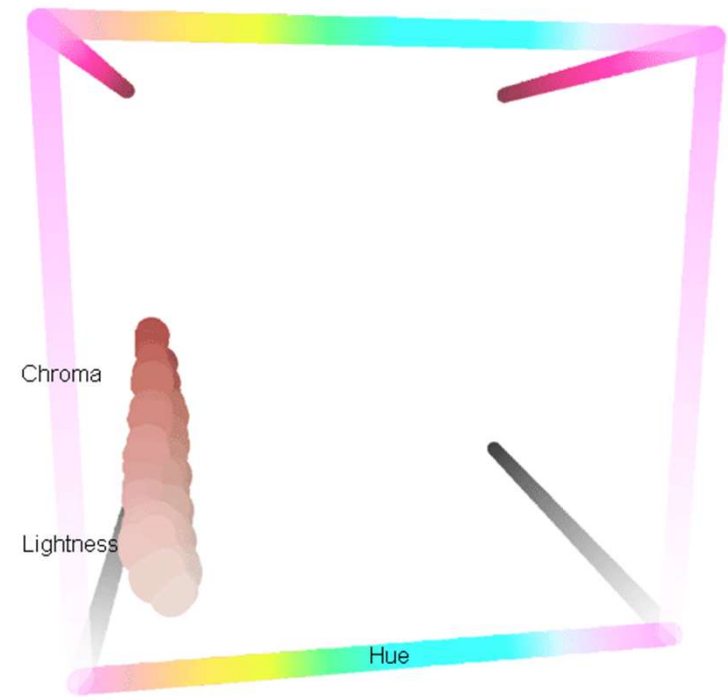
Color Analysis

Map 156 Colors

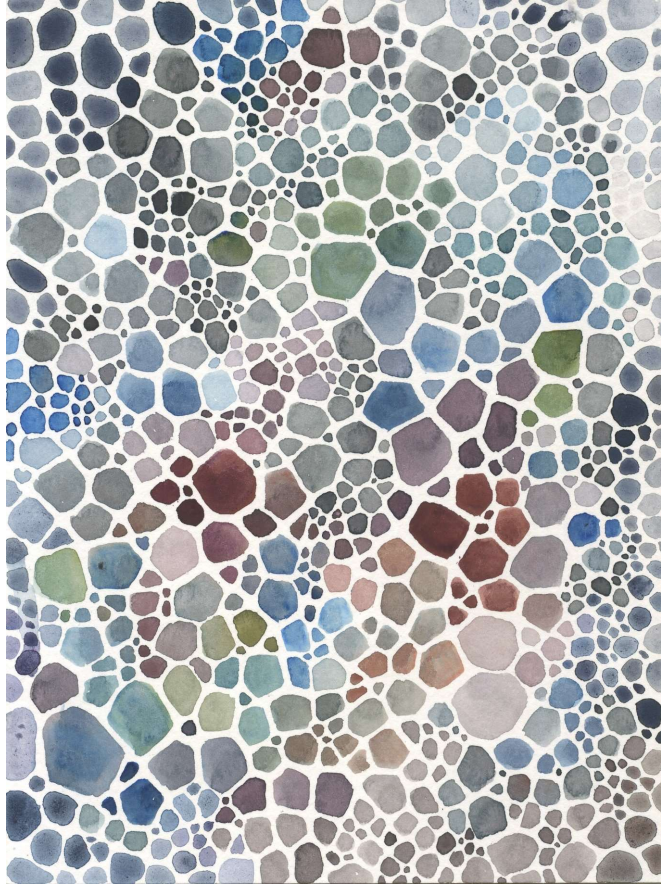


Color Analysis

Map 156 Colors

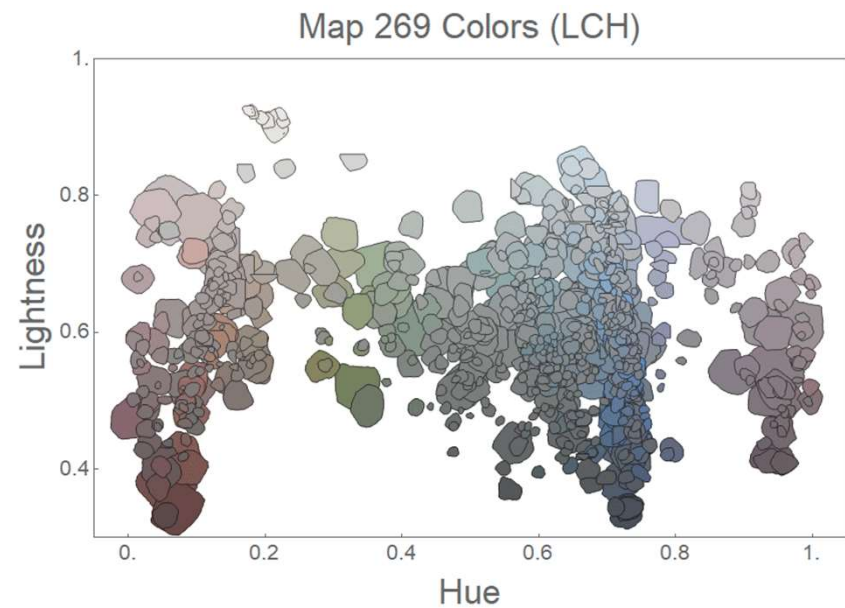
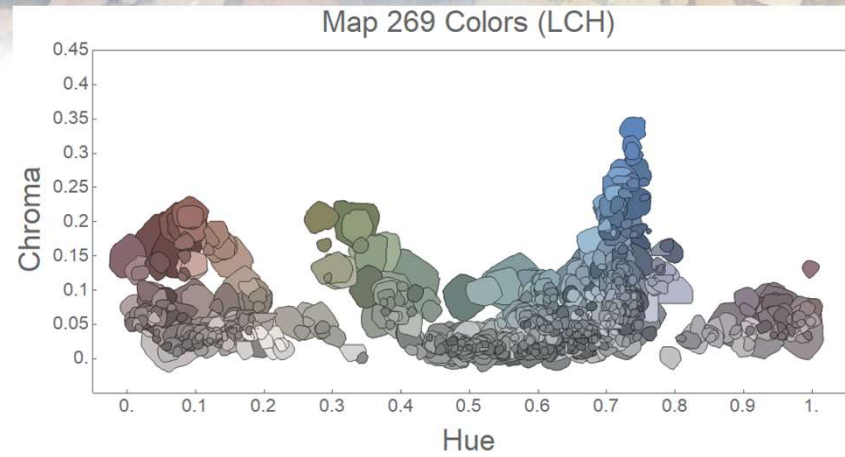
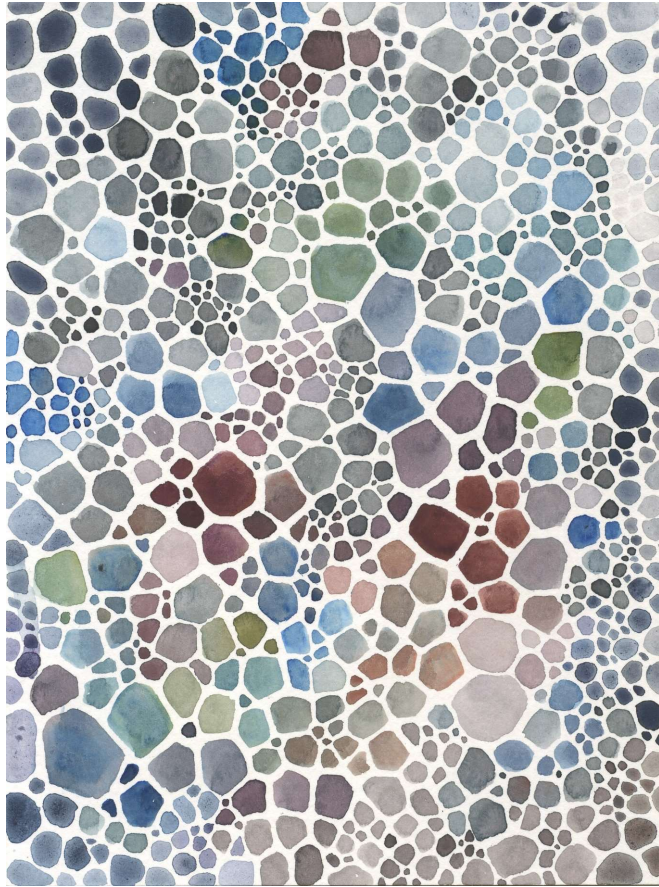


Color Analysis – Cityspace #269

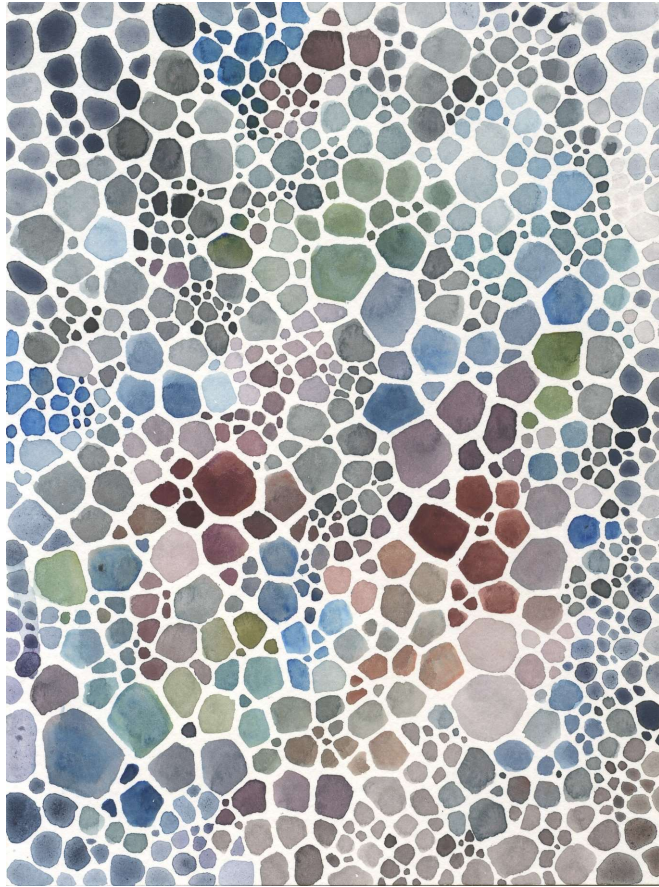


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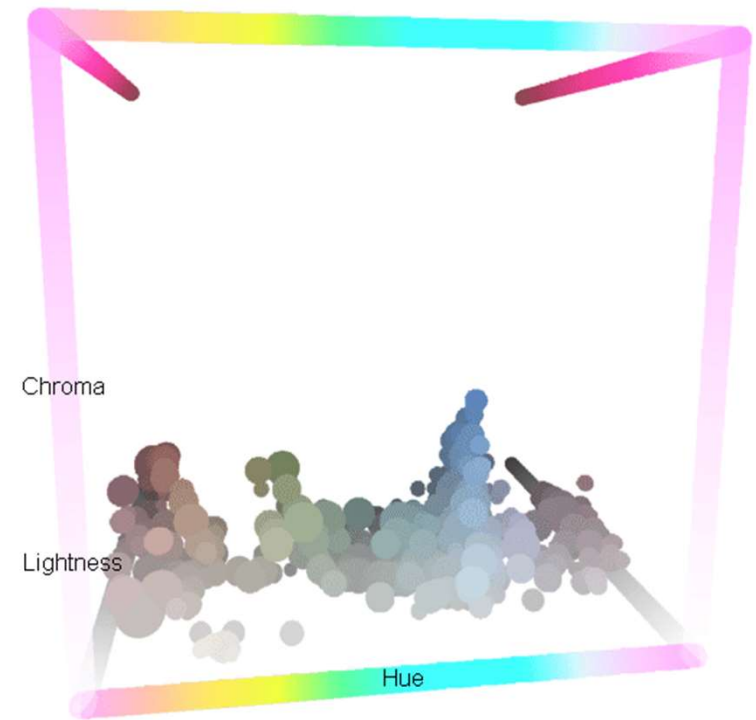
Color Analysis



Color Analysis



Map 269 Colors



Cityspace #156



Cityspace #268



Cityspace #297



Cityspace #199



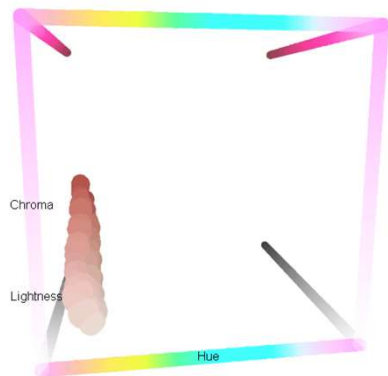
Cityspace #269



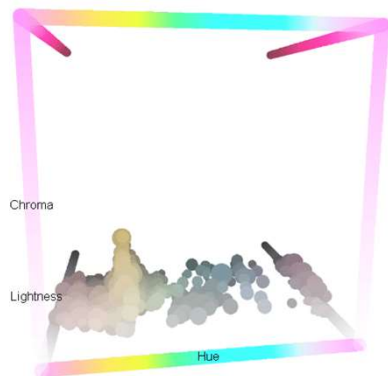
Cityspace #311



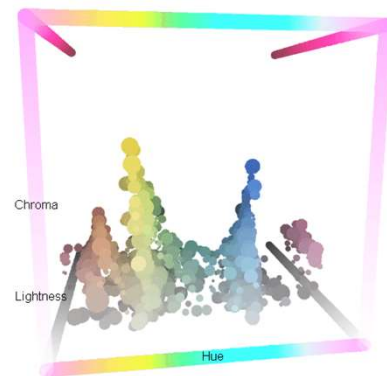
Map 156 Colors



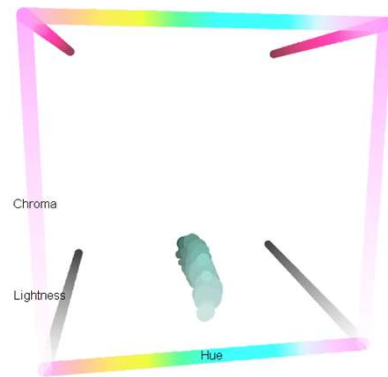
Map 268 Colors



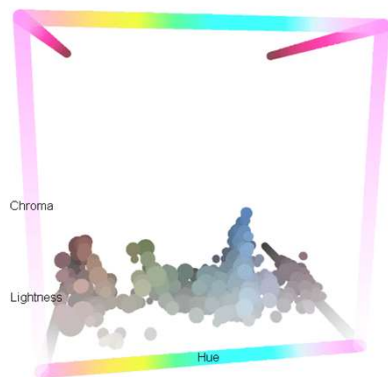
Map 297 Colors



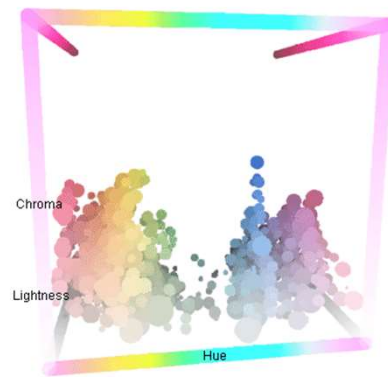
Map 199 Colors



Map 269 Colors



Map 311 Colors



Block Analysis – Provides a Fingerprint

- Size – What is the area?
- Density – How dense is the neighborhood?
- Shape – How rectangular is it?



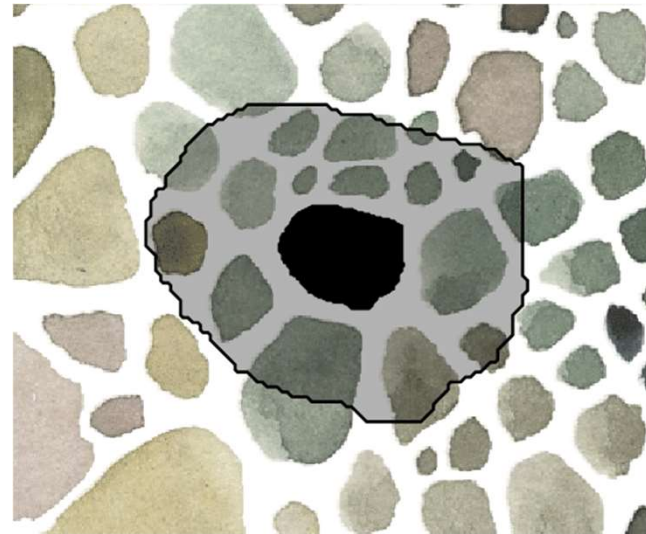
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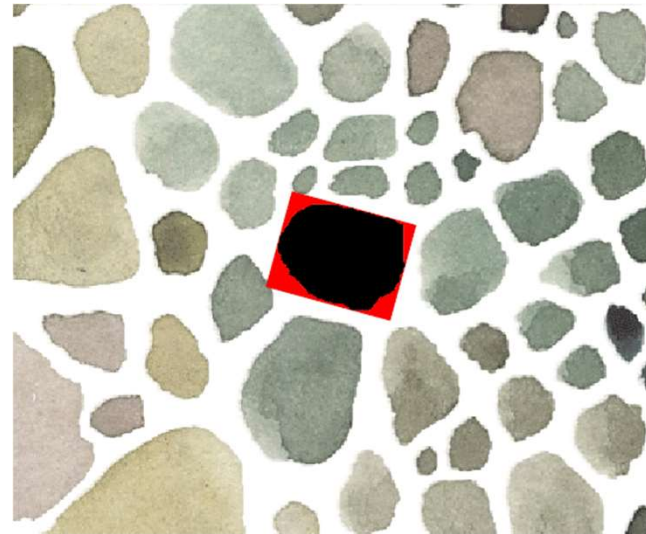
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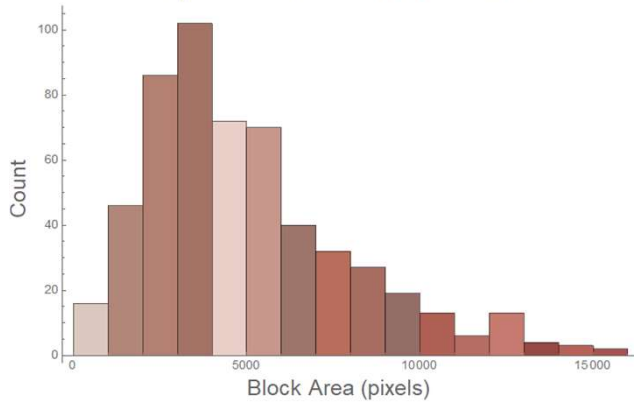
Block Analysis – Provides a Fingerprint

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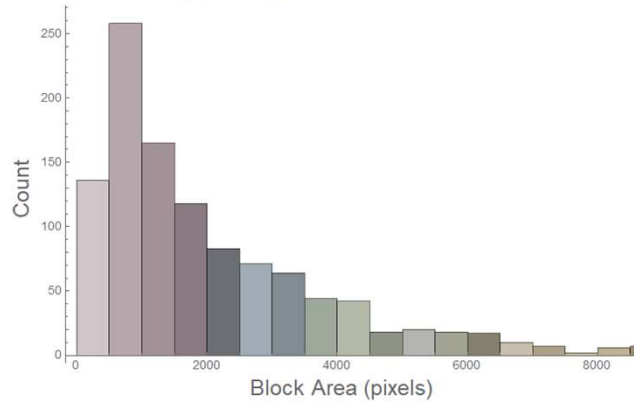


Block Size Analysis

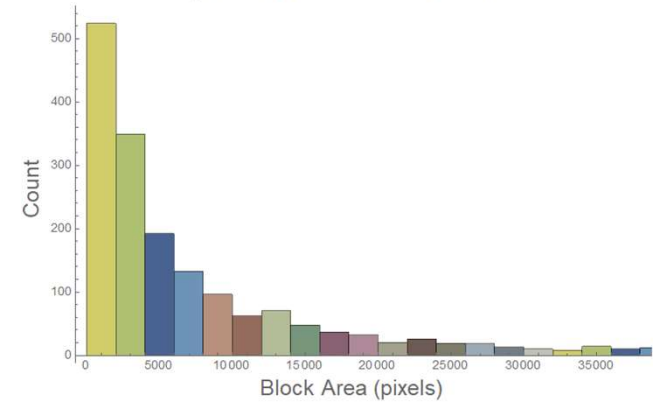
Map 156: Distribution of Block Area



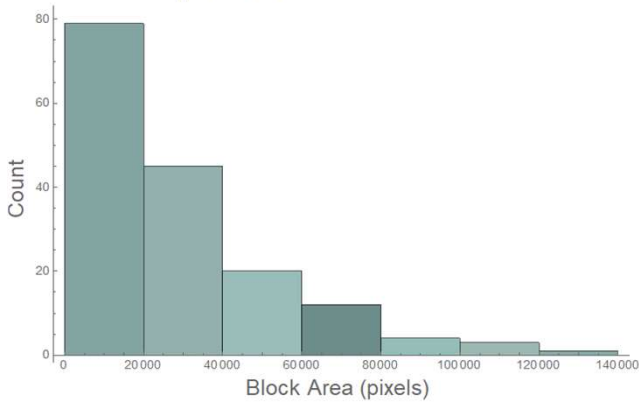
Map 268: Distribution of Block Area



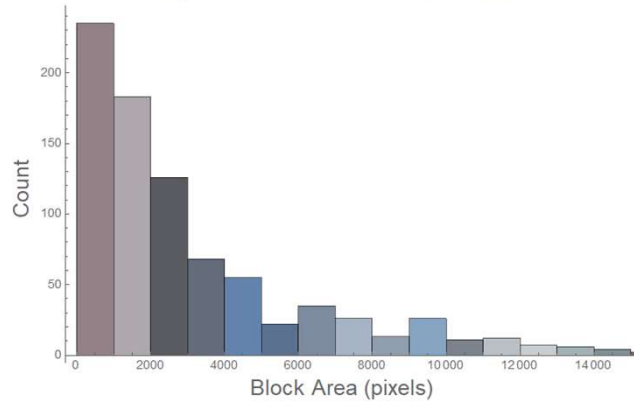
Map 297: Distribution of Block Area



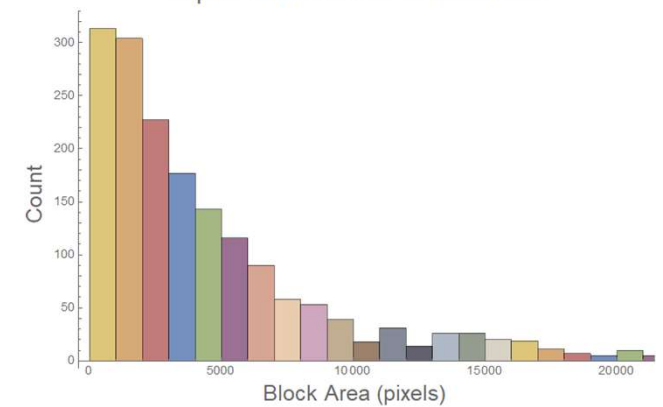
Map 199: Distribution of Block Area



Map 269: Distribution of Block Area

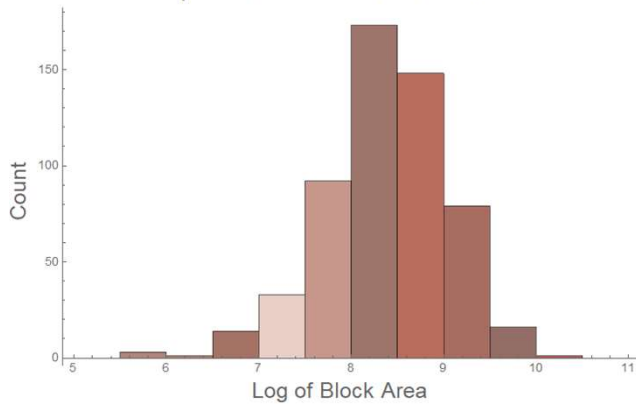


Map 311: Distribution of Block Area

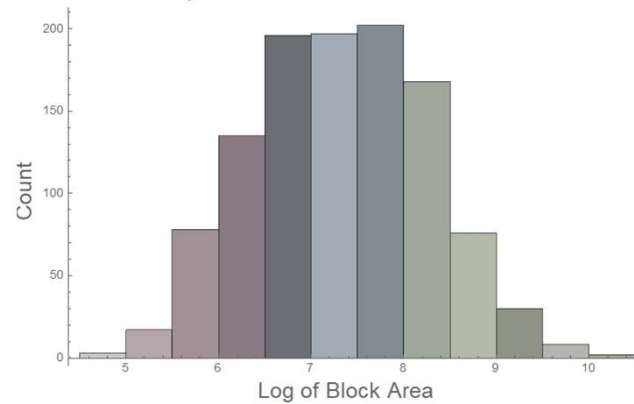


Block Size Analysis (Logarithmic)

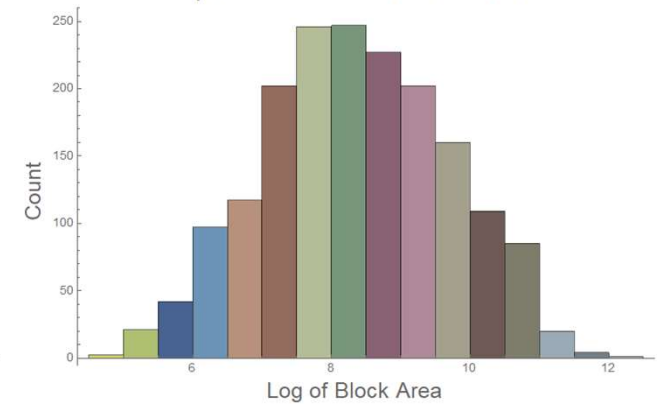
Map 156: Distribution of Block Area



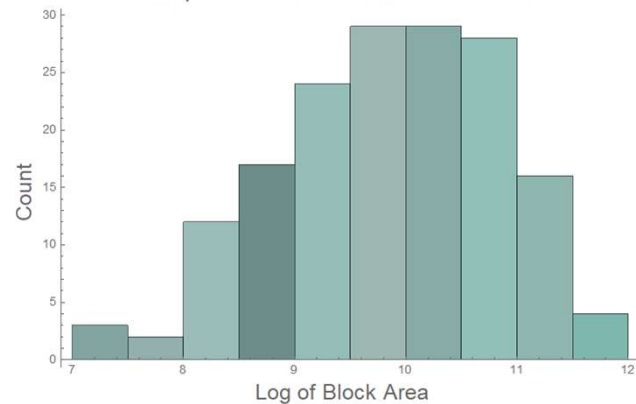
Map 268: Distribution of Block Area



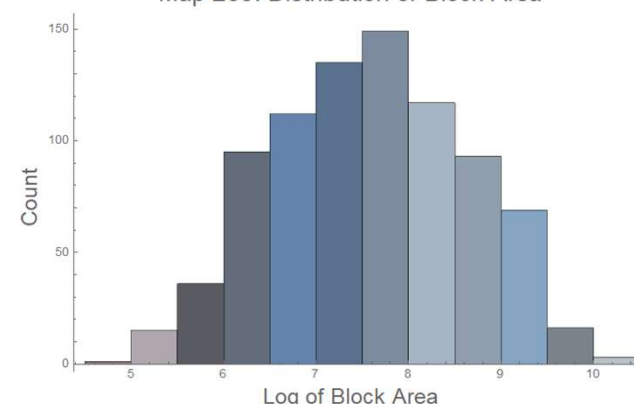
Map 297: Distribution of Block Area



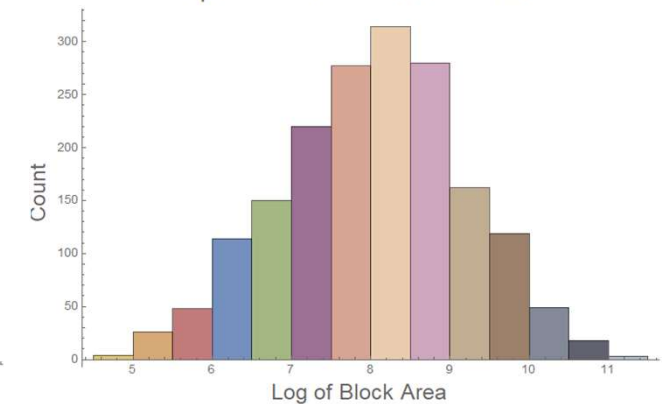
Map 199: Distribution of Block Area



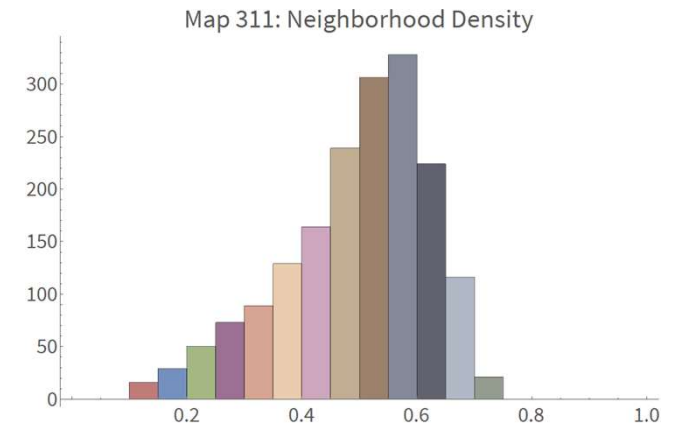
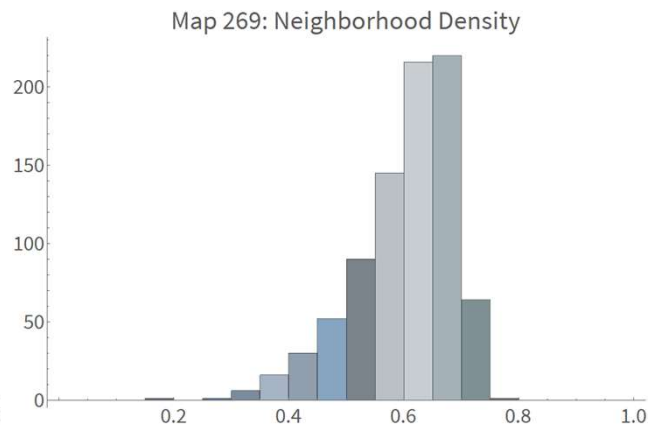
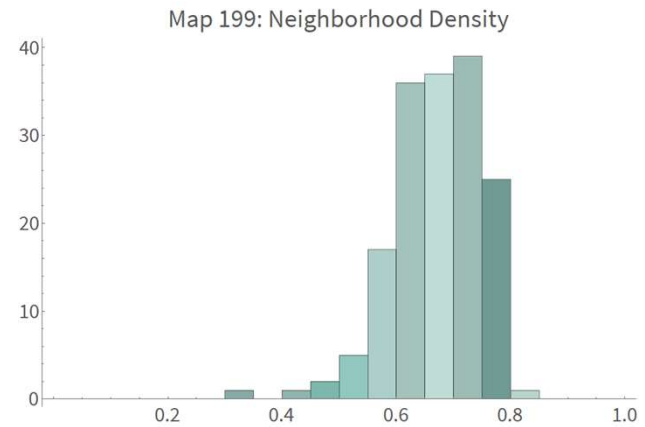
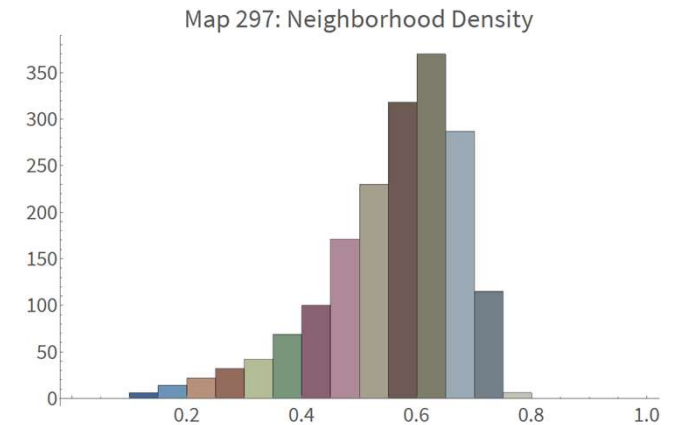
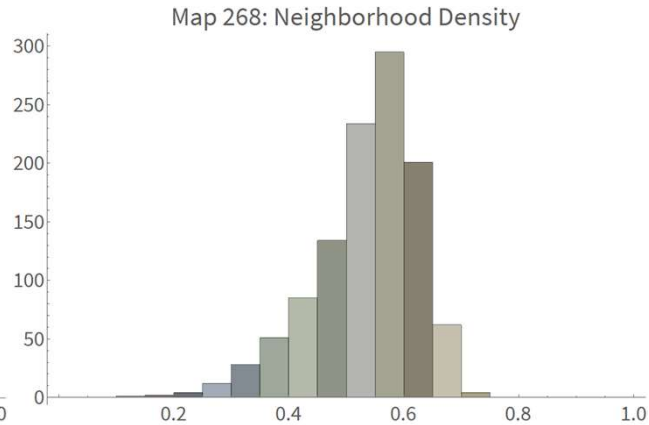
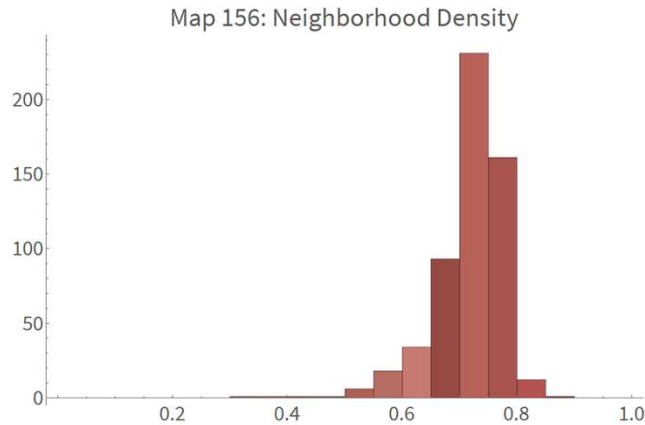
Map 269: Distribution of Block Area



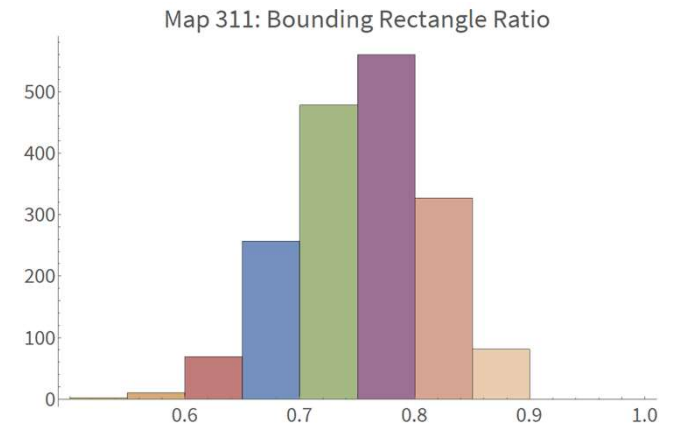
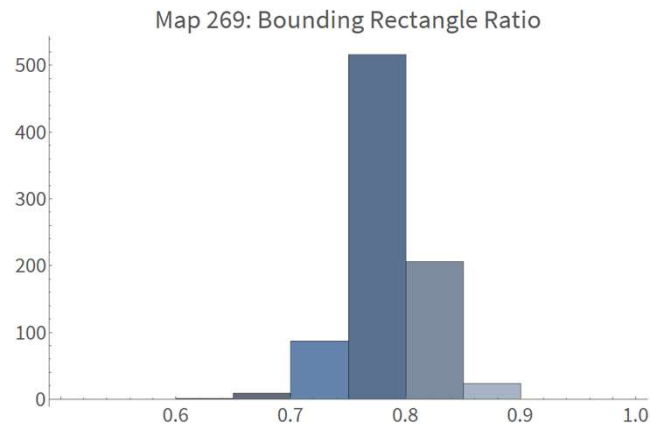
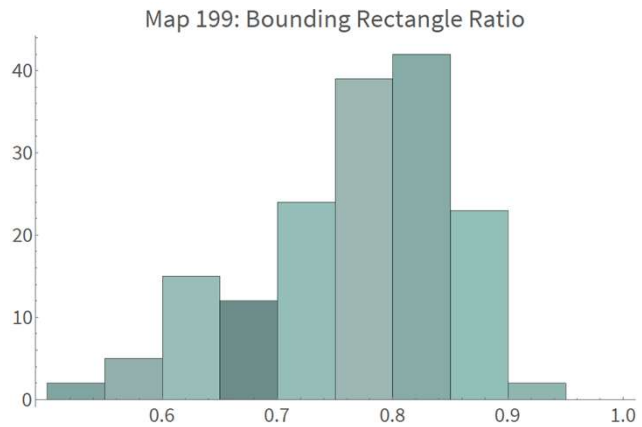
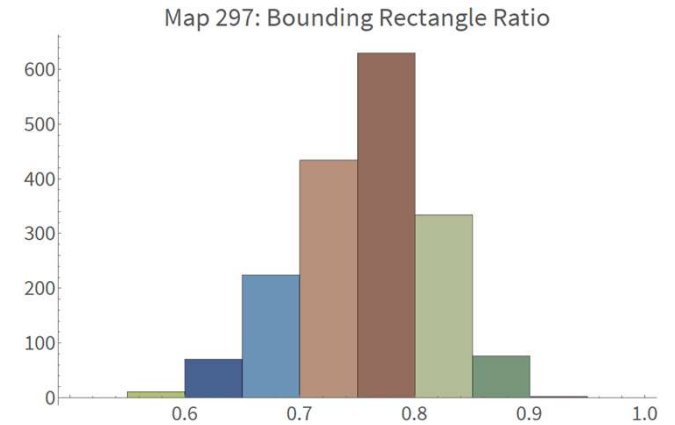
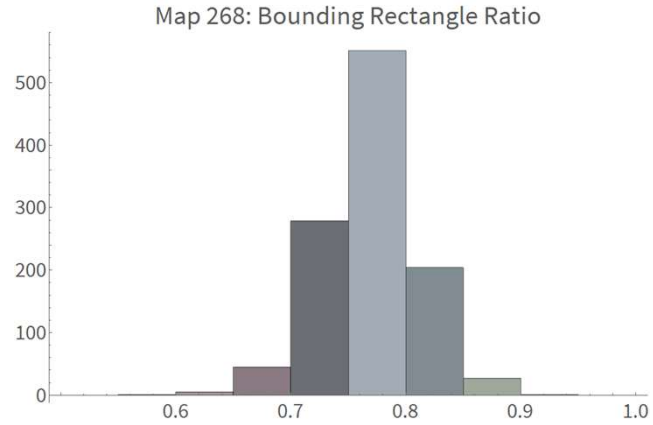
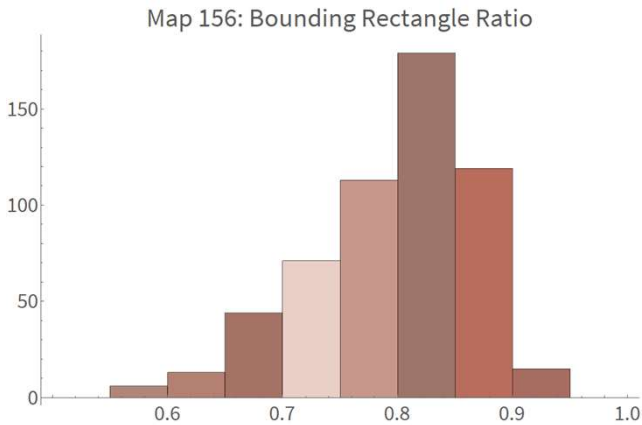
Map 311: Distribution of Block Area



Neighborhood Density

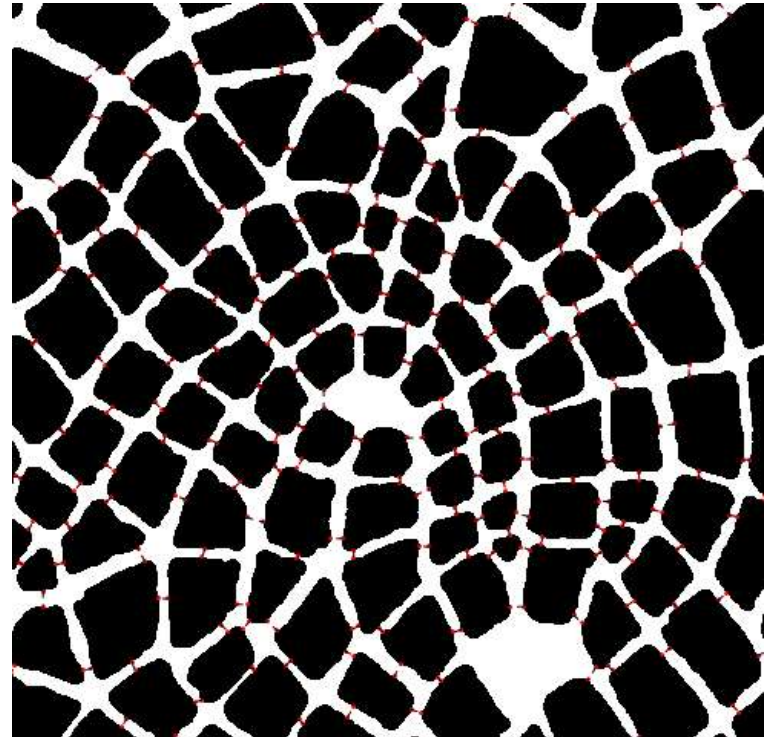


Block Rectangularity



Road analysis

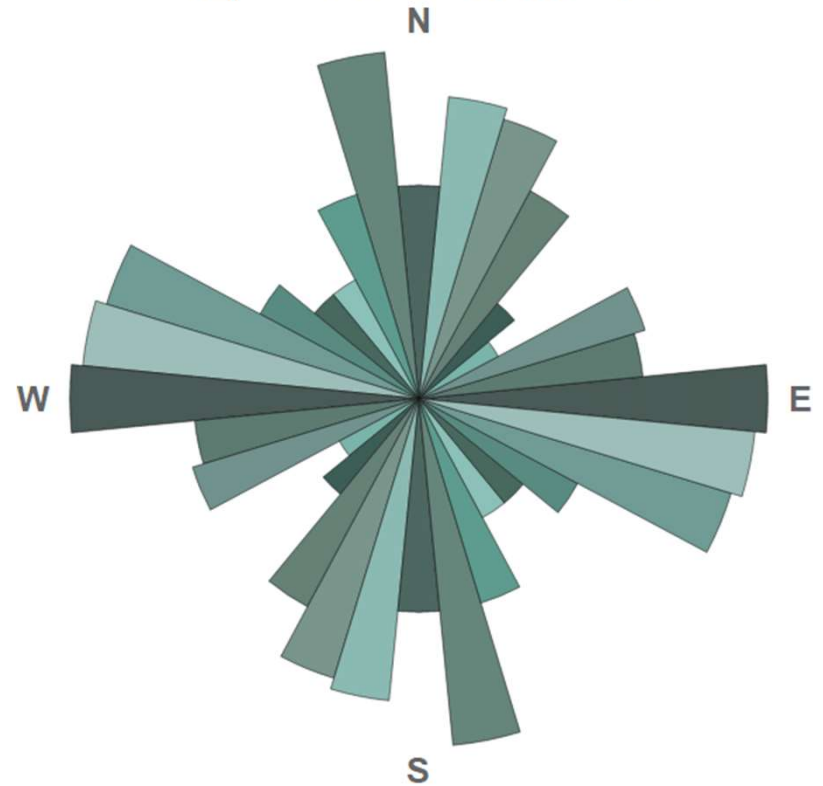
- Width – Skinniest part of road
- Length – Distance between intersections
- Orientation – Street Direction



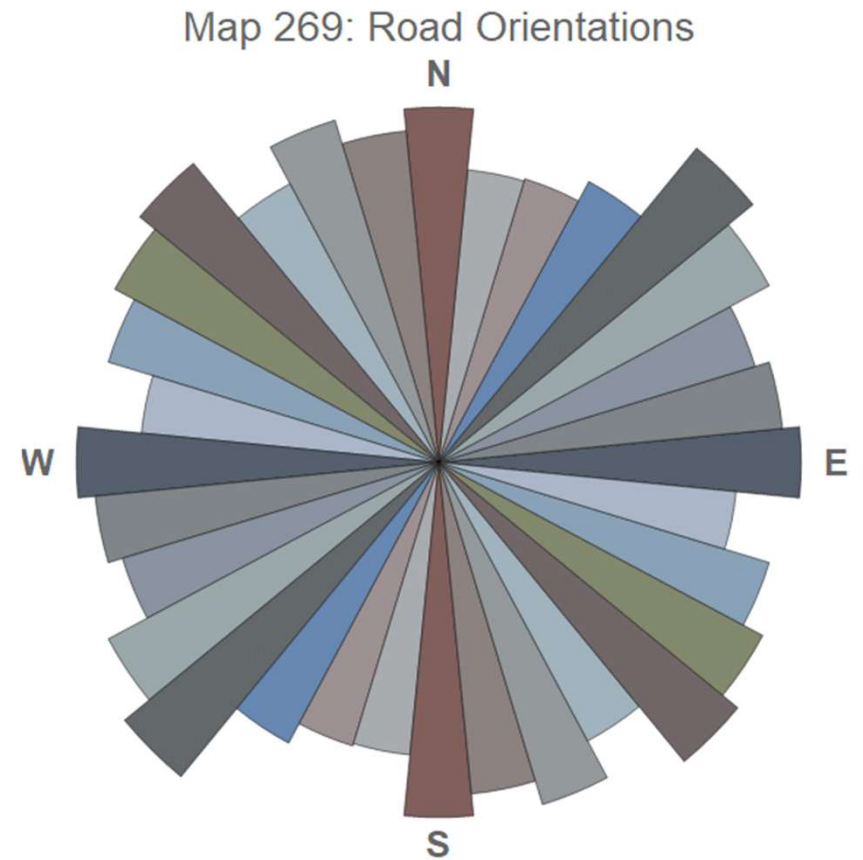
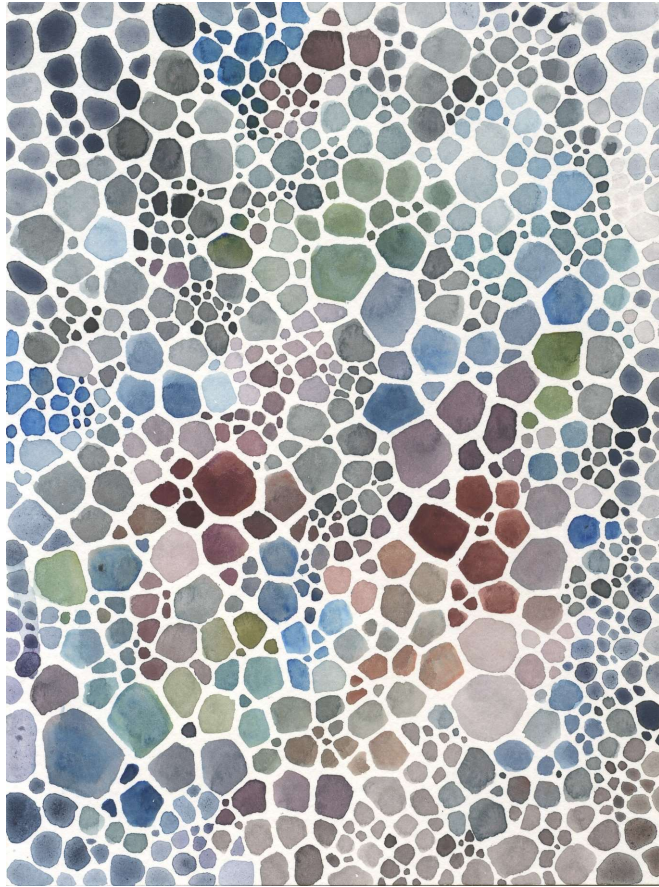
Road Orientation



Map 199: Road Orientations

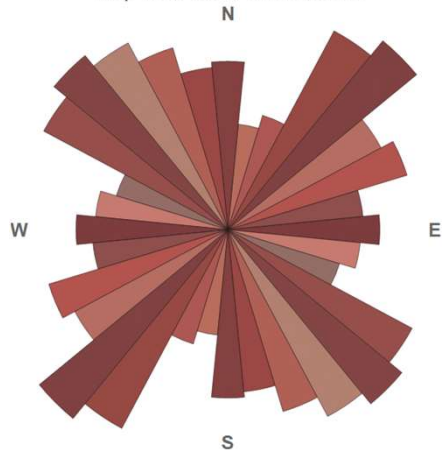


Road Orientation

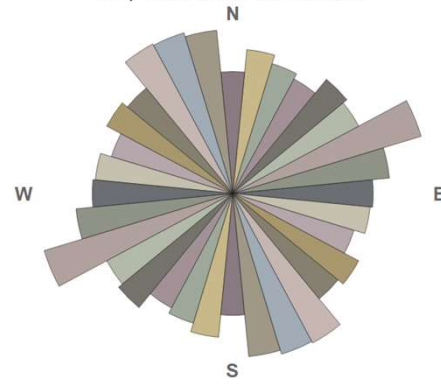


Road Orientation

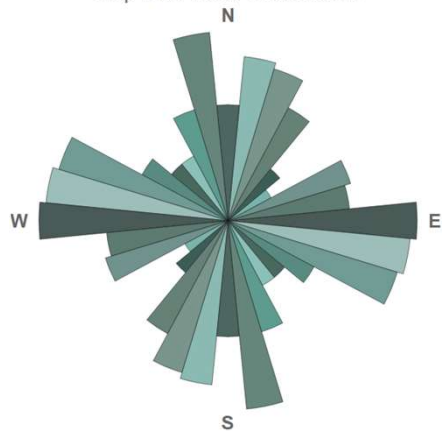
Map 156: Road Orientations



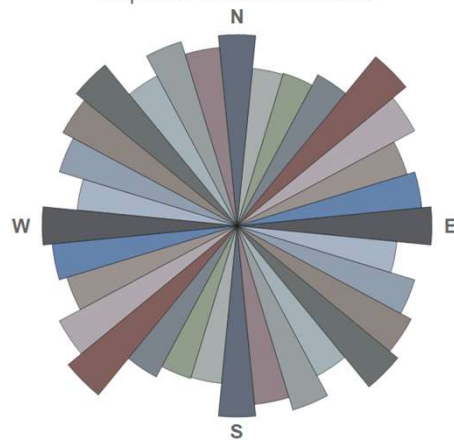
Map 268: Road Orientations



Map 199: Road Orientations

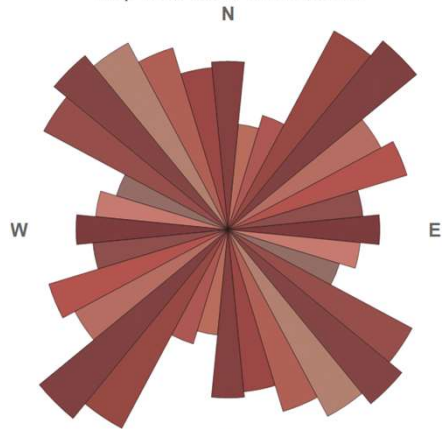


Map 269: Road Orientations

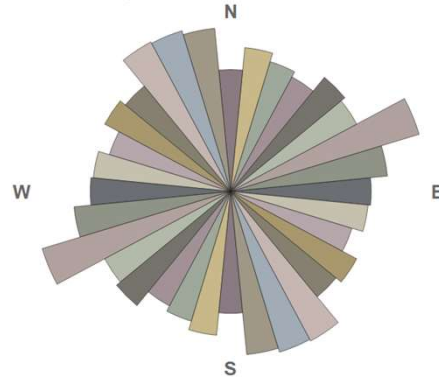


Road Orientation

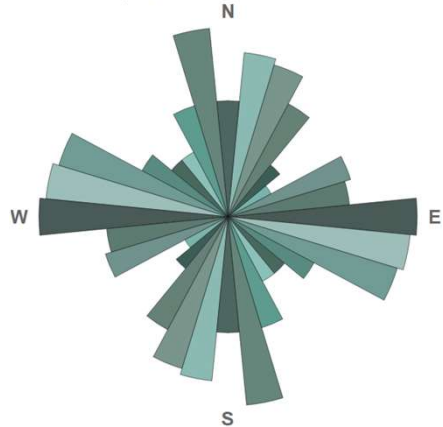
Map 156: Road Orientations



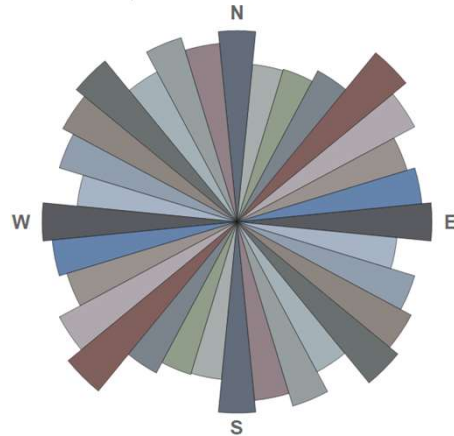
Map 268: Road Orientations



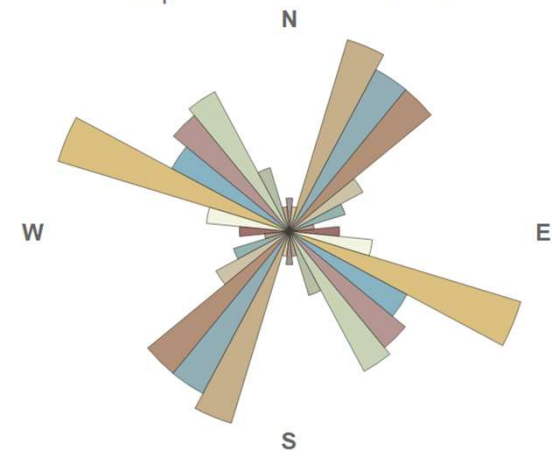
Map 199: Road Orientations



Map 269: Road Orientations



Map 804: Road Orientations



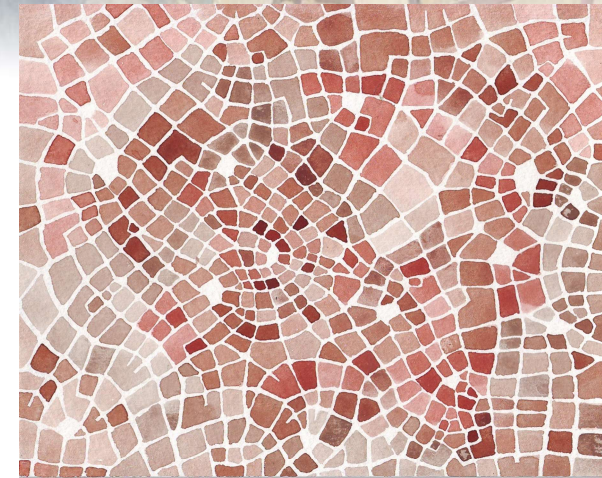
Davis Square – Emily Garfield

Neighbor analysis

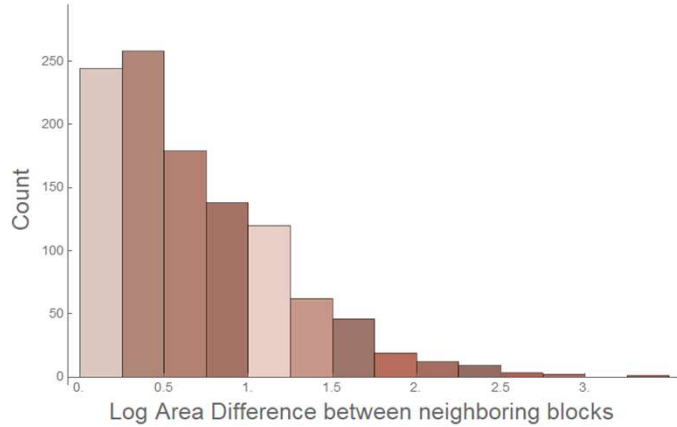
- Number of neighbors
- Neighbor Size Ratio
(Difference in Log Area)
- Neighbor Color Difference



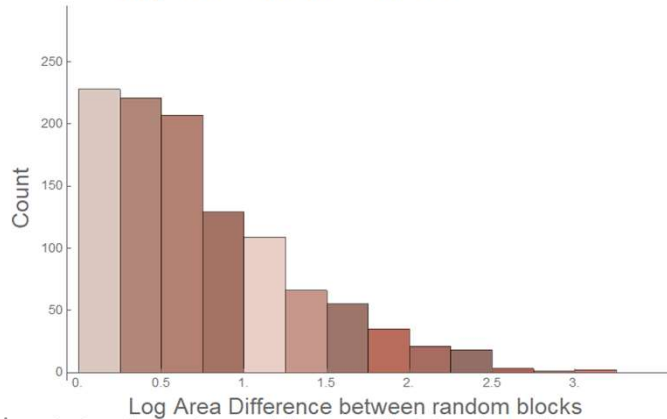
How close in size are neighbors?



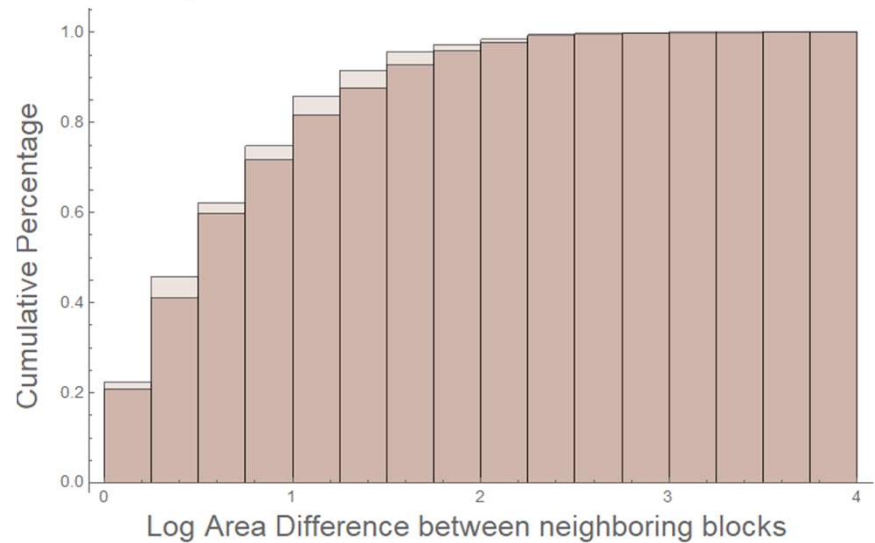
Map 156: Neighboring Block Area Differences



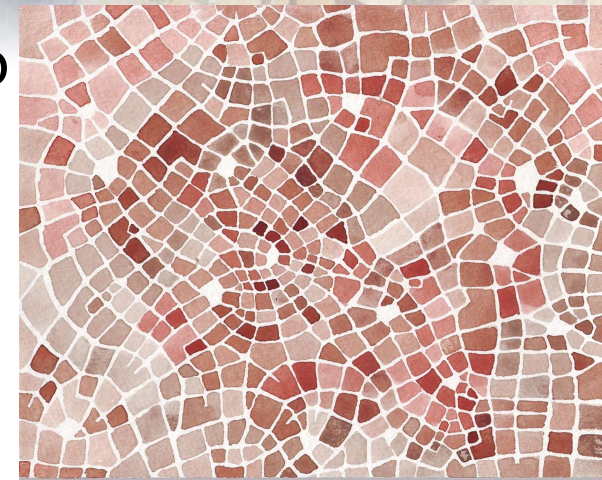
Map 156: Random Block Area Differences



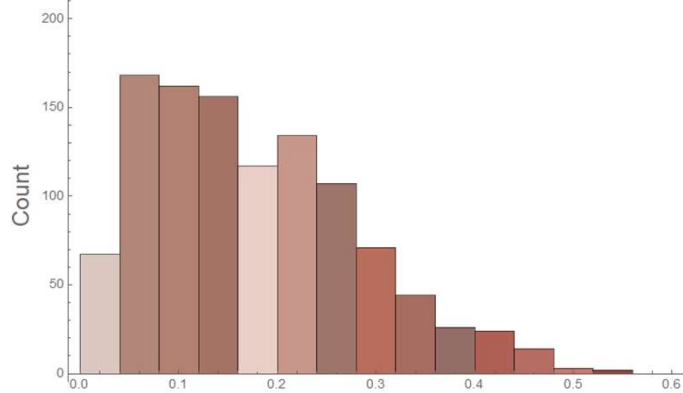
Map 156: Cumulative Block Area Differences



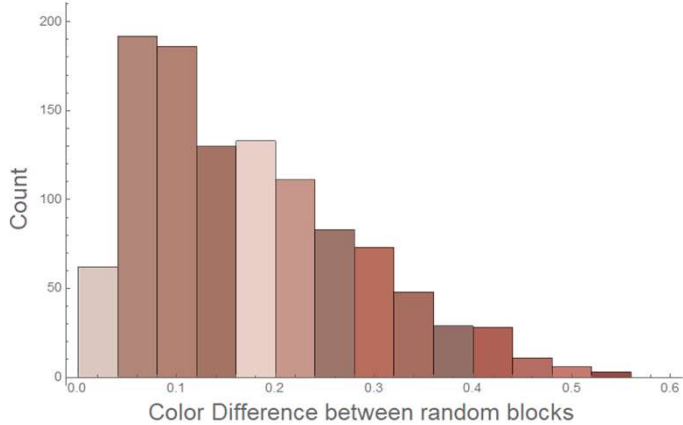
How close in COLOR are neighbors?



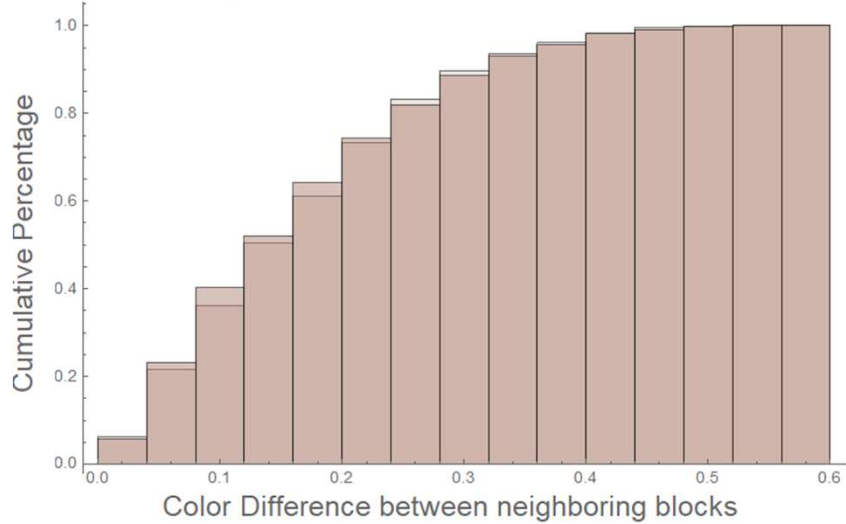
Map 156: Neighboring Block Color Differences



Map 156: Random Block Color Differences

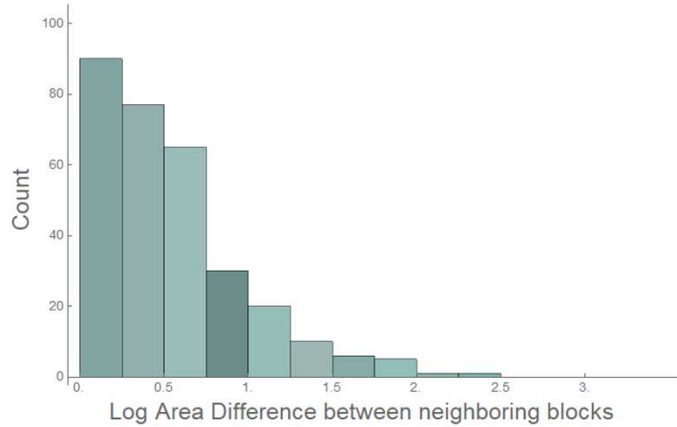


Map 156: Cumulative Color Differences

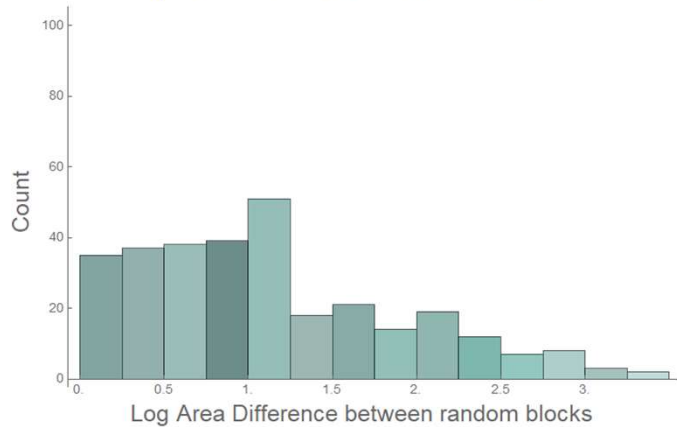


How close in size are neighbors?

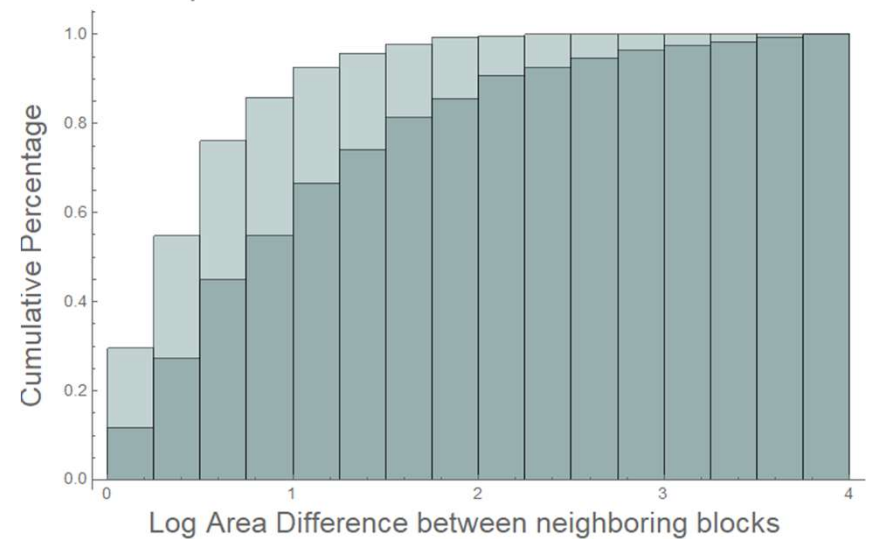
Map 199: Neighboring Block Area Differences



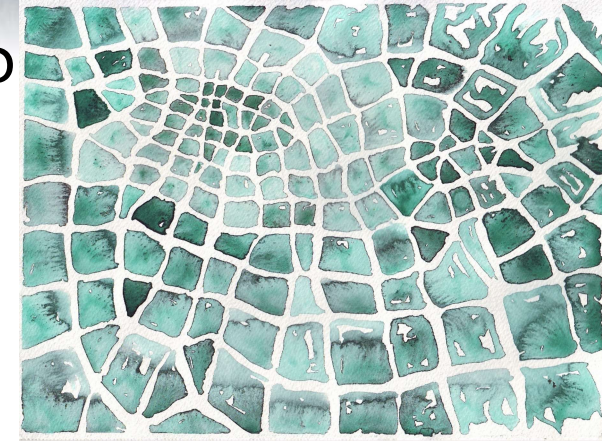
Map 199: Random Block Area Differences



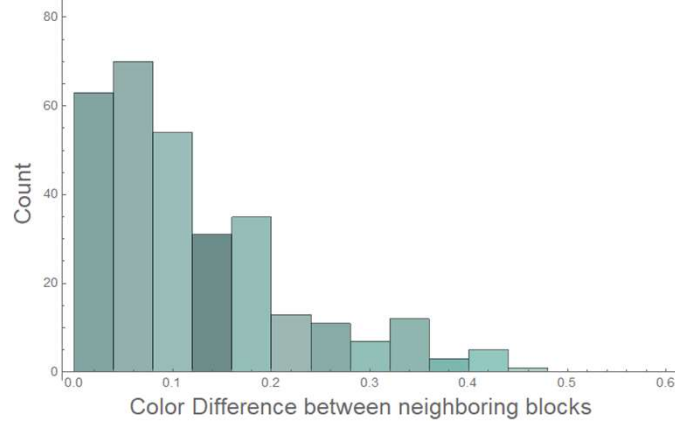
Map 199: Cumulative Block Area Differences



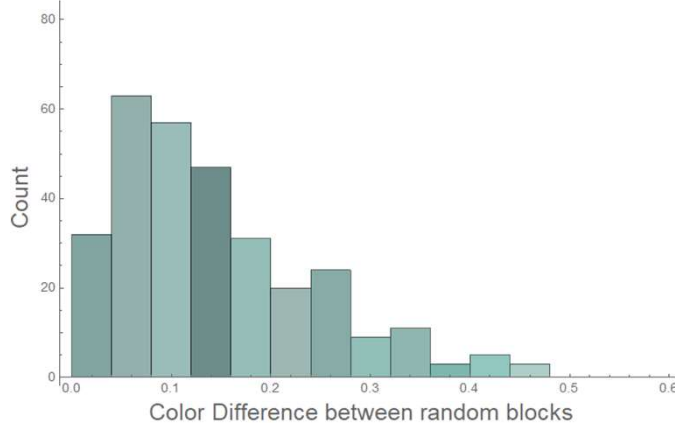
How close in COLOR are neighbors?



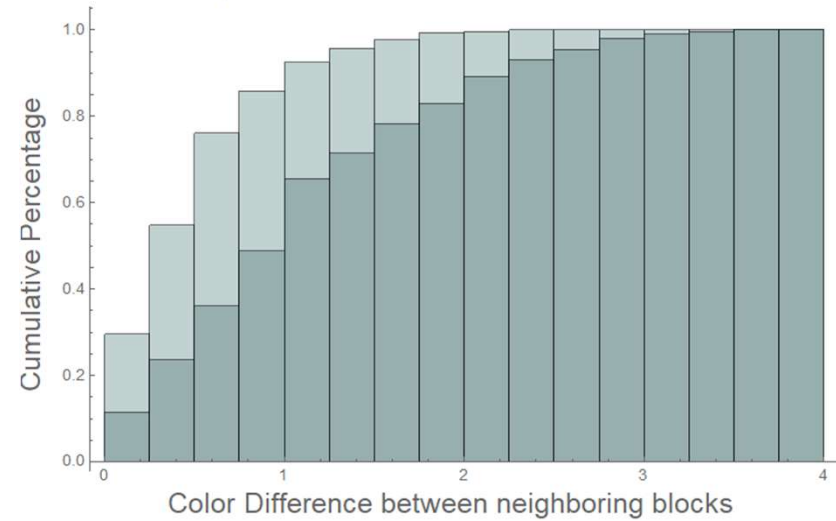
Map 199: Neighboring Block Color Differences



Map 199: Random Block Color Differences



Map 199: Cumulative Color Differences





Fractal Analysis

Sub-images \approx Whole image ?

Neighborhoods of small blocks \approx Neighborhoods of large blocks ?

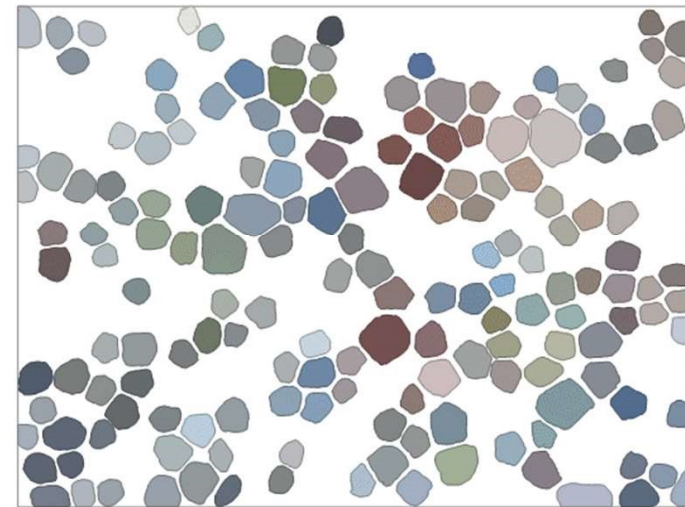
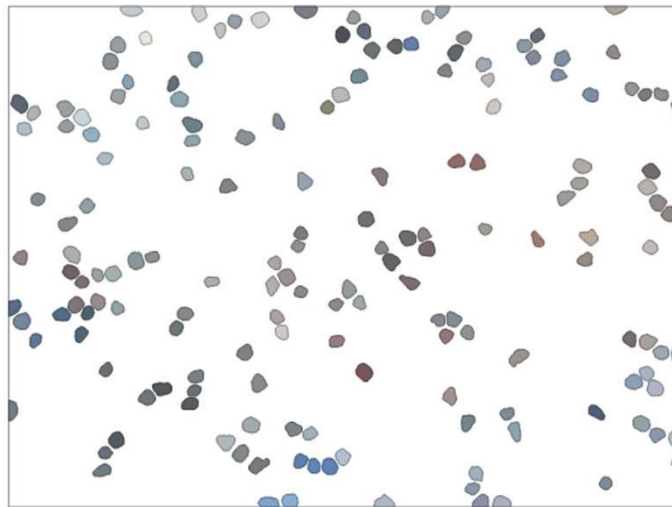
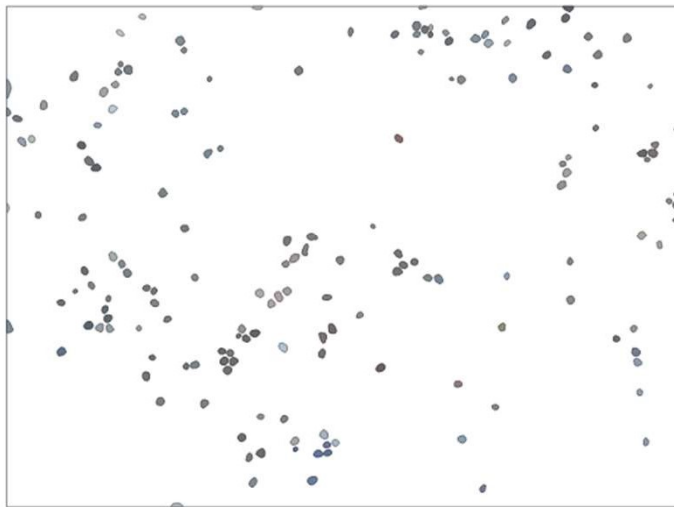
Fractal Analysis

Sub-images \approx Whole image ?

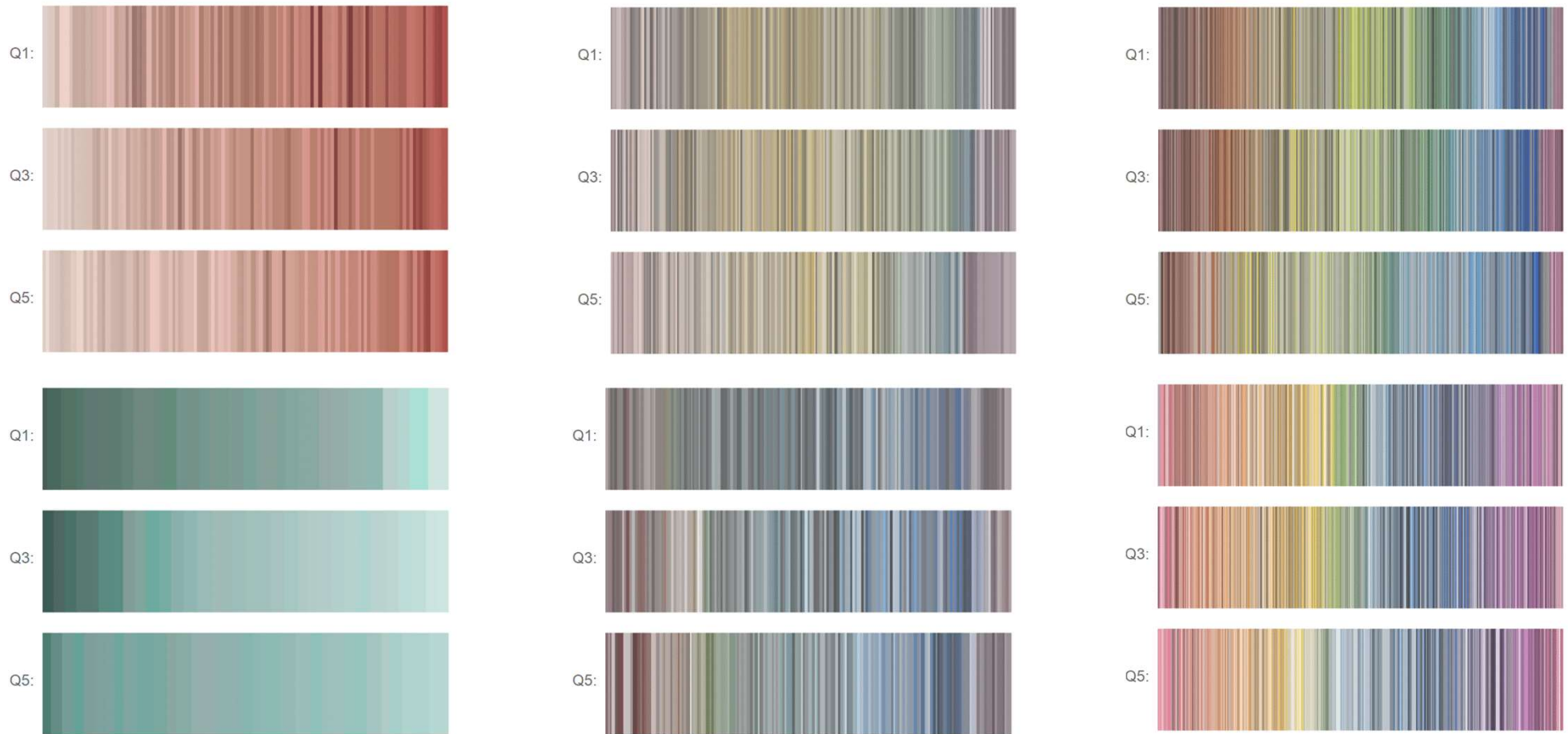
Neighborhoods of small blocks \approx Neighborhoods of large blocks ?

Partition blocks based on size \rightsquigarrow Compare Quintiles 1, 3, and 5:

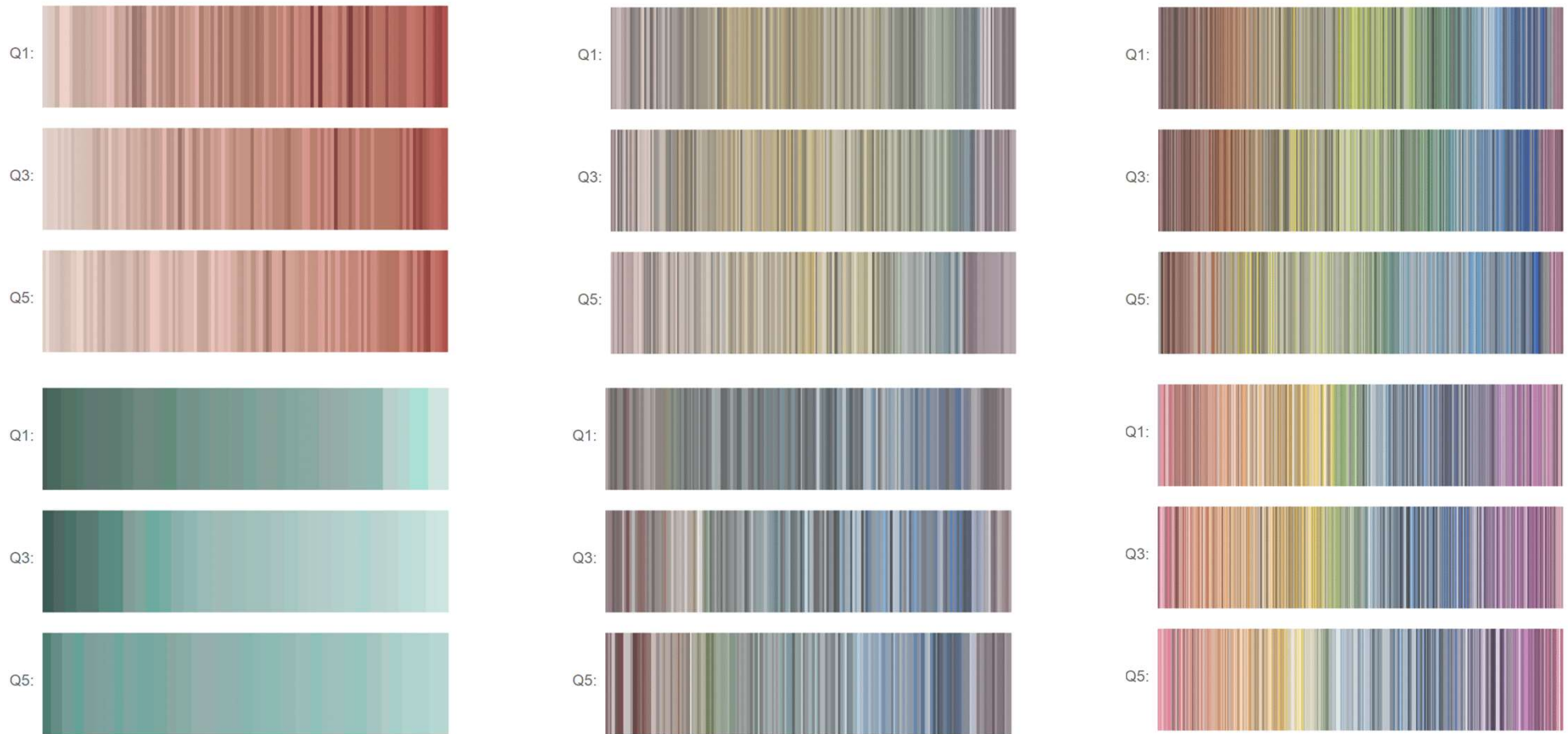
Map 269: Blocks in Size Quintiles 1, 3, 5



Color Distributions are Independent of Block Size

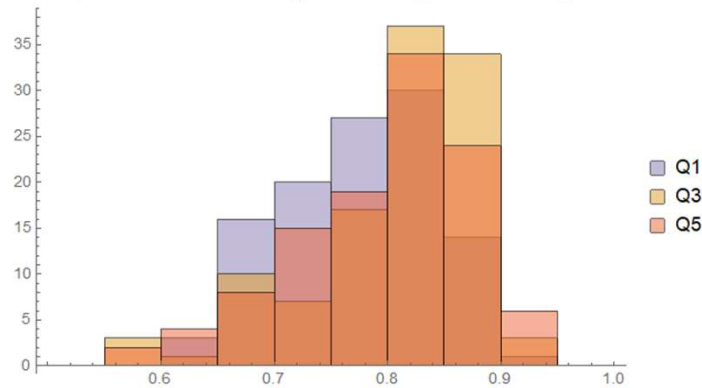


Color Distributions are ^{MOSTLY} Independent of Block Size

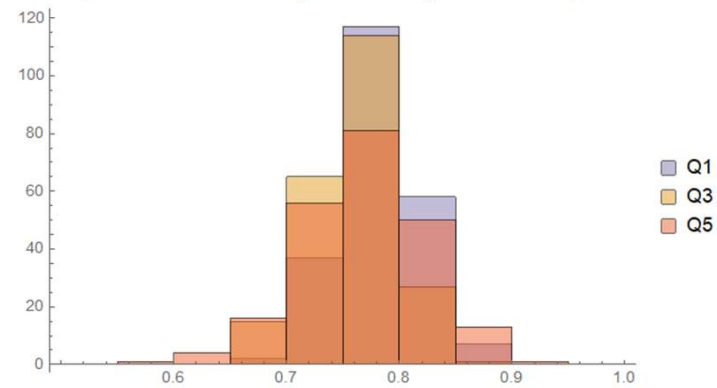


Bounding Rectangle Ratio is Independent

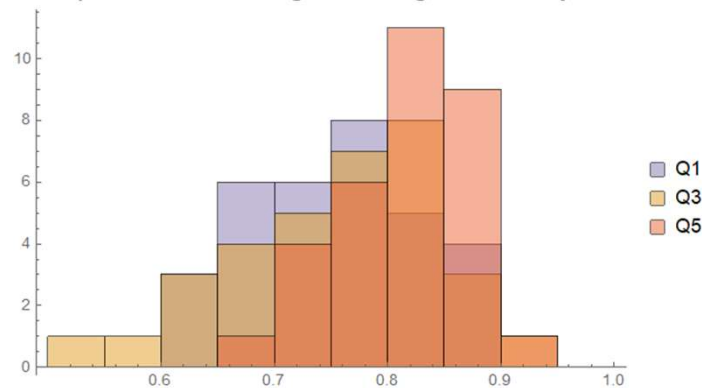
Map 156: Bounding Rectangle Ratio by Quintile



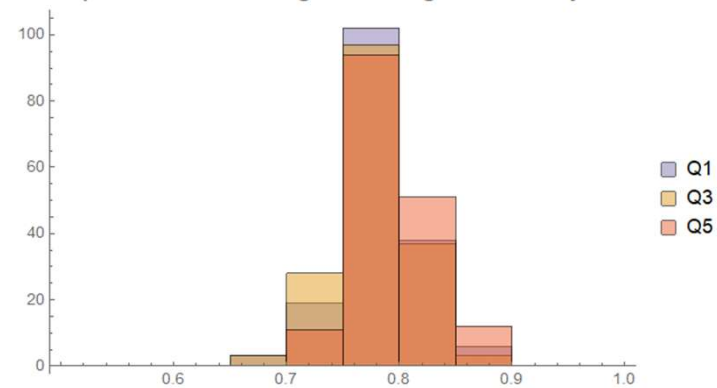
Map 268: Bounding Rectangle Ratio by Quintile



Map 199: Bounding Rectangle Ratio by Quintile

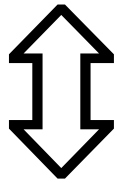


Map 269: Bounding Rectangle Ratio by Quintile



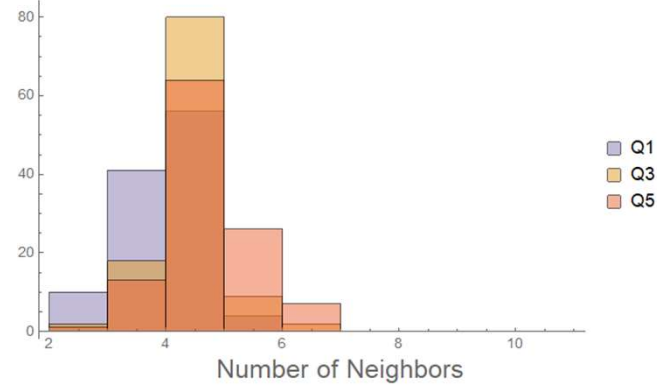
Number of Neighbors is Dependent

Larger
block

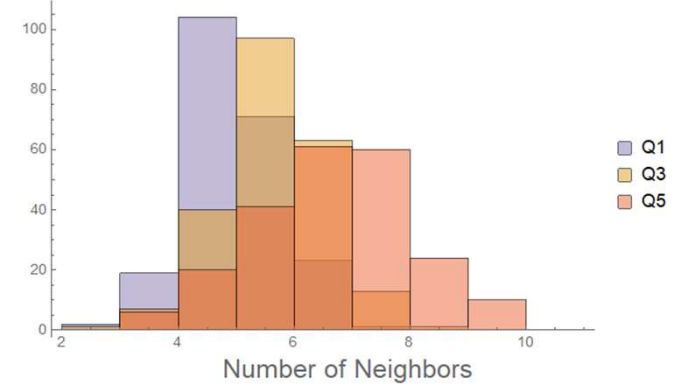


More
Neighboring
Blocks

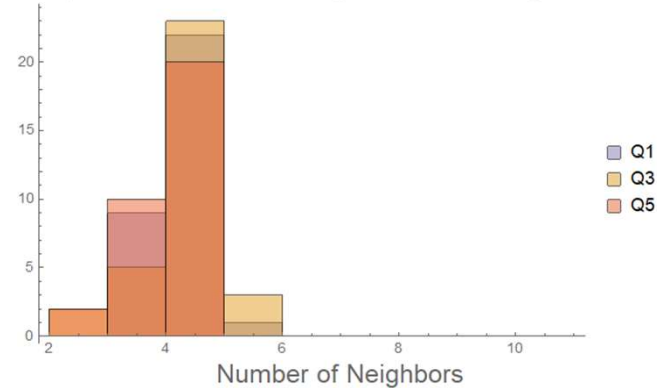
Map 156: Number of Adjacent Blocks by Quintile



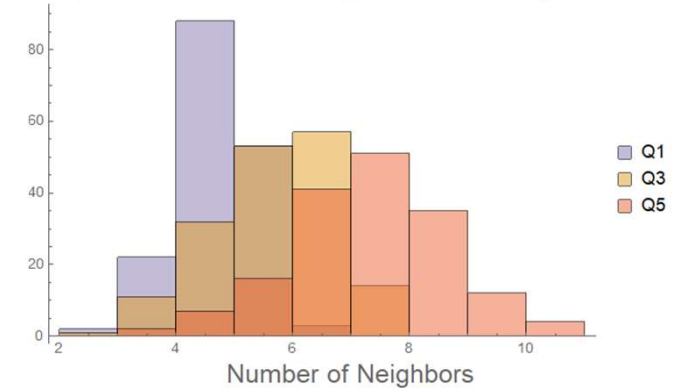
Map 268: Number of Adjacent Blocks by Quintile



Map 199: Number of Adjacent Blocks by Quintile

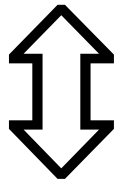


Map 269: Number of Adjacent Blocks by Quintile



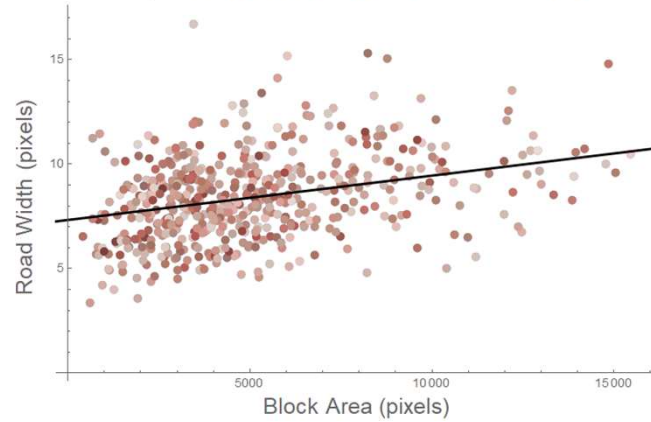
Road Width is Dependent

Larger
block

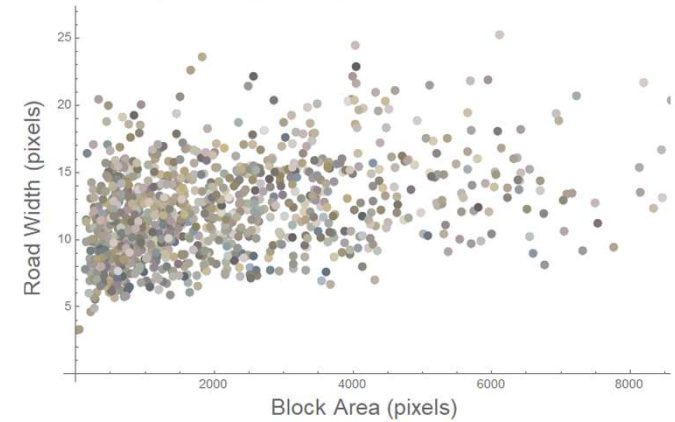


Wider
Road

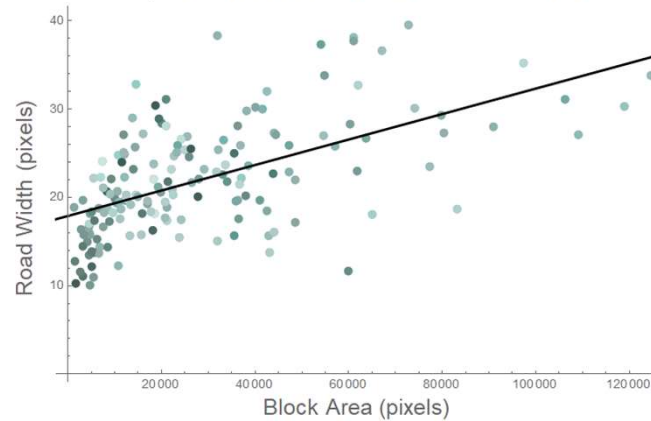
Map 156: Road Width as a Function of Area



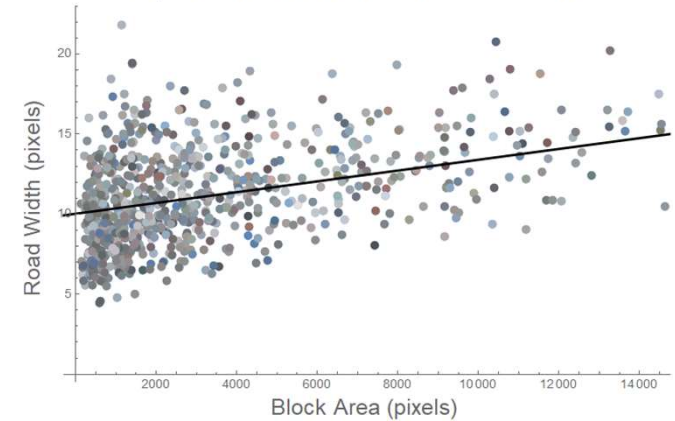
Map 268: Road Width as a Function of Area



Map 199: Road Width as a Function of Area

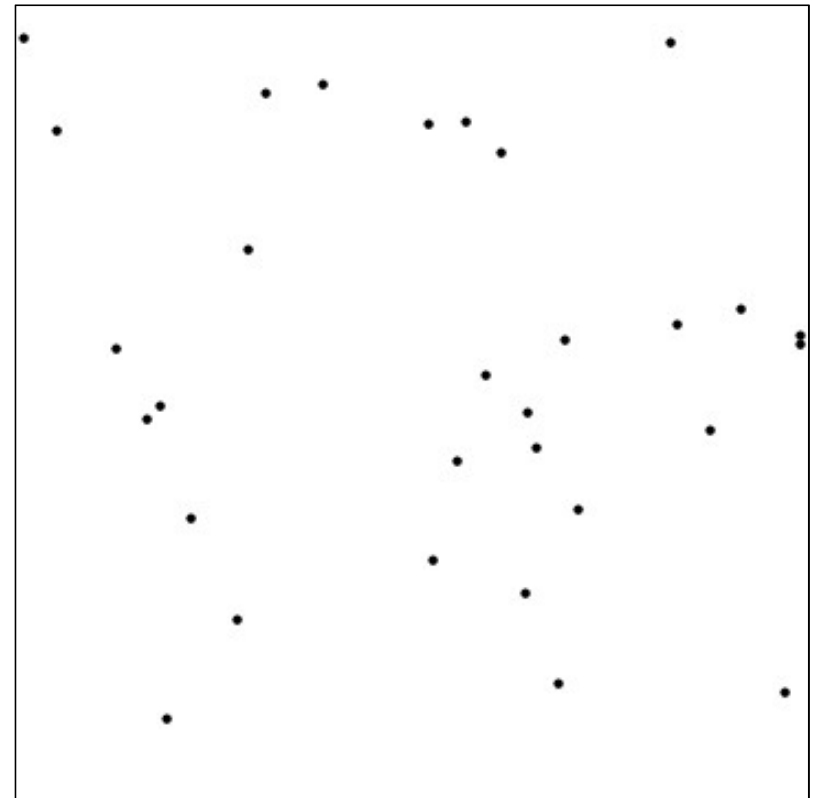


Map 269: Road Width as a Function of Area



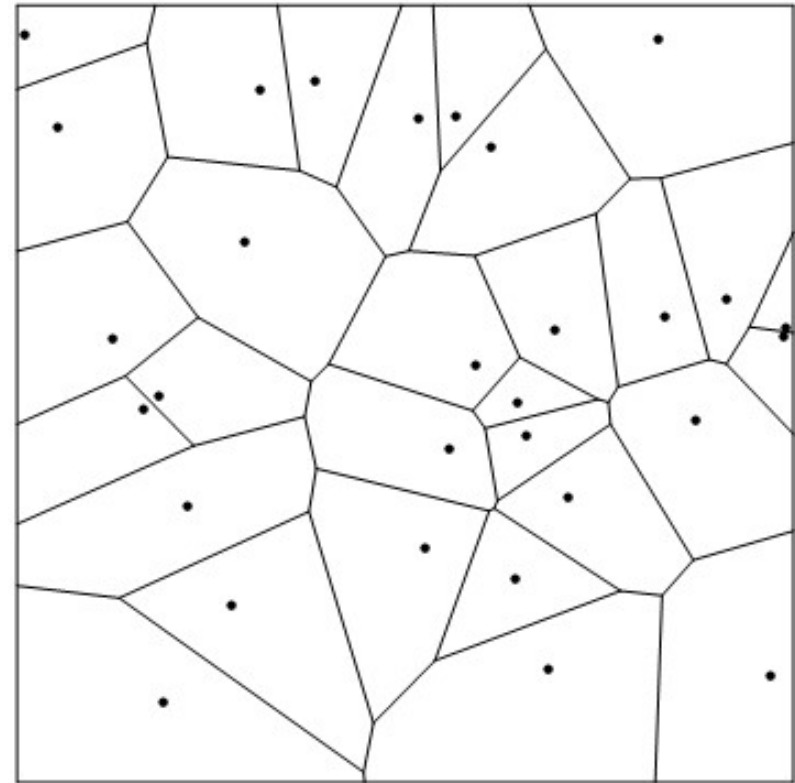
Creating a new map

- Generate block locations
 - Find point sets



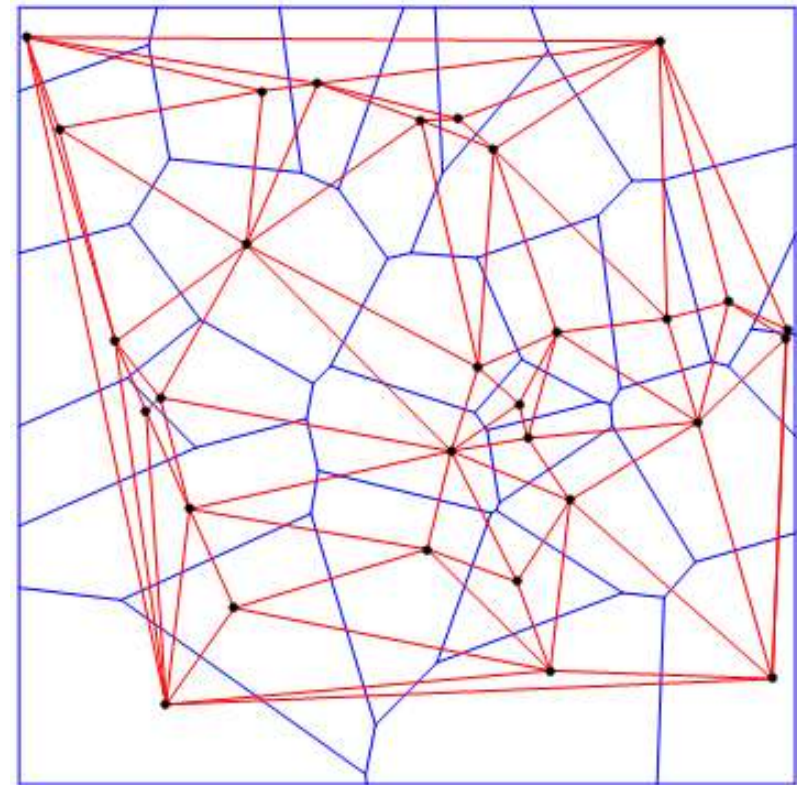
Creating a new map

- Generate block locations
 - Find point sets
- Determine block boundaries
 - Voronoi / Delaunay



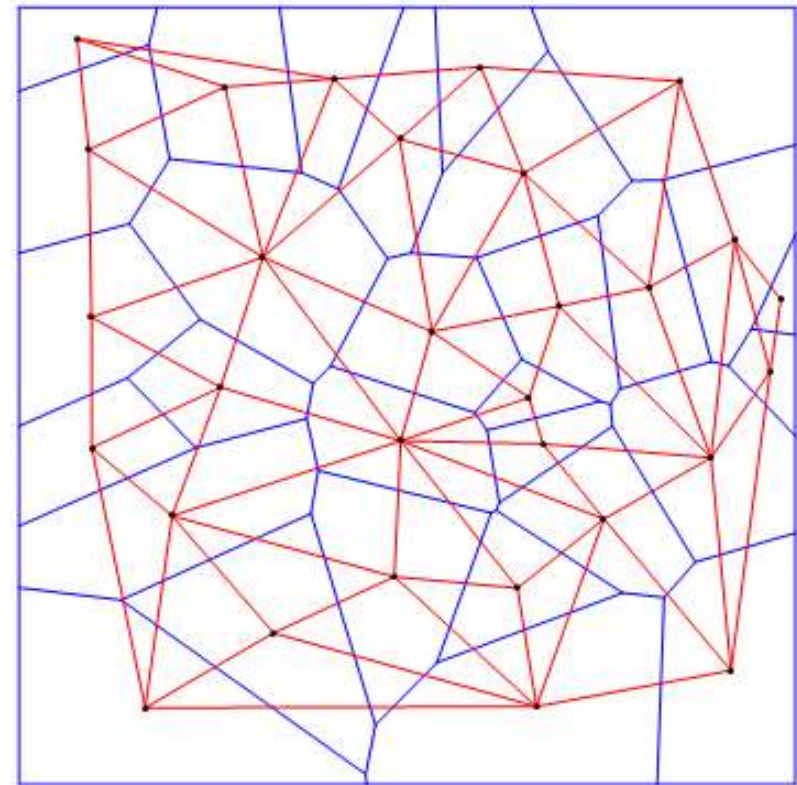
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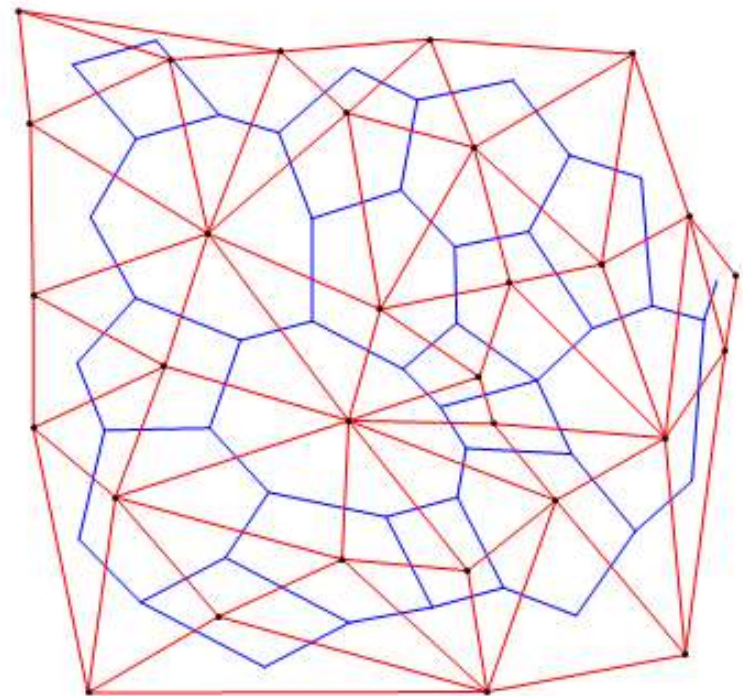
Creating a new map

- Generate block locations
 - Find point sets
- Determine block boundaries
 - Voronoi / Delaunay
 - Use the dual graph



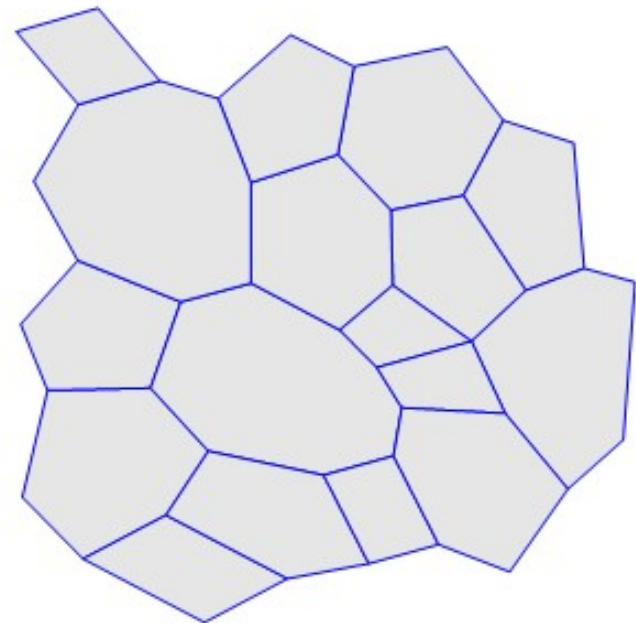
Creating a new map

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 - Use the dual graph



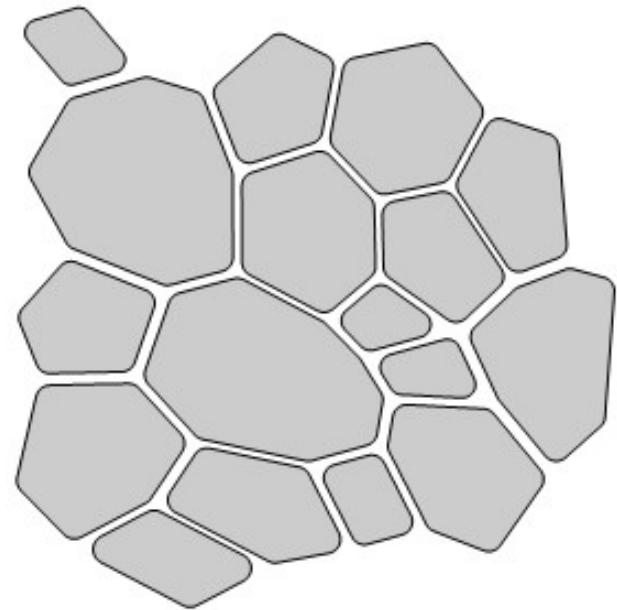
Creating a new map

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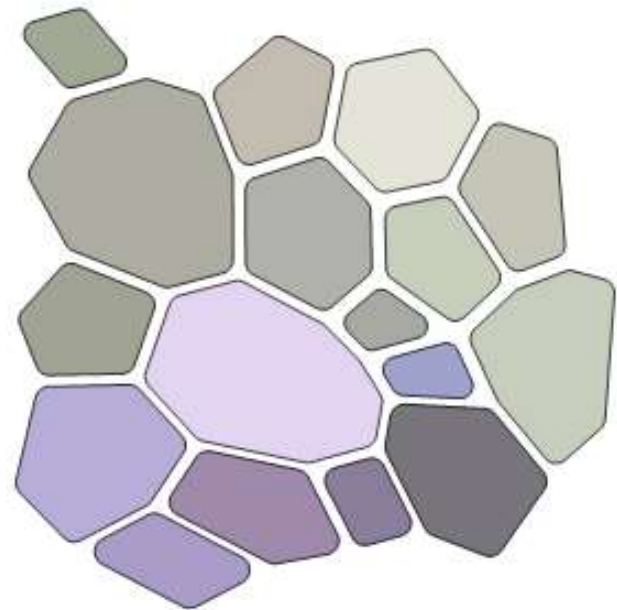
Creating a new map

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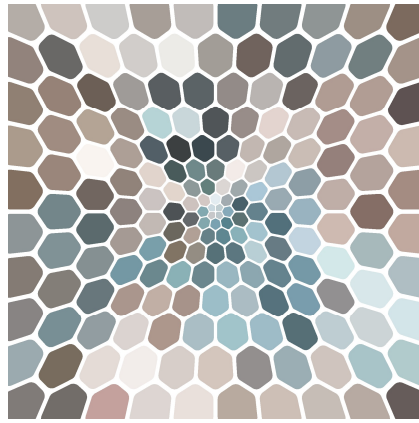
Creating a new map

- Generate block locations
 - Find point sets
- Determine block boundaries
 - Voronoi / Delaunay
 - Use the dual graph
- Color the blocks
 - Generate similar distributions
 - Nearby blocks prioritized

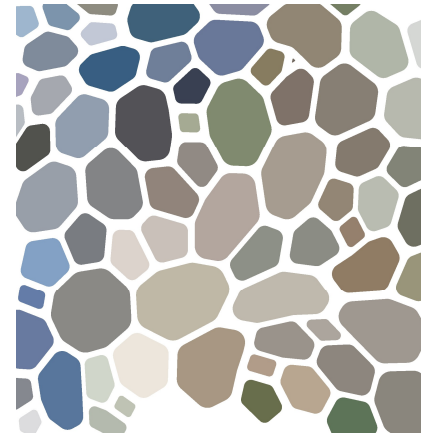


Algorithmically Generated Imaginary Maps

Deliberate Vertices



Random Vertices





Our Takeaways

- We can quantify Garfield's maps
- Have defining characteristics
- Not "fractal"
- Making new maps is fun
 - Choosing points is hard!
 - ♥ Generative Art
- The power of *Mathematica*
- Statistical analysis of my artwork
- Think differently
- Artworks are more random than expected
- Does quantification take us out of the realm of artwork?

Future Exploration

- Compare to real world cities
- Compare to other cellular networks
- GIS specialist (Geographic Information System)
- Enhance map generation
- What is an intersection?
- What is the scale of an imaginary map?
- What other artworks have this color distribution?
- How do we quantify aesthetics?



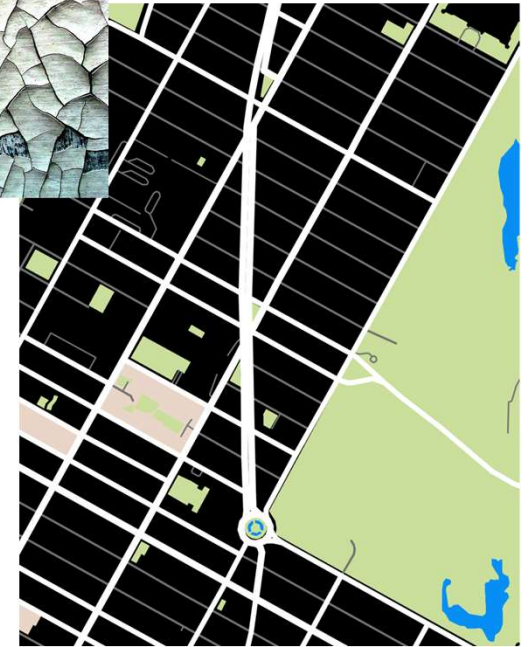
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Future Exploration





- Compare to real world cities
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- What other artworks have this color distribution?
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Thank you!



Christopher Hanusa

qc.edu/~chanusa
christopherhanusa.com

  @mathzorro
  @hanusadesign
(Mathematical Jewelry)

Emily Garfield

emilygarfield.com

 @EmilyGarfield
 @emilymap

SciArt Initiative

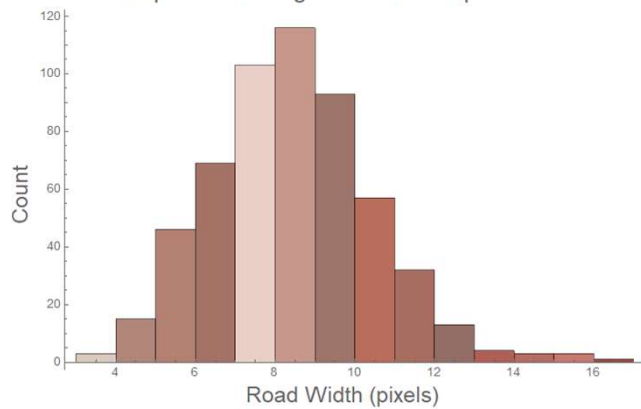
sciartinitiative.org



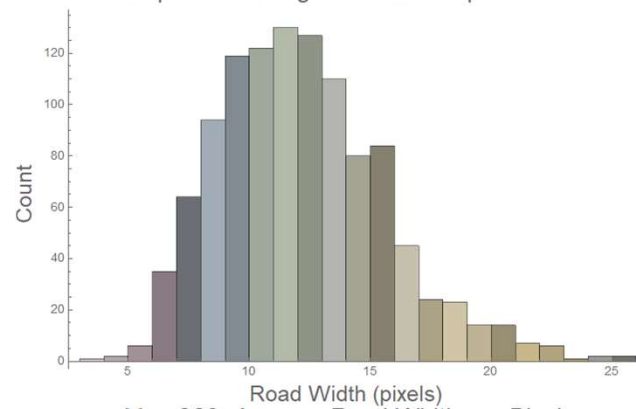


Road Width (Average around each block)

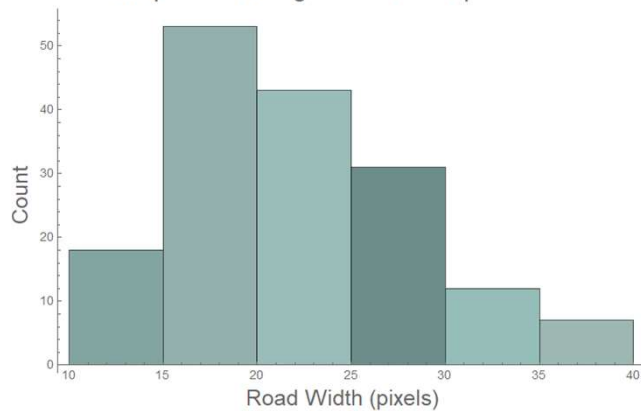
Map 156: Average Road Width per Block



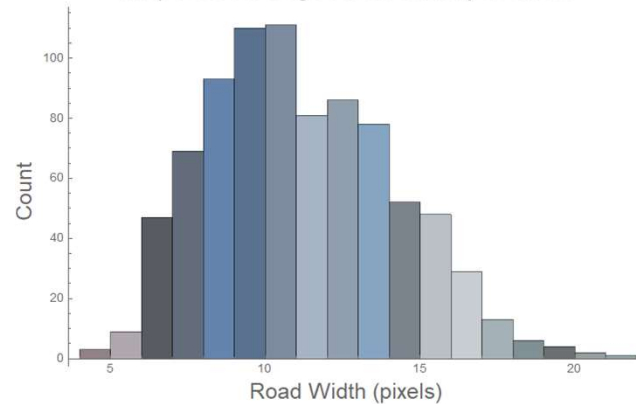
Map 268: Average Road Width per Block



Map 199: Average Road Width per Block

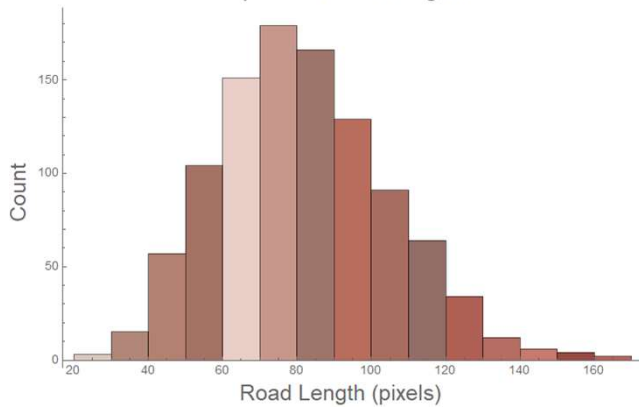


Map 269: Average Road Width per Block

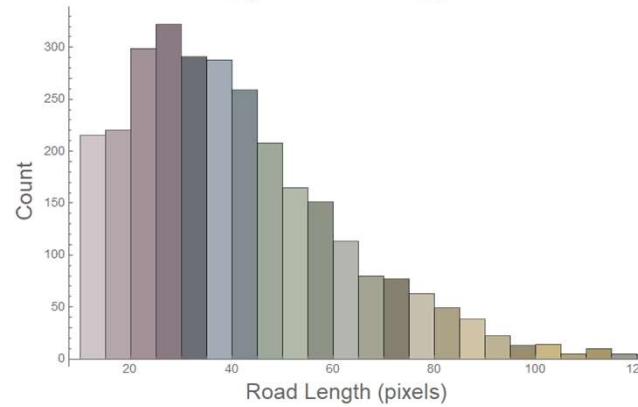


Road Length

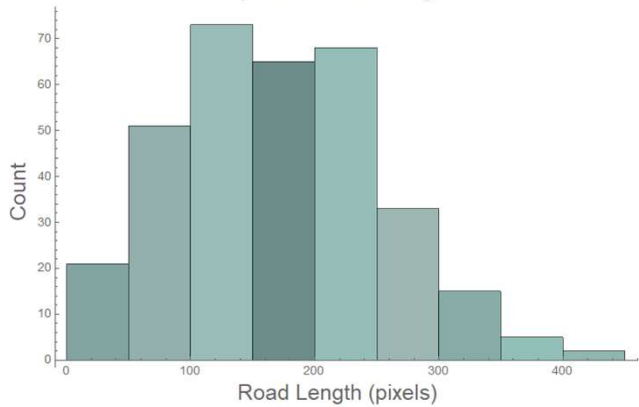
Map 156: Road Lengths



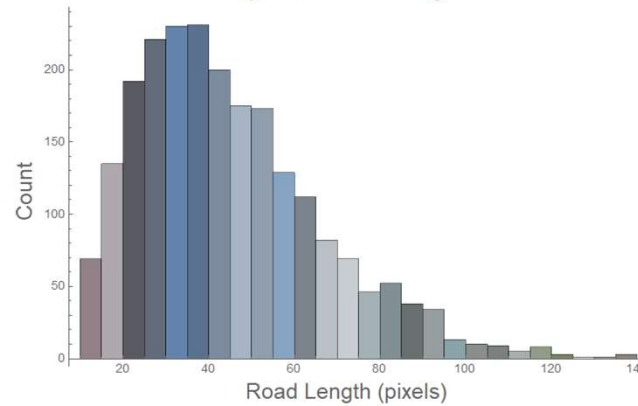
Map 268: Road Lengths



Map 199: Road Lengths

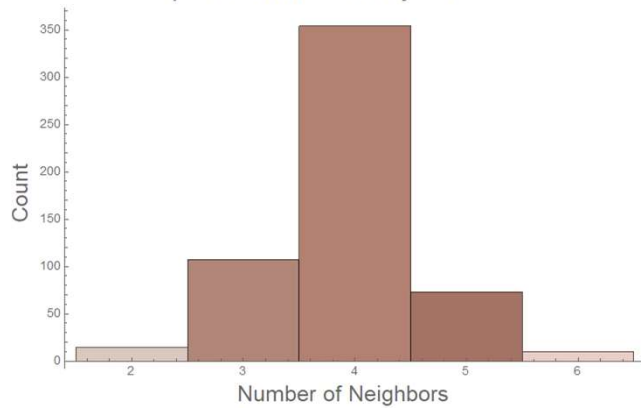


Map 269: Road Lengths

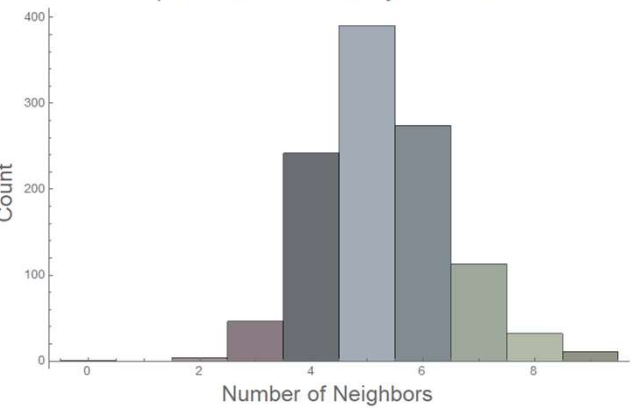


Number of Neighbors

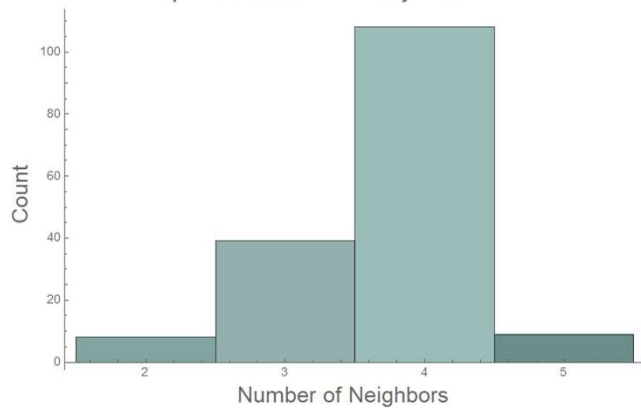
Map 156: Number of Adjacent Blocks



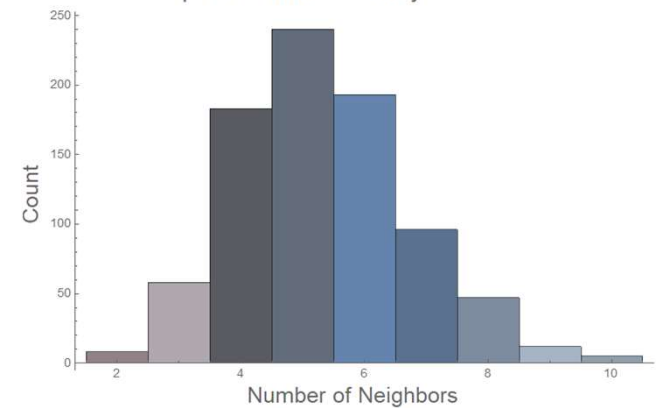
Map 268: Number of Adjacent Blocks



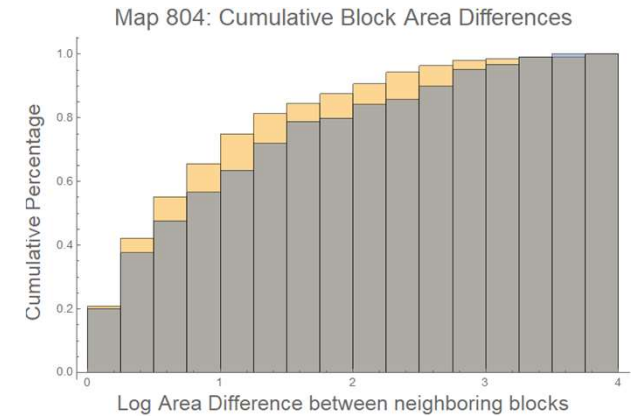
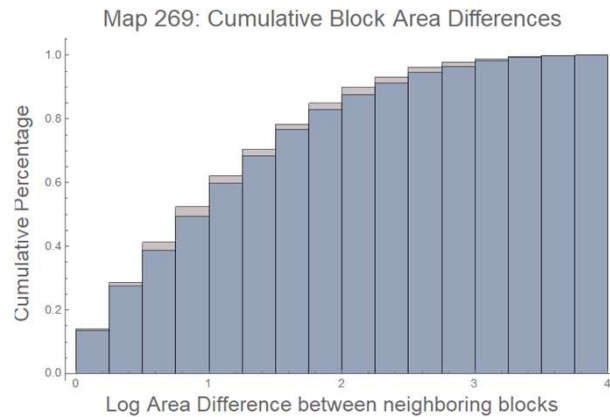
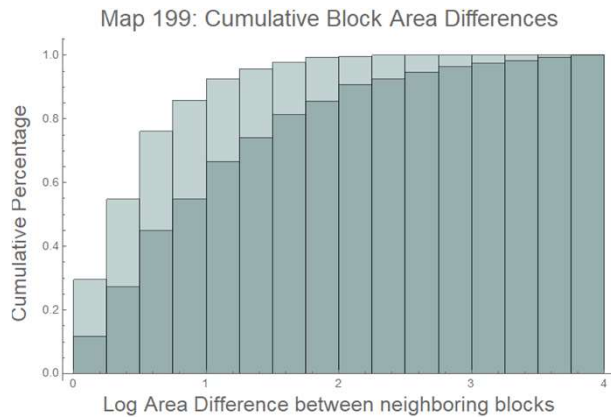
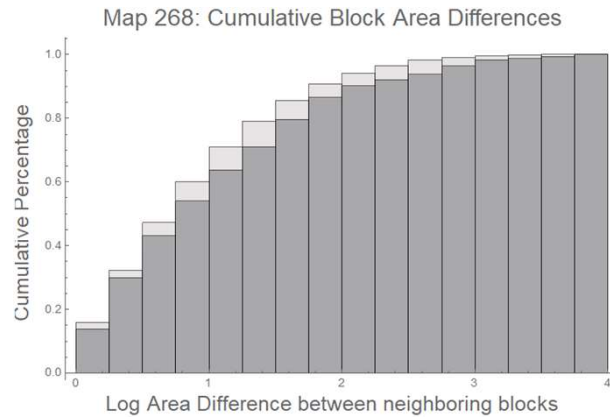
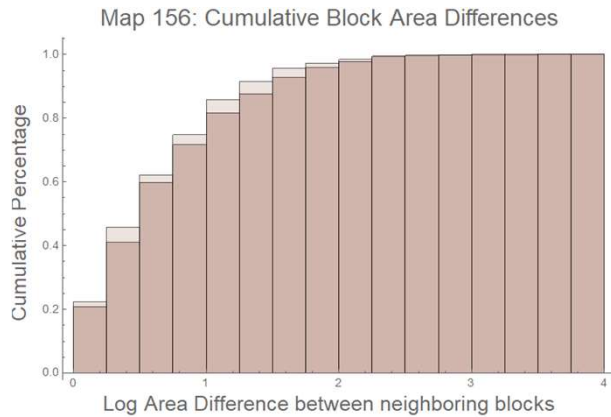
Map 199: Number of Adjacent Blocks



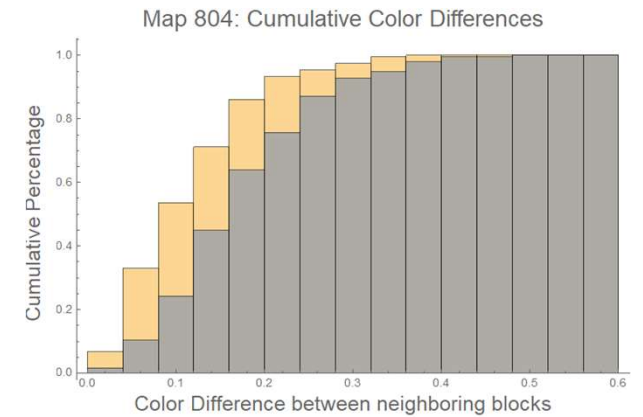
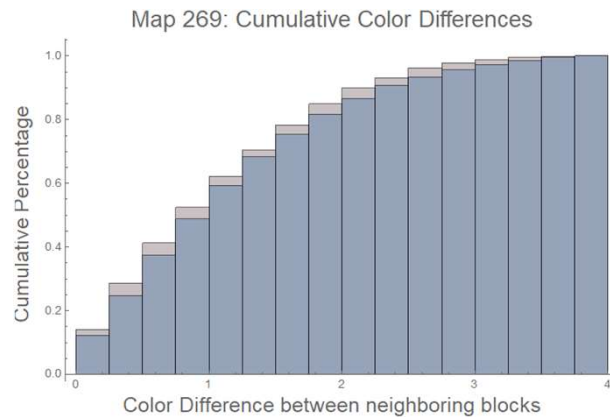
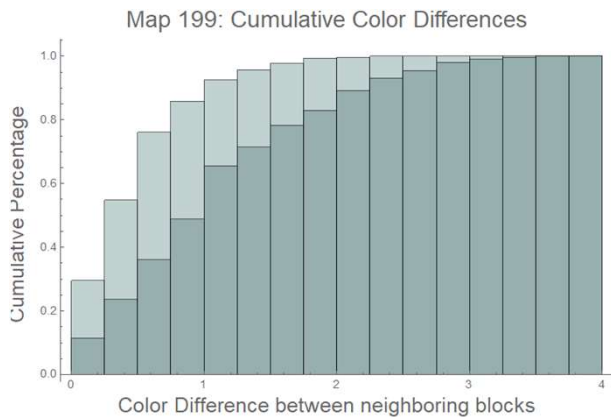
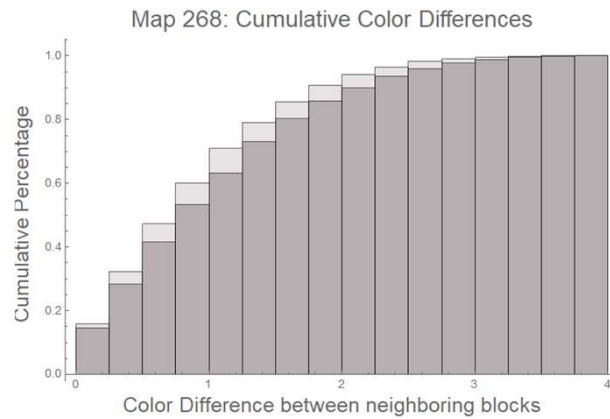
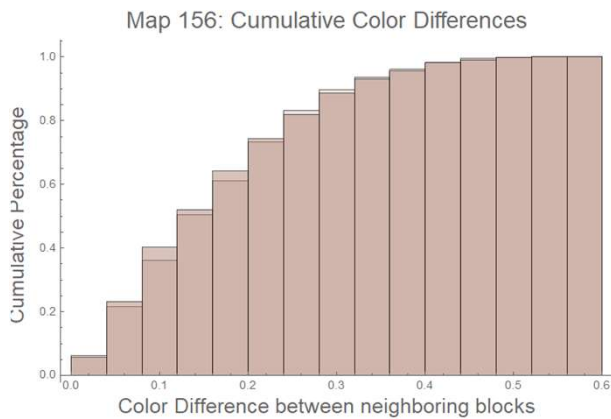
Map 269: Number of Adjacent Blocks



How close in size are neighbors?



How close in COLOR are neighbors?





Fractal Analysis

Block-size-independent metrics

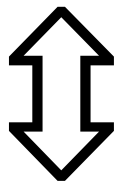
- Color Distribution
- Bounding Rectangles Ratios

Block-size-dependent metrics

- Number of Adjacent Blocks
- Neighborhood Density
- Road Width

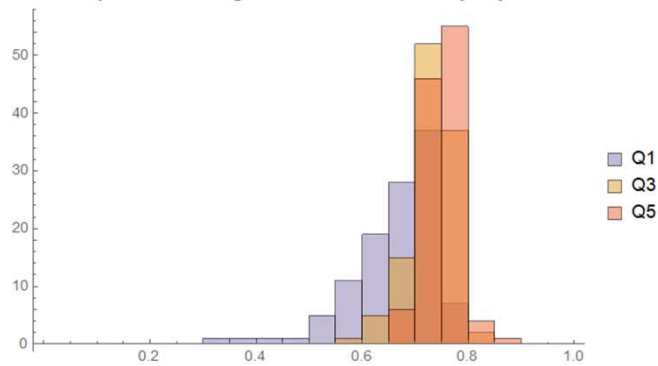
Neighborhood Density is Dependent

Larger
block

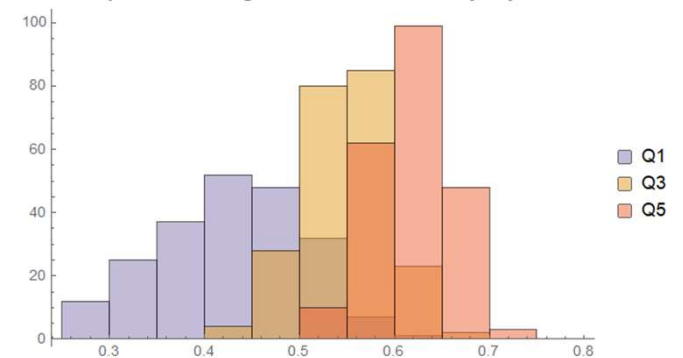


Denser
neighborhood

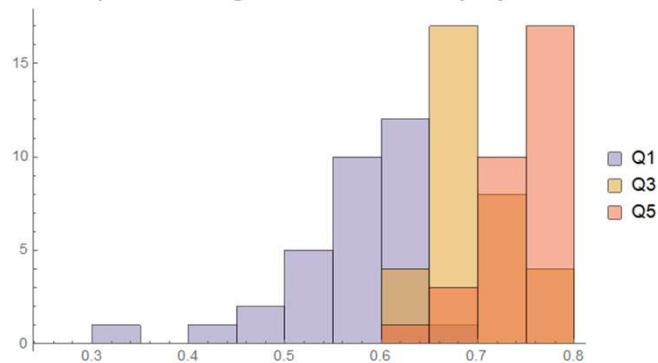
Map 156: Neighborhood Density by Quintile



Map 268: Neighborhood Density by Quintile



Map 199: Neighborhood Density by Quintile



Map 269: Neighborhood Density by Quintile

