GEOG 432/832: Programming, Scripting, and Automation for GIS

Unit 11.01: Formalizations of space and spatial relationships

Dr. Bitterman

Today's schedule

- Open discussion
- Slides and discussion - more lecture than normal
- For next class
- Open work time (if there is any)

Open discussion

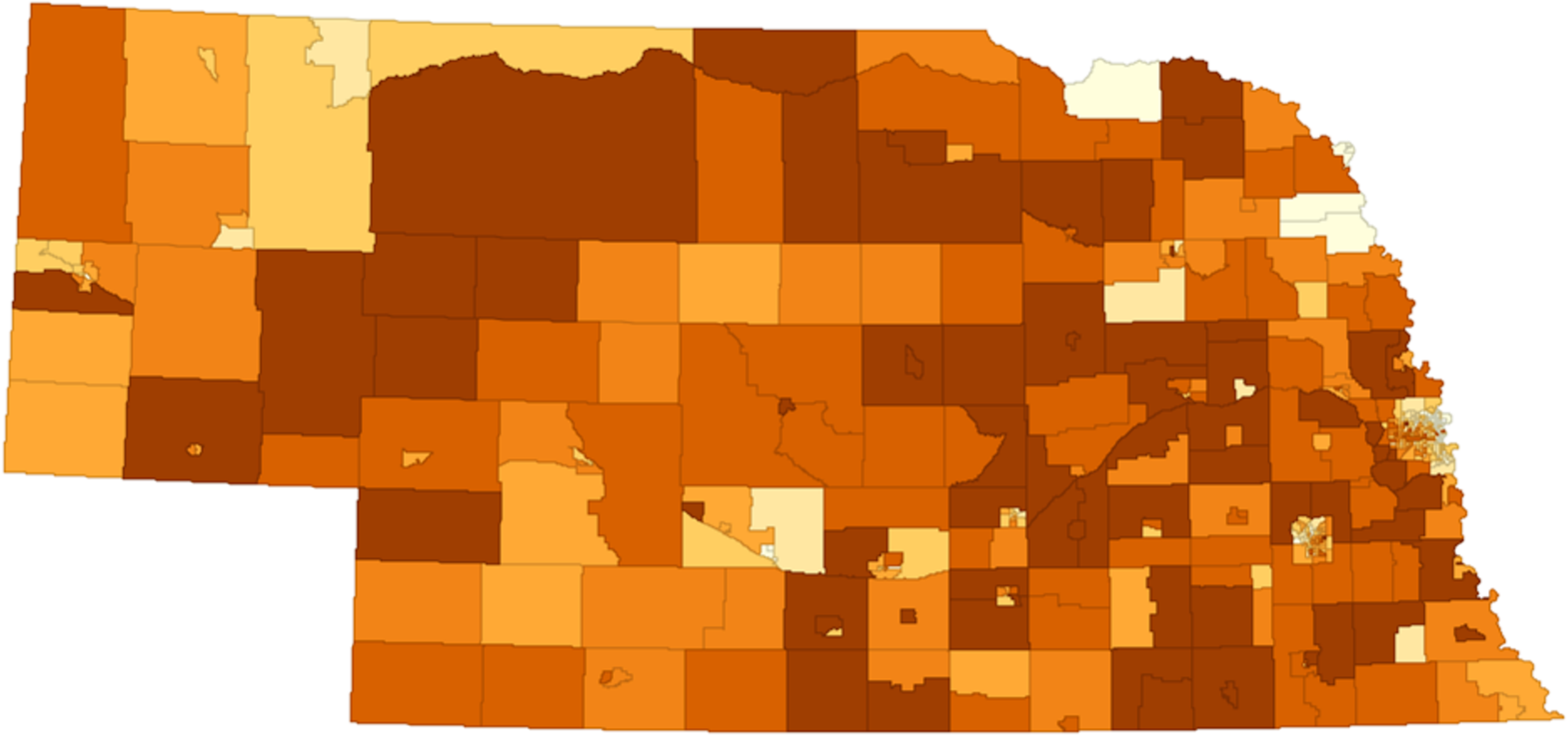
Today is about formalization

- Why?
- But also, WHY???
- Formalizing spatial relationships is foundational
    - "Global" spatial autocorrelation
    - Local spatial autocorrelation metrics
    - Spatial clustering
    - Hot spots/cold spots

Tobler's first law of Geography

- Everything is related to everything else, but nearer things are more related than farther (or something like that)
- Formally, *spatial autocorrelation*

Spatial autocorrelation of areal units (% white, 2010 Census)



Relevant questions

- Which areas are important?
- Which areas are unusual?
- Are there “hotspots” of some phenomena?
- How much influence do neighbors have?
- How should we measure/ conceptualize “neighbors”?
- Implications of our choices?

Spatial context matters

- For a statistical method to be explicitly spatial, it needs to contain some representation of the geography, or spatial context
- One of the most common ways is through *spatial weights matrices*

Formalizing processes

- **(Geo)Visualization**: translating numbers into a (visual) language that the human brain “speaks better”
- **Spatial Weights Matrices**: translating geography into a (numerical) language that a computer “speaks better”

Spatial weights matrices

Core element in several spatial analysis techniques:

- Spatial autocorrelation
- Spatial clustering / geodemographics
- Spatial regression

Formalization

W as a formal representation of space

W (the spatial weights matrix)

- *N x N positive matrix* that contains **spatial relations** between all the observations in the sample
- FORMALLY, w_{ij}... the weight from zone *i* to zone *j*
- Core concept in statistical analysis of areal data
- Two steps involved:
  - define which relationships between observations are to be given a nonzero weight, i.e., define spatial neighbors
  - assign weights to the neighbors

$w_{ii} = 0$ (by convention)

...what is a neighbor?

How would you define a "neighbor"?

- Making the neighbors and weights is not easy as it seems to be
- Which states are near Nebraska?

Washington
Seattle
Spokane
Portland
Missoula
Montana
Minot
North Dakota
Bismarck
Fargo
Minnesota
Duluth
Lake Superior
Maine
Bangor
Billings
Idaho
Oregon
Boise
Idaho Falls
South Dakota
Rapid City
Wisconsin
Minneapolis
St. Paul
Lake Huron
Lake Michigan
Burlington
VT
NH
Portland
Concord
Toronto
Lake Ontario
Boston
Massachusetts
New York
Eureka
Casper
Wyoming
Sioux Falls
Madison
Milwaukee
Michigan
Buffalo
Hartford
Rhode Island
Connecticut
Detroit
Lake Erie
New York
New Jersey
Reno
Salt Lake City
Cheyenne
Nebraska
Omaha
Cedar Rapids
Iowa
Chicago
Cleveland
Pennsylvania
Ft Wayne
Pittsburgh
Philadelphia
San Francisco
San Jose
Nevada
Lincoln
Peoria
Columbus
Ohio
Baltimore
Delaware
Indianapolis
Denver
Utah
Colorado
Topeka
Kansas City
Illinois
Indiana
Cincinnati
Washington D. C.
Maryland
Virginia
West Virginia
Louisville
Frankfort
Richmond
Pueblo
U. S. A.
Kansas
St. Louis
Lexington
Norfolk
Las Vegas
California
Wichita
Missouri
Kentucky
Springfield
Raleigh
Flagstaff
Santa Fe
Oklahoma
Nashville
North Carolina
Los Angeles
Arizona
Tulsa
Tennessee
Charlotte
Albuquerque
Amarillo
Oklahoma City
Little Rock
Memphis
San Diego
Phoenix
New Mexico
South Carolina
Atlanta
Birmingham
Lubbock
Arkansas
Charleston
Tucson
Mississippi
Georgia
Dallas
Alabama
Savannah
El Paso
Jackson
Louisiana
Texas
Mobile
Tallahassee
Jacksonville
Beaufort Sea
Baton Rouge
Austin
New Orleans
Alaska
San Antonio
Houston
Orlando
Pacific Ocean
Tampa
Florida
Anchorage
Berring Sea
Honolulu
Hawaii
Juneau
Gulf of Alaska
Ft Myers
Miami
0
500 Miles
0
500 Km
0
100 Miles
0
100 Km
Key West

What IS a neighbor?

A neighbor is “somebody” who is:

- Next door → **Contiguity**-based Ws
- Close → **Distance**-based Ws
- In the same “place” as us → **Block** weights

Spatial neighbors

Contiguity-based neighbors

- Zone i and j are neighbors if zone i is contiguity or adjacent to zone j
- But what constitutes contiguity?

Distance-based neighbors

- Zone i and j are neighbors if the distance between them are less than the threshold distance
- But what distance do we use?

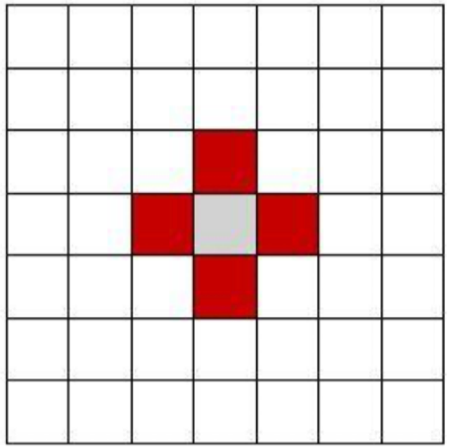
Block weights

- Weights are assigned based on discretionary rules loosely related to geography
- Census blocks into Census tracts

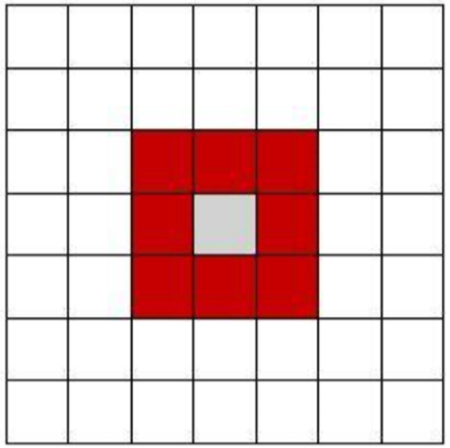
Choice of W

- Should be based on and reflect the underlying channels of interaction for the question at hand. Examples:
  - Processes propagated by inmediate contact (e.g. disease contagion) → Contiguity weights
  - Accessibility → Distance weights
  - Effects of county differences in laws → Block weights

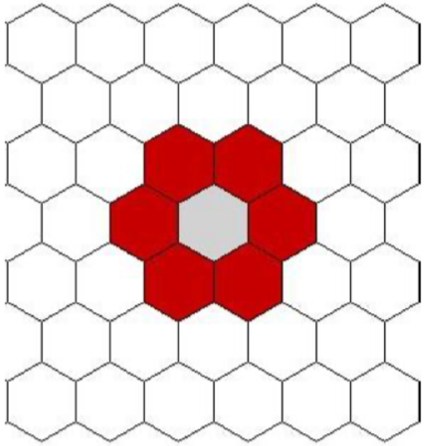
Contiguity-based Spatial Neighbors



Rook



Queen



Hexagons

Irregular

Example

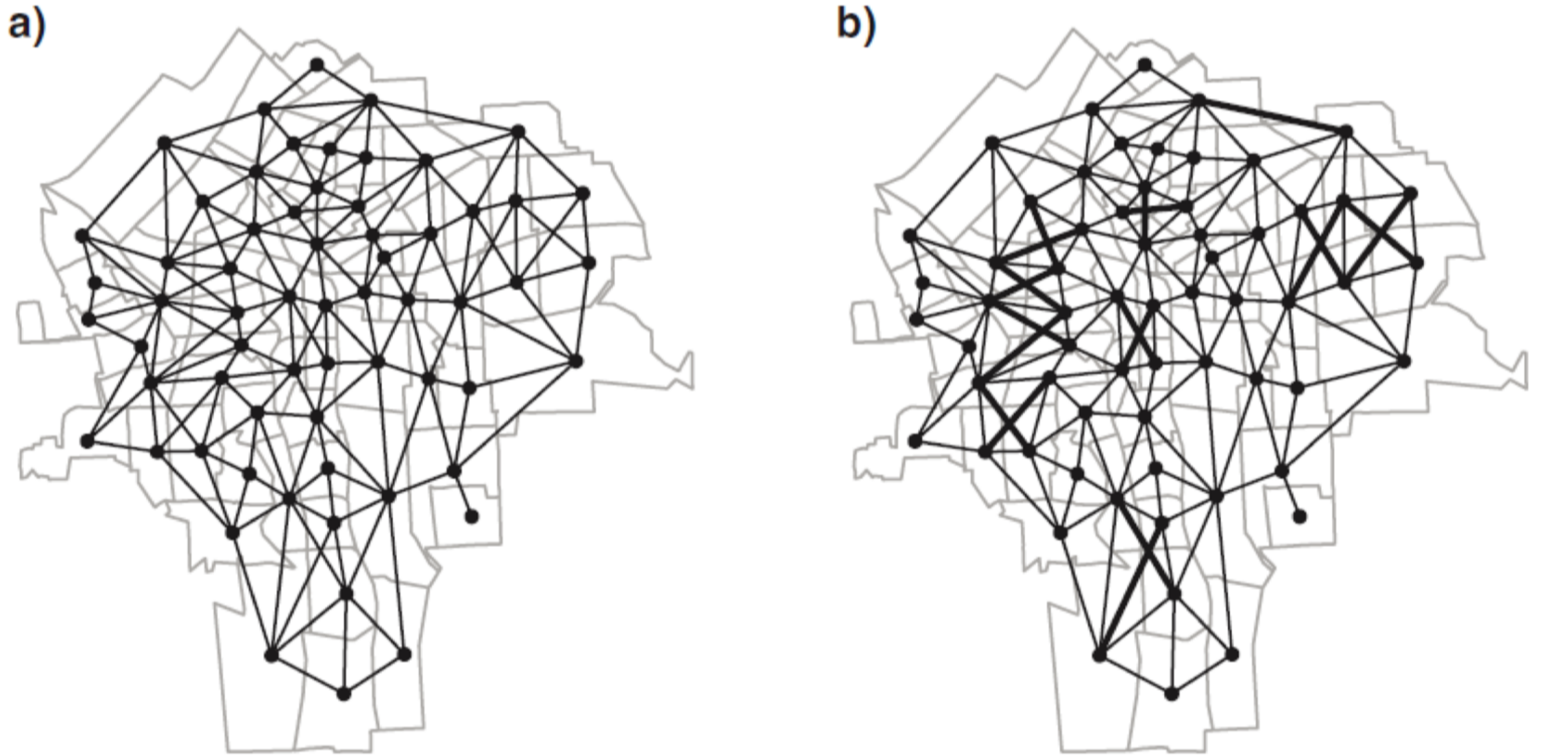
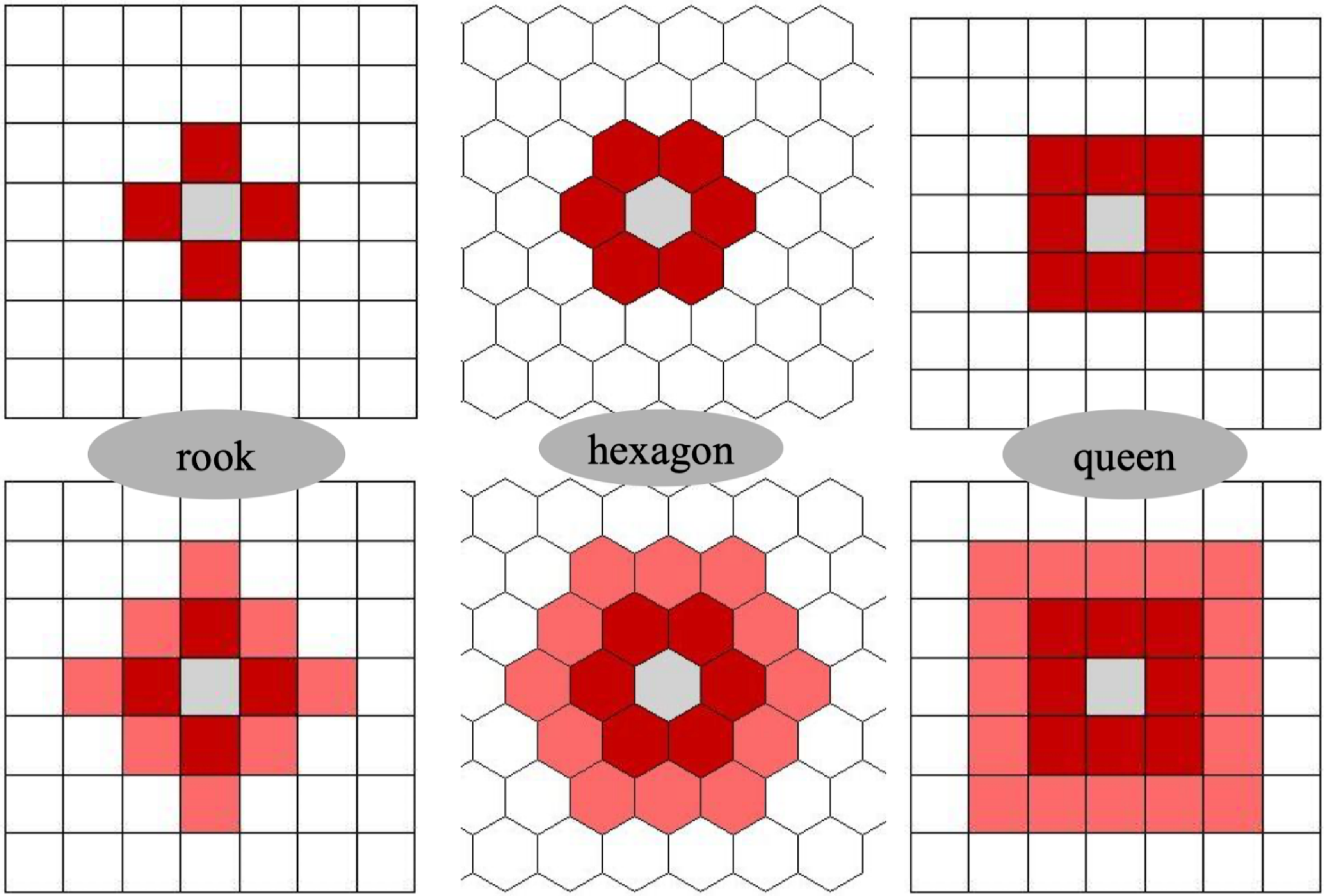


Fig. 9.3. (**a**) Queen-style census tract contiguities, Syracuse; (**b**) Rook-style contiguity differences shown as thicker lines

Higher-order contiguity

1st order
Nearest neighbor

2nd order
Nearest neighbor



Distance-based neighbors

- How do we measure distance between polygons?
- Distance metrics
  - 2D Cartesian distance (projected data)
  - 3D spherical distance/great-circle distance (lat/long data)
- *But where do we measure from?*
- *Any implications of our choices?*

Distance-based neighbors (k-nearest)

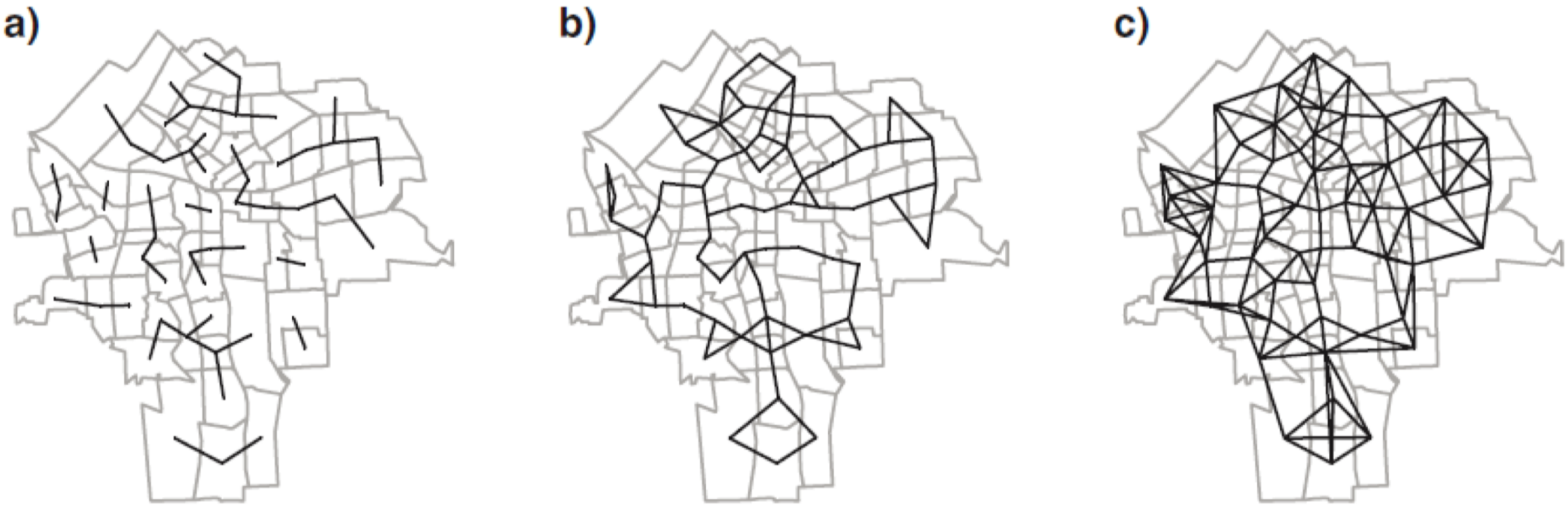


Fig. 9.5. (**a**) $k = 1$ neighbours; (**b**) $k = 2$ neighbours; (**c**) $k = 4$ neighbours

Distance-based neighbors (threshold distance)

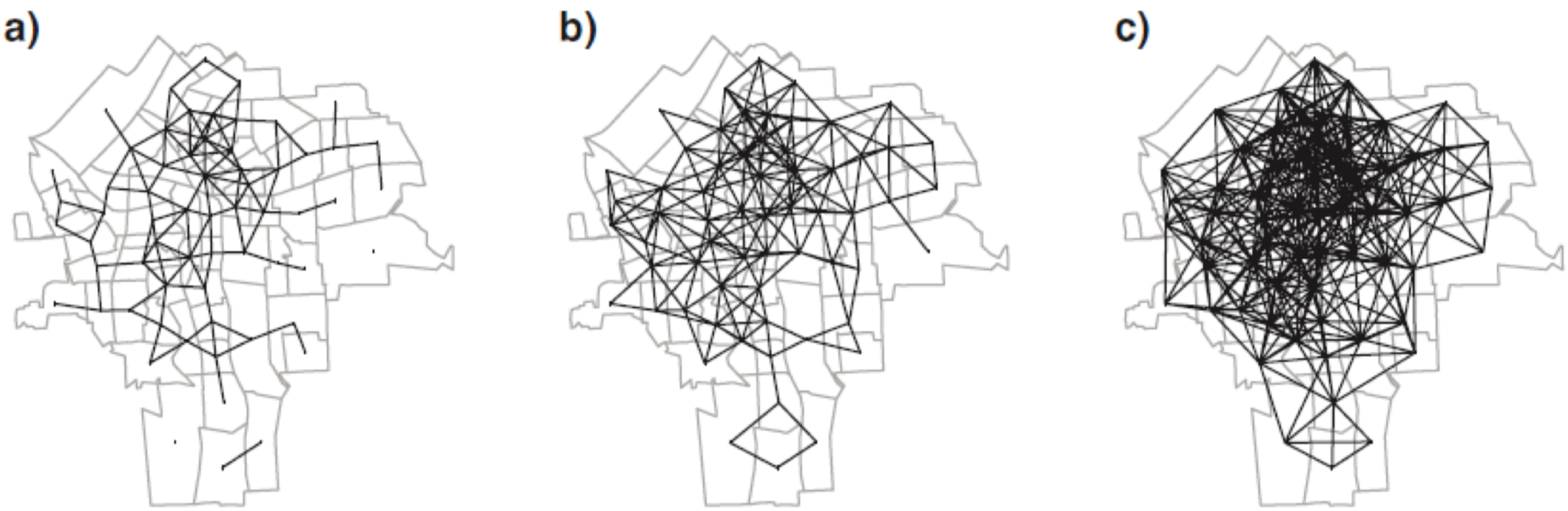
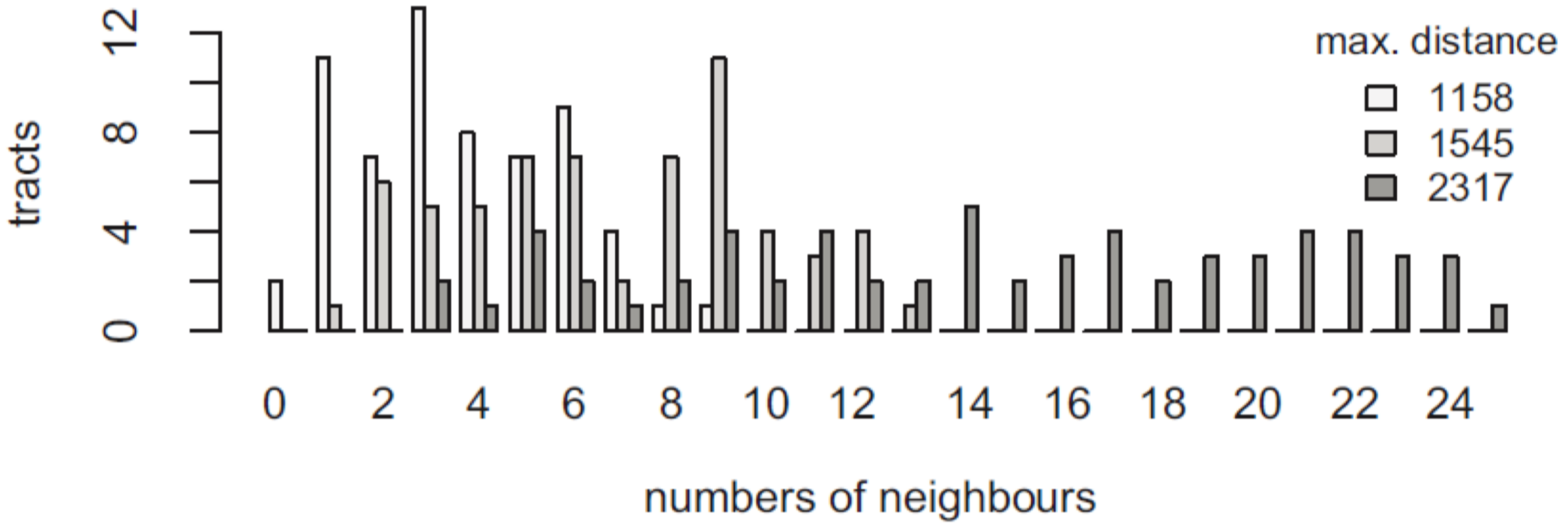


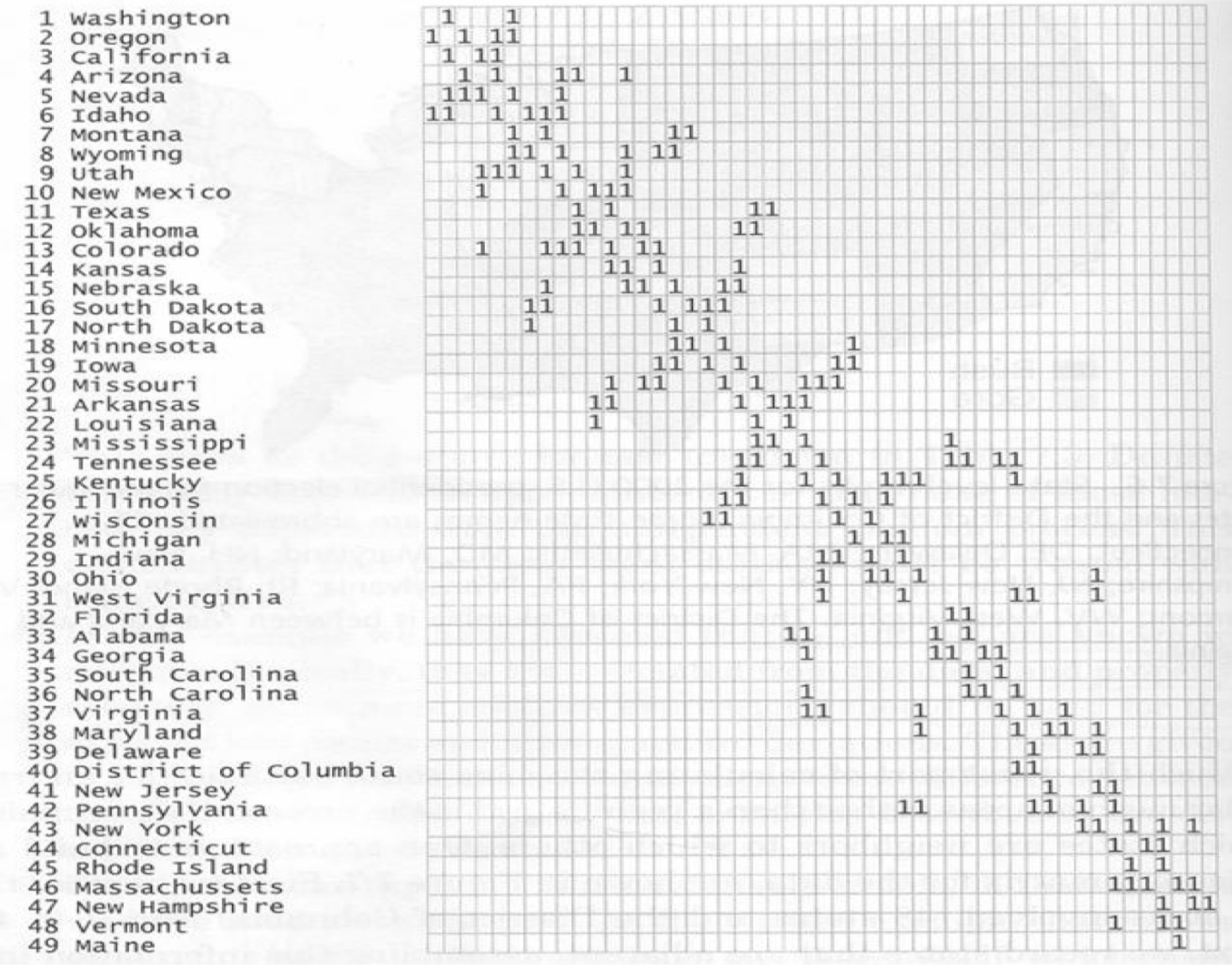
Fig. 9.6. (**a**) Neighbours within 1,158 m; (**b**) neighbours within 1,545 m; (**c**) neigh-
bours within 2,317 m

Connectivity histogram



A simple spatial weights matrix

1 if adjacent,
2 if not



Decay functions of distance

- Most common choice is the inverse (reciprocal) of the distance between locations i and j
- Other functions also used
    - inverse of squared distance
    - Or negative exponential

Standardization

- In some applications (e.g. spatial autocorrelation) it is common to standardize W
- The most widely used standardization is row- based: divide every element by the sum of the row

For next class

- Lab 6 due April 8th
- Lab 7 starts Friday - I WILL NOT BE HERE FRIDAY
- Readings are linked/posted on Canvas… BE SURE TO DO IT THIS WEEK