SPATIAL STATISTICS IN LANDSCAPE ECOLOGY

REM 429

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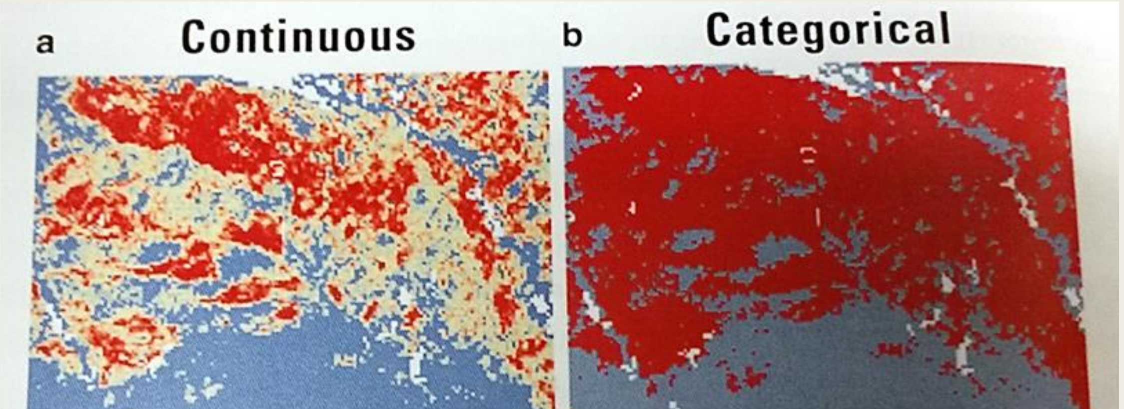
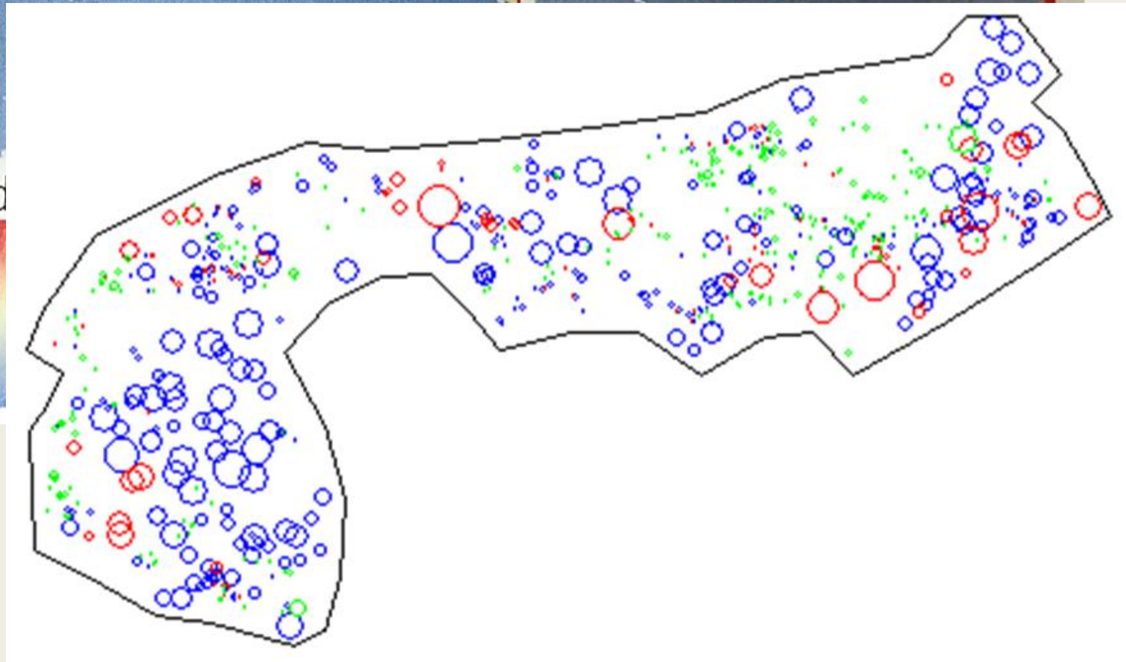
Spring 2017

What is “spatial statistics”?

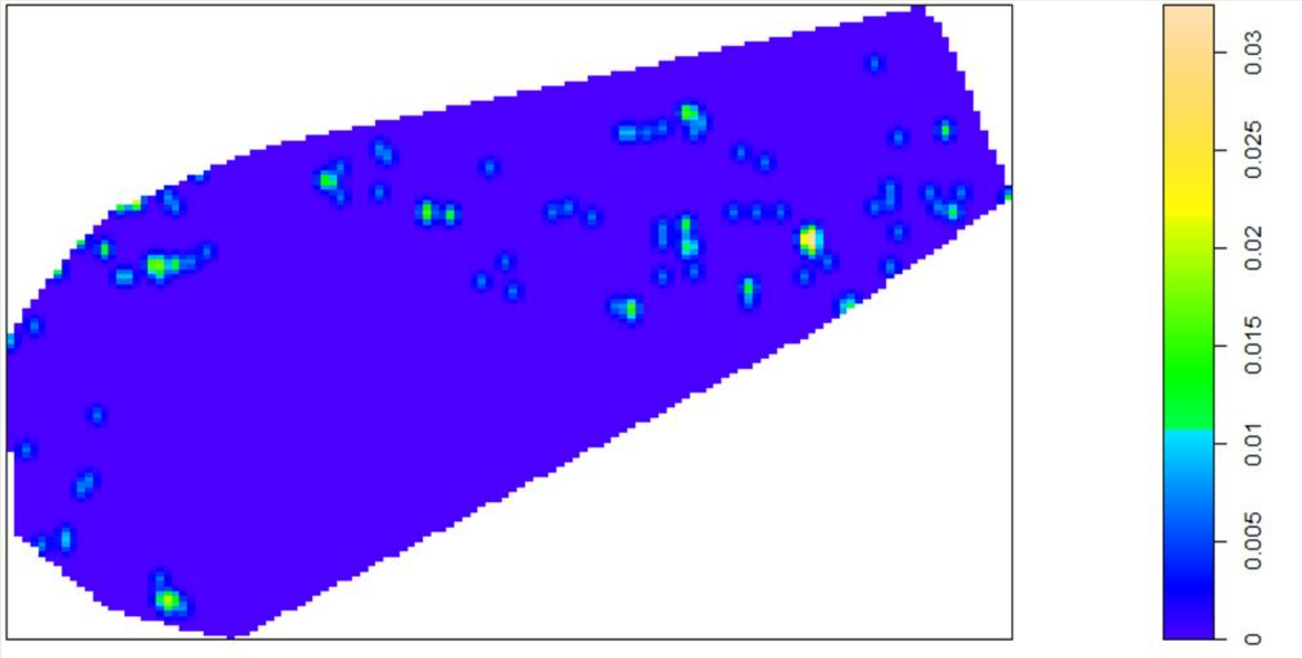
- Chapter 5 – Turner & Gardner 2015 (2nd edition only)
- Quantify the spatial structure of continuous data
  - *Spatial structure?*
  - *Continuous data?*
- Why would we use this in landscape ecology?
  - *Spatial independence*
  - *Nature of spatial structure*
  - *Spatial interpolation*





Caveats and Considerations
(Turner and Gardner 2015)

- Spatial dependence must be characterized and considered
- Spatial autocorrelation is not always a problem
- Coincidence of scales does not prove causality
- Scale always matters
- Interpretation is an art and a science
- Stationarity matters



Spatial dependence

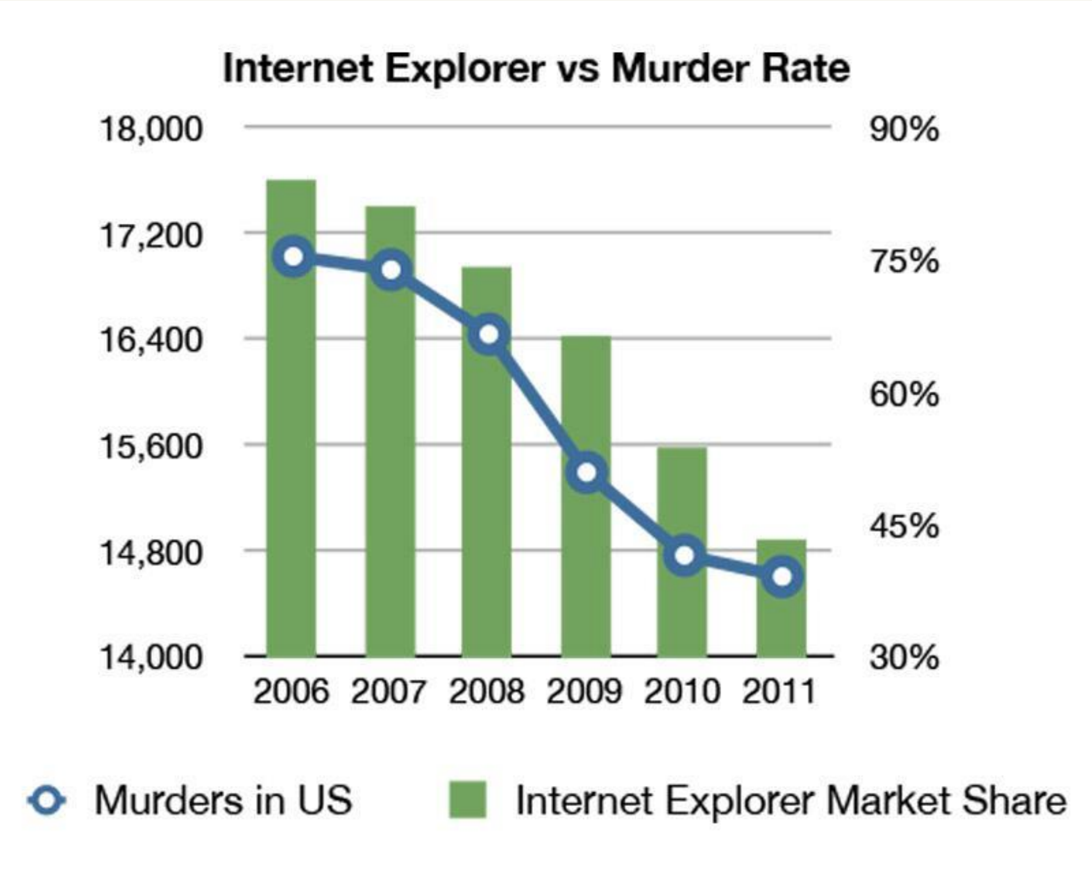
- **Tobler's first law of geography**
  - *Everything is related to everything else, but near things are more related than distant things.*
- Spatial autocorrelation

Spatial autocorrelation is not automatically bad

- Changes in the scale of variability is itself useful and interesting data
- Fraterrigo et al. 2005
  - *Historic agriculture*
  - *Soil resources varied*
    - Spatially but not averaged!

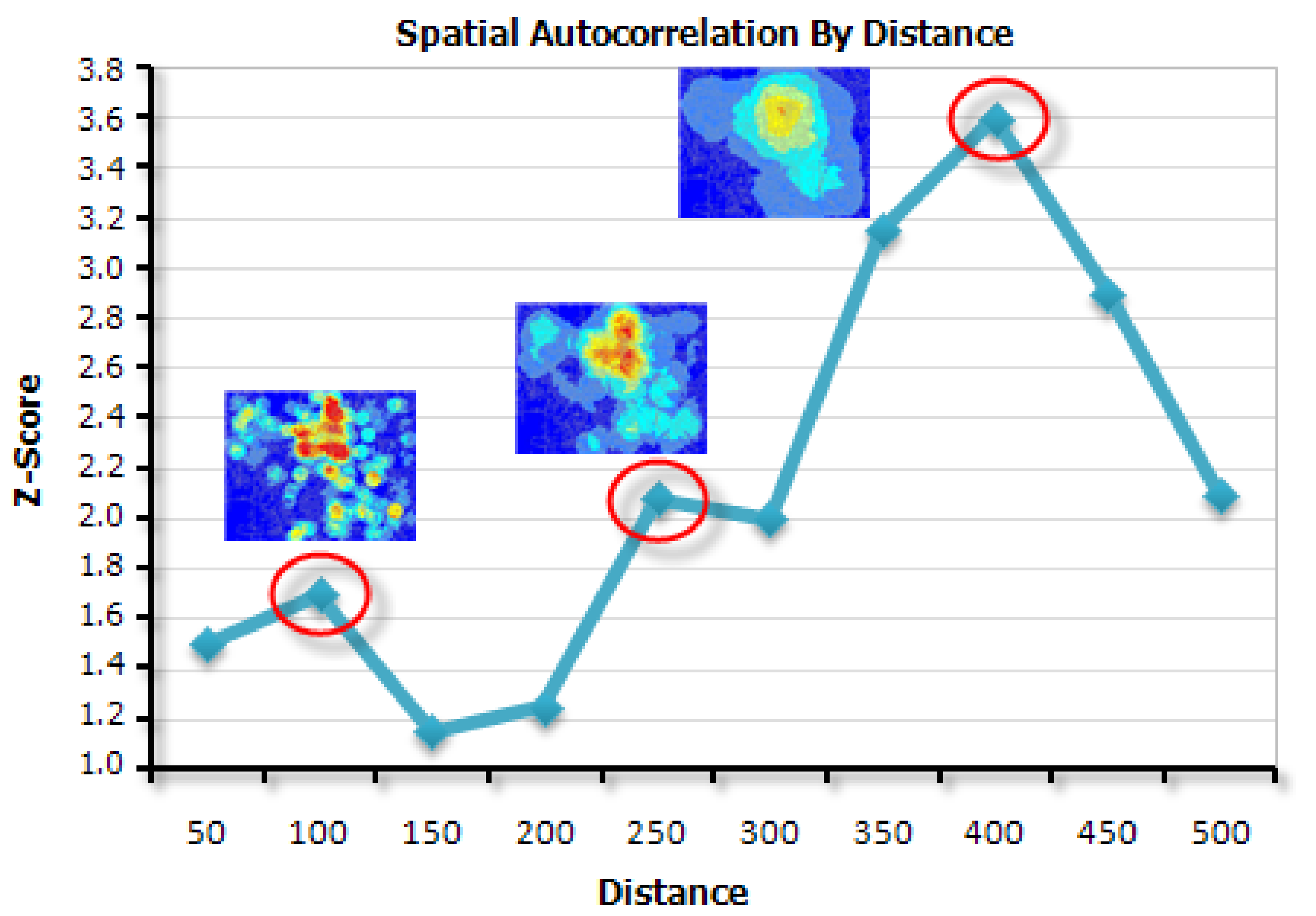
Coincidence of scales does not prove causality

- Sharing the same scale of spatial dependence or variability =/= same underlying causal mechanism
- Correlation is not causation!



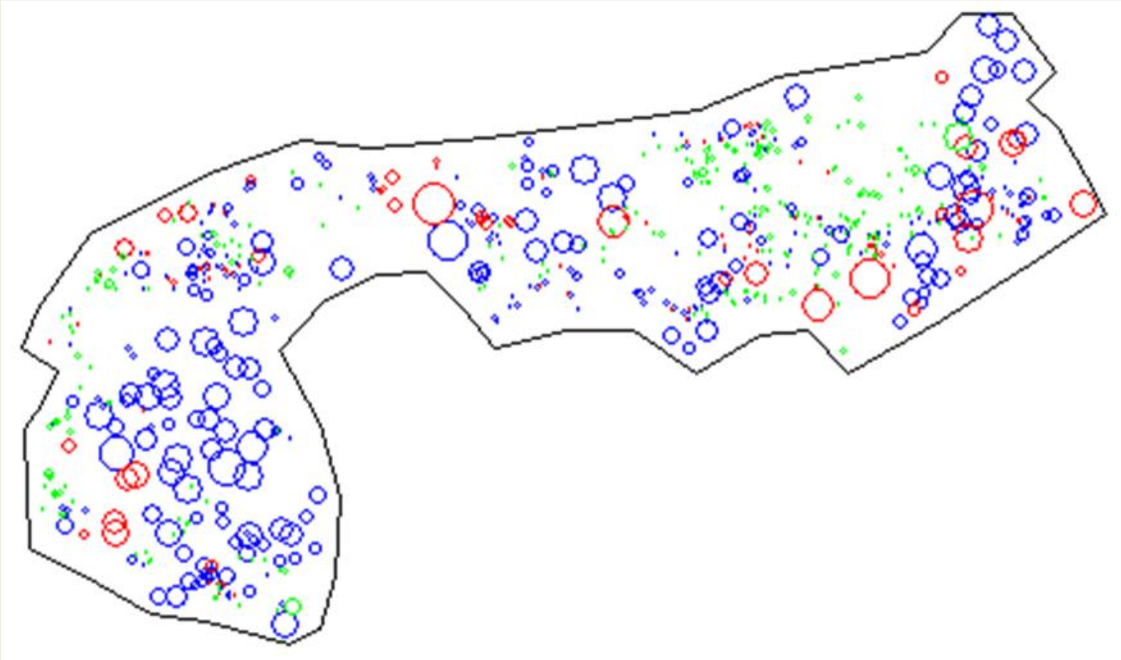
Scale always matters

- Grain and extent
- Boundaries and edges
- Beware binned data!



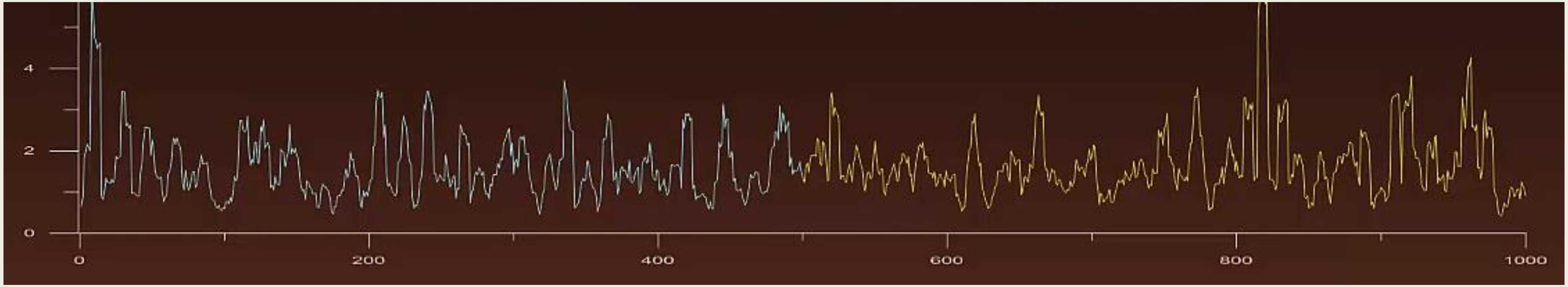
Interpretation is an art and a science

- Real data is messy and your results will often not be clear-cut
  - *Don’t give up!*
  - *Use your understanding of the ecosystem*
  - *Ask for help!*



Stationarity is an important assumption

- Assumption: the local mean and variance of a particular variable will not change with the location of measurement
- Likely causes of violation
  - *Unrecognized gradient*
  - *Topography*
- Solutions
  - *“Detrend” the data*
  - *Simply account for this trend*



0
2
4
0
200
400
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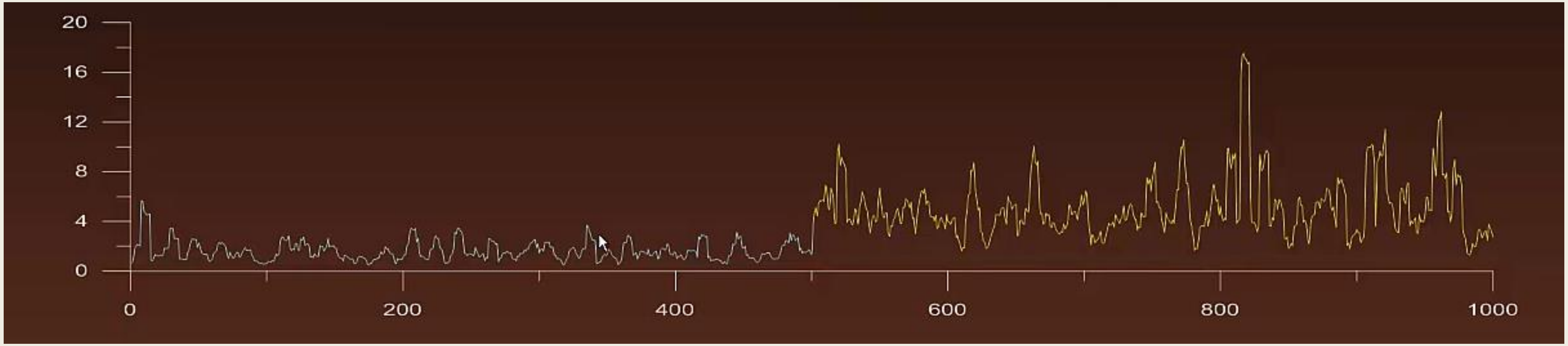
800
1000



20
16
12
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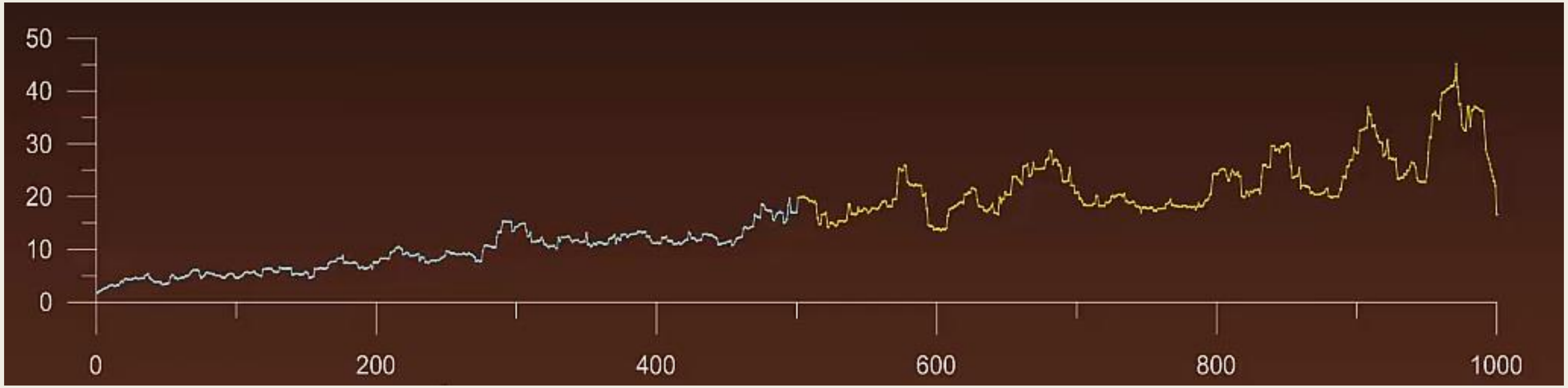


50
40
30
20
10
0
0
200
400
600
800
1000

Variography and Autocorrelation

- What is variance?

Sample Variance

$$s^2 = \frac{\sum(x - \bar{x})^2}{n - 1}$$

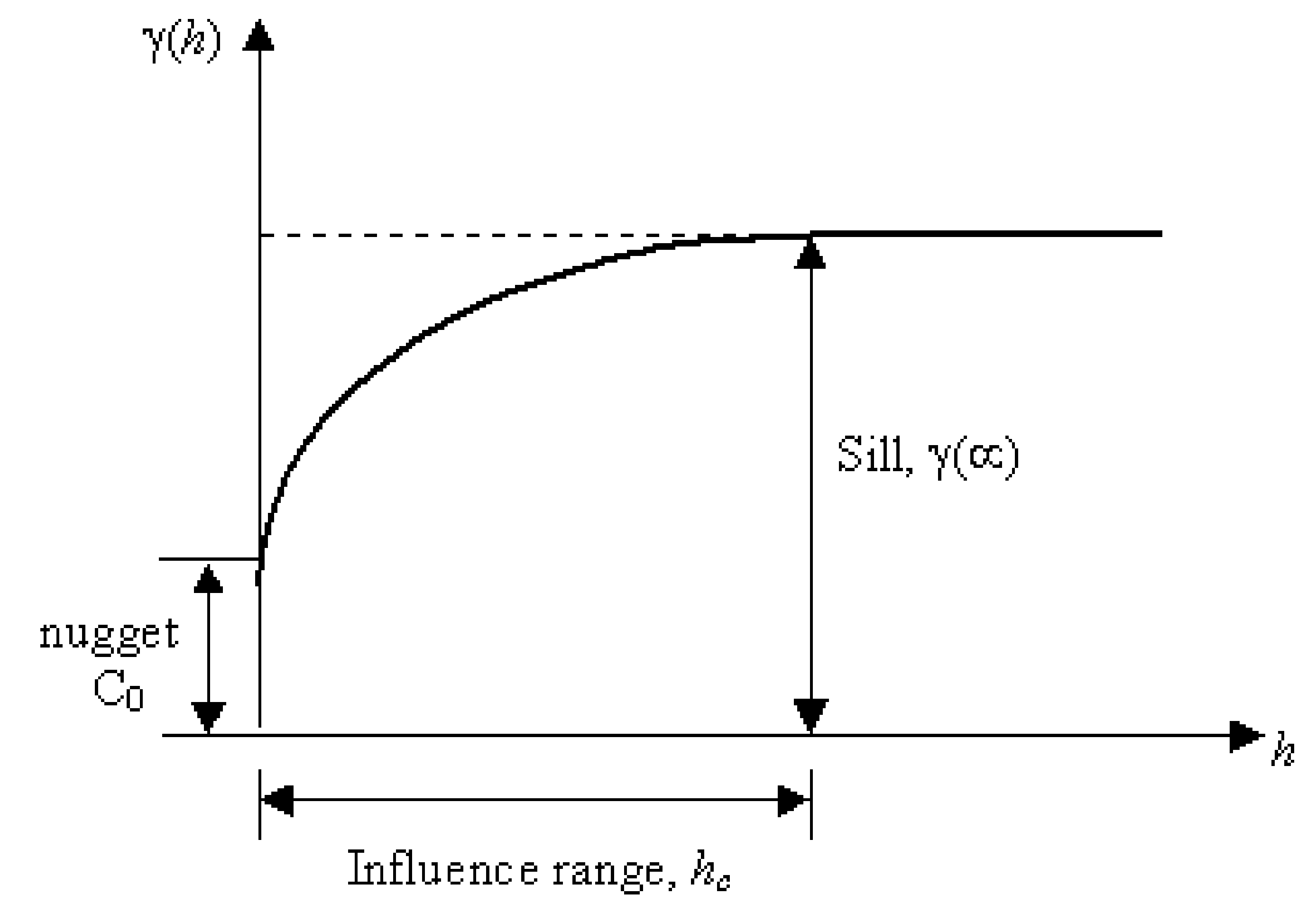
Sample Standard Deviation

$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$$

- Variance is a measure of how far a set of numbers are spread

Variography and Autocorrelation

- Semivariance
  - *Half of the squared difference of all pairs of points separated by distance h.*
- Sill
- Nugget
- Influence range



Variography and Autocorrelation

- Sill
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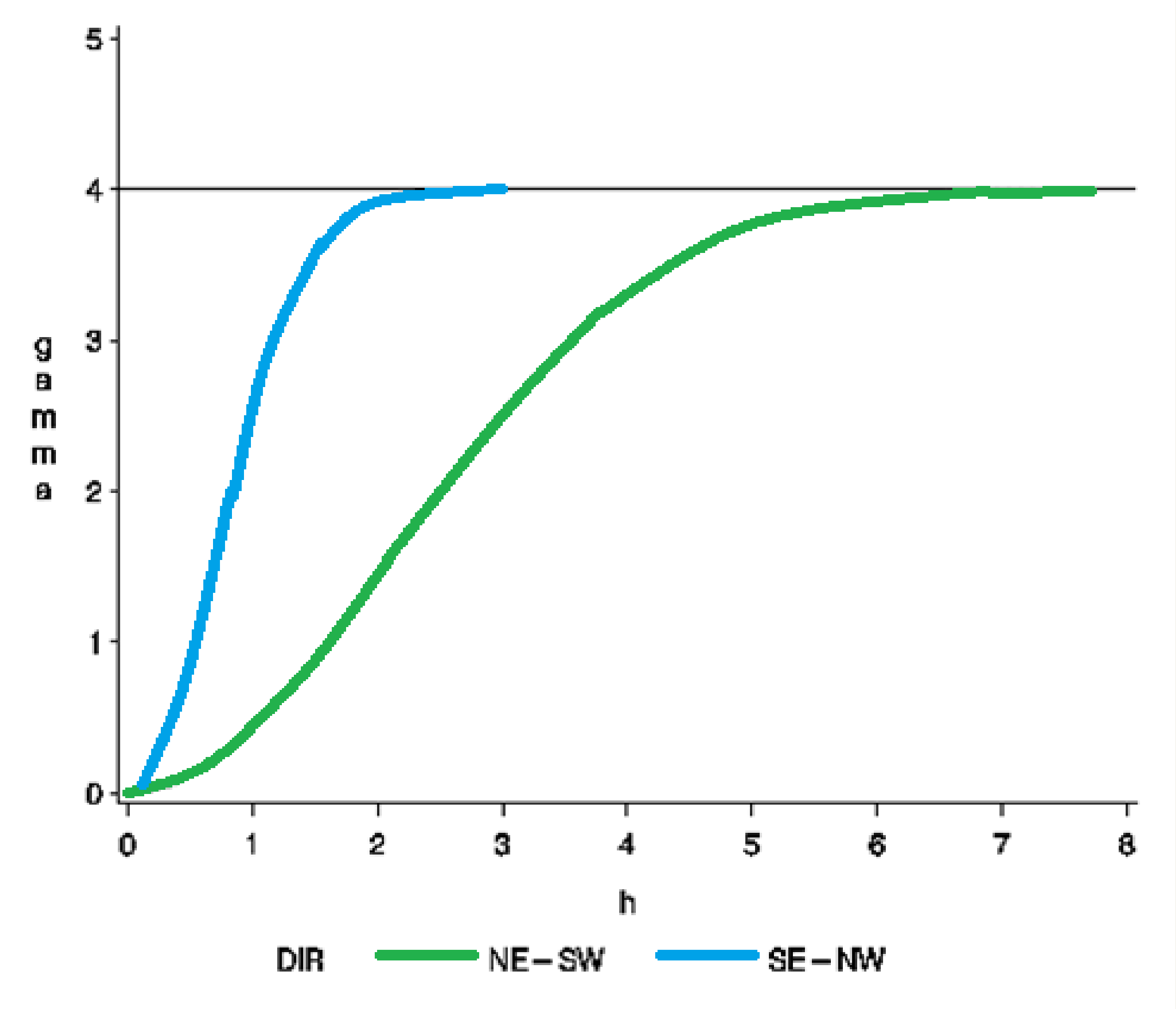
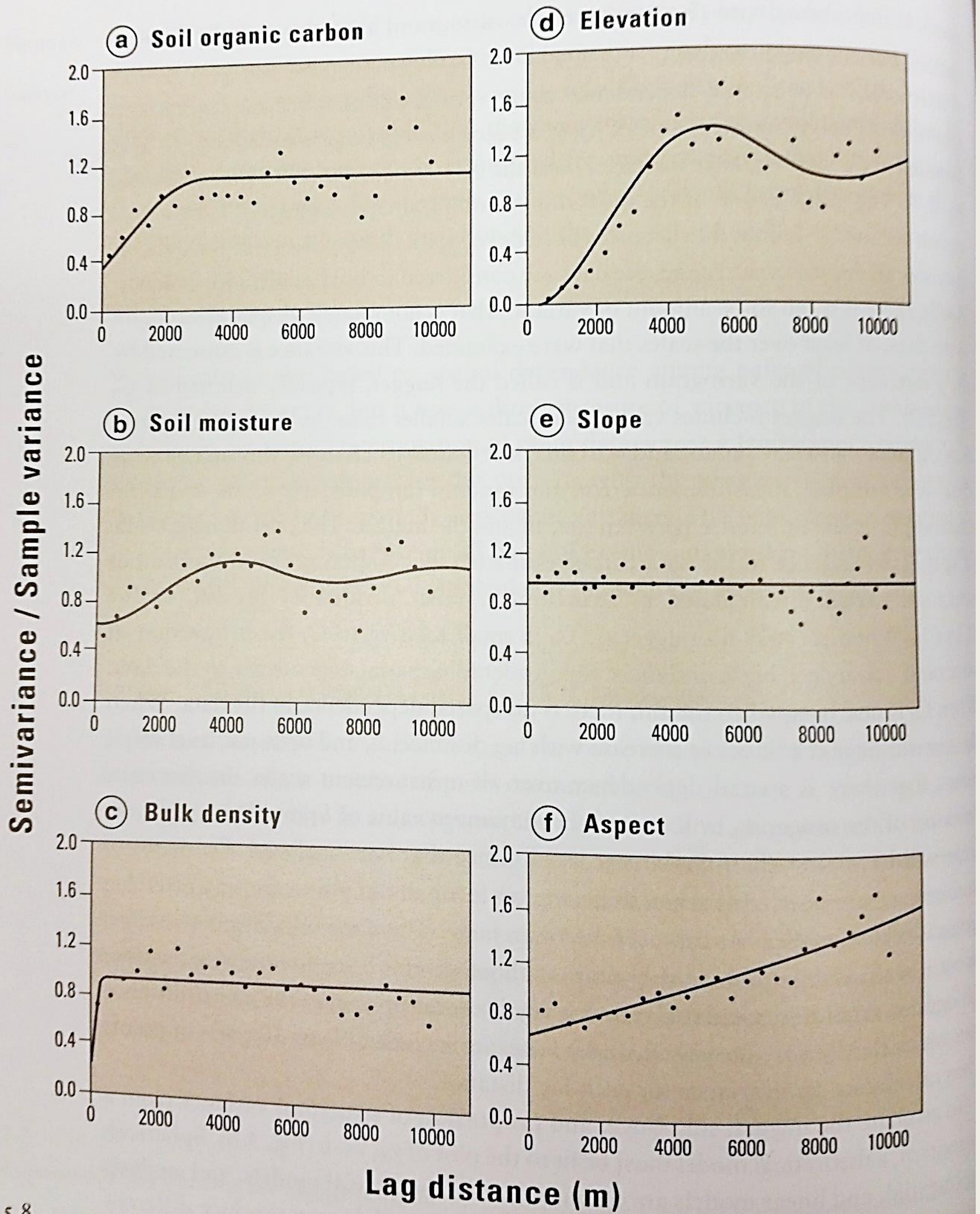


Variography and Autocorrelation



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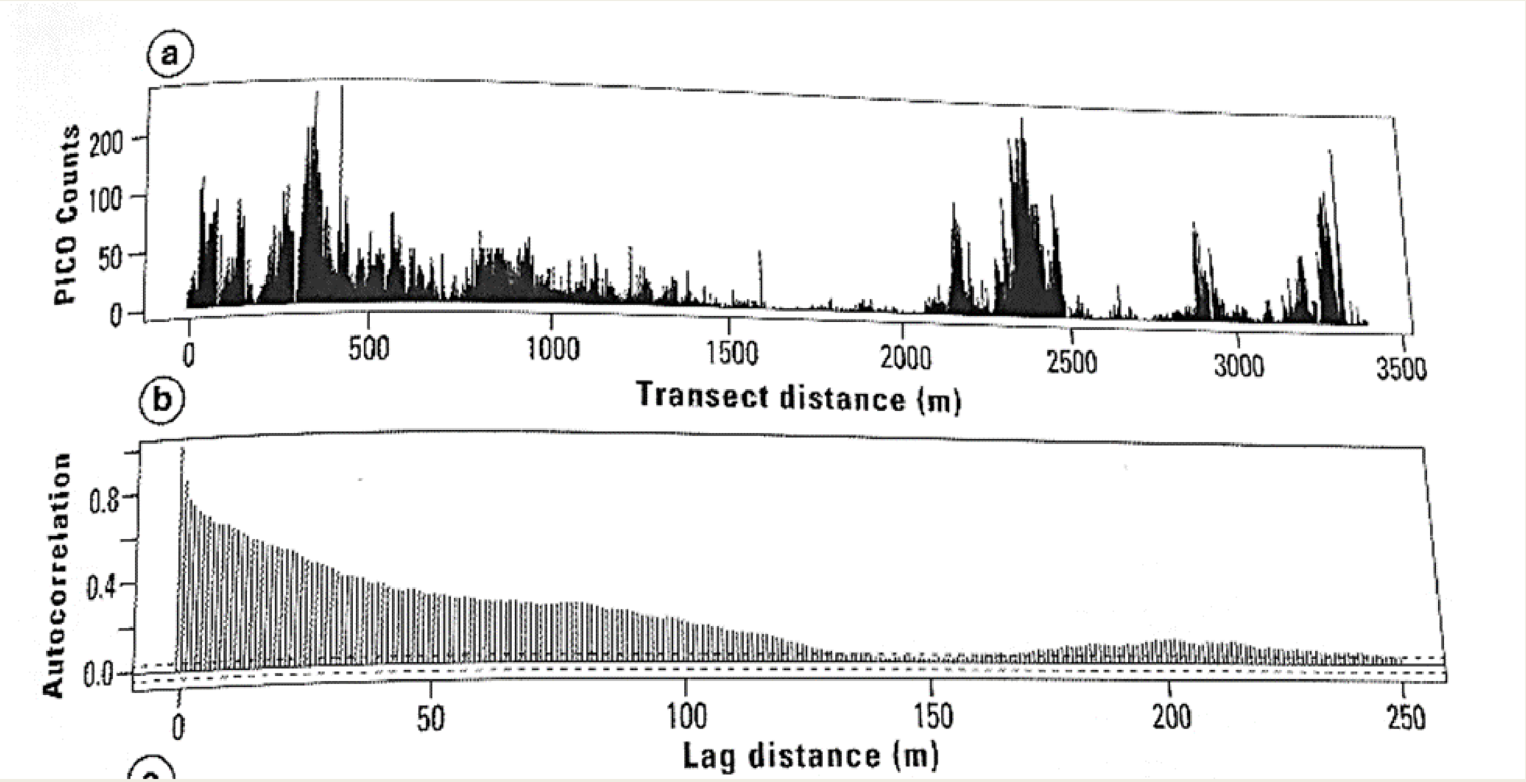
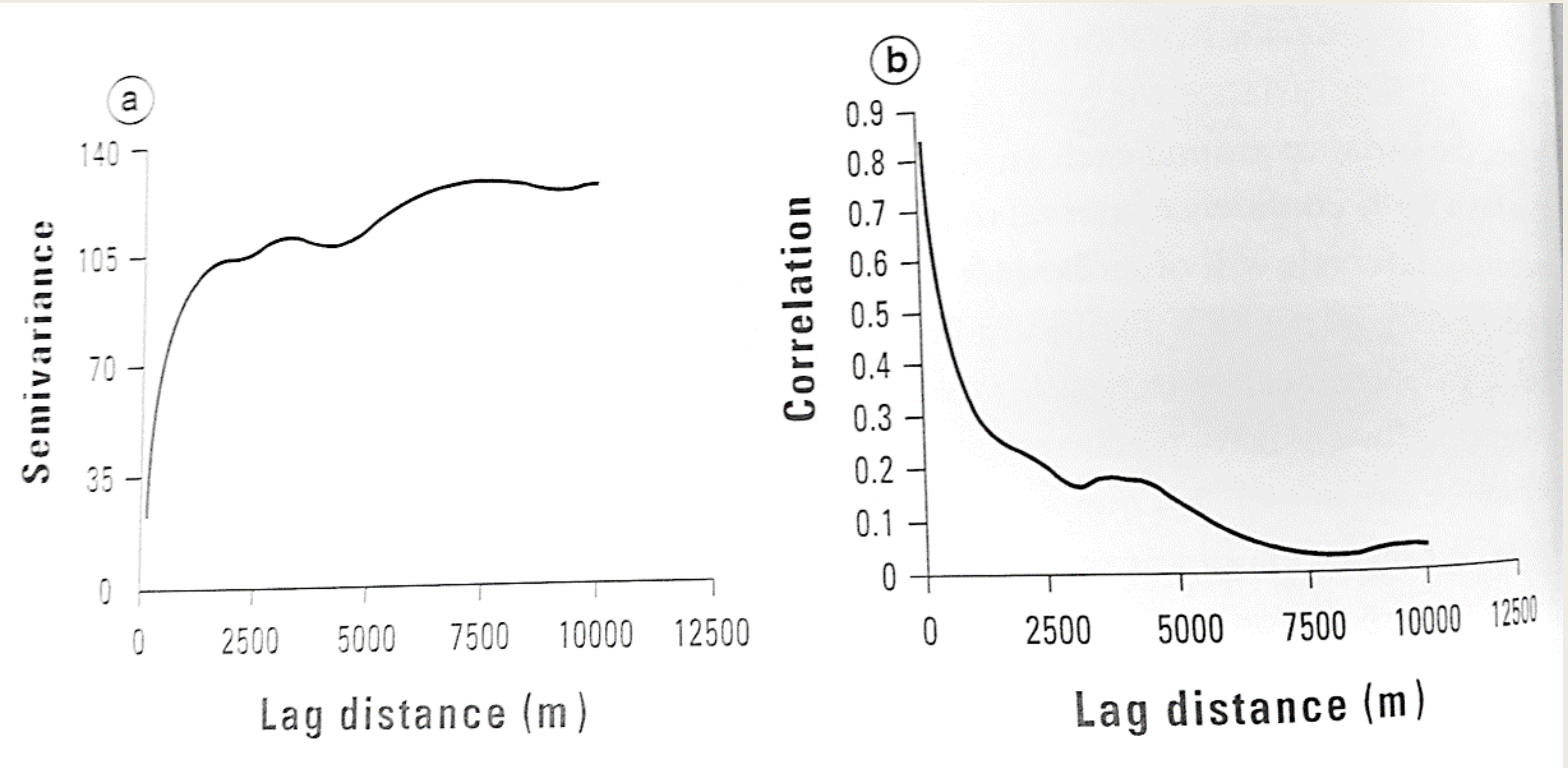
Variography and Autocorrelation

- Correlogram
- Post-fire lodgepole pine in Yellowstone NP



Variography and Autocorrelation

- Semivariance vs Correlation



Review: Caveats and Considerations
(Turner and Gardner 2015)

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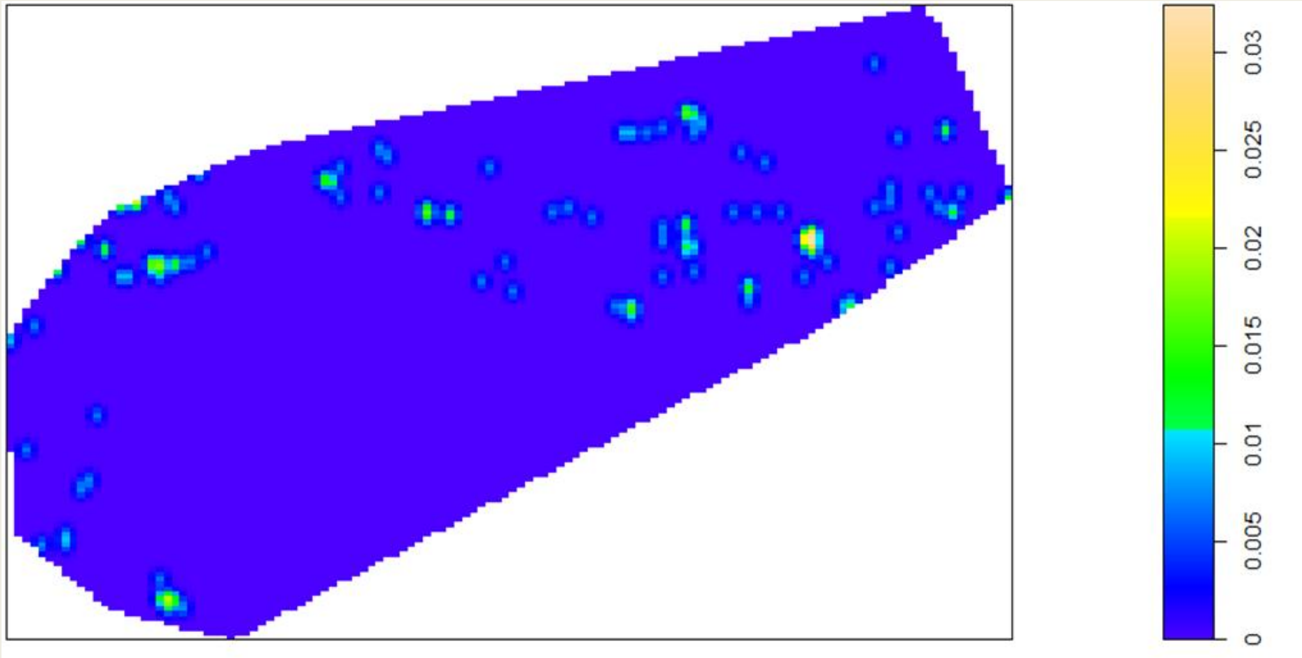
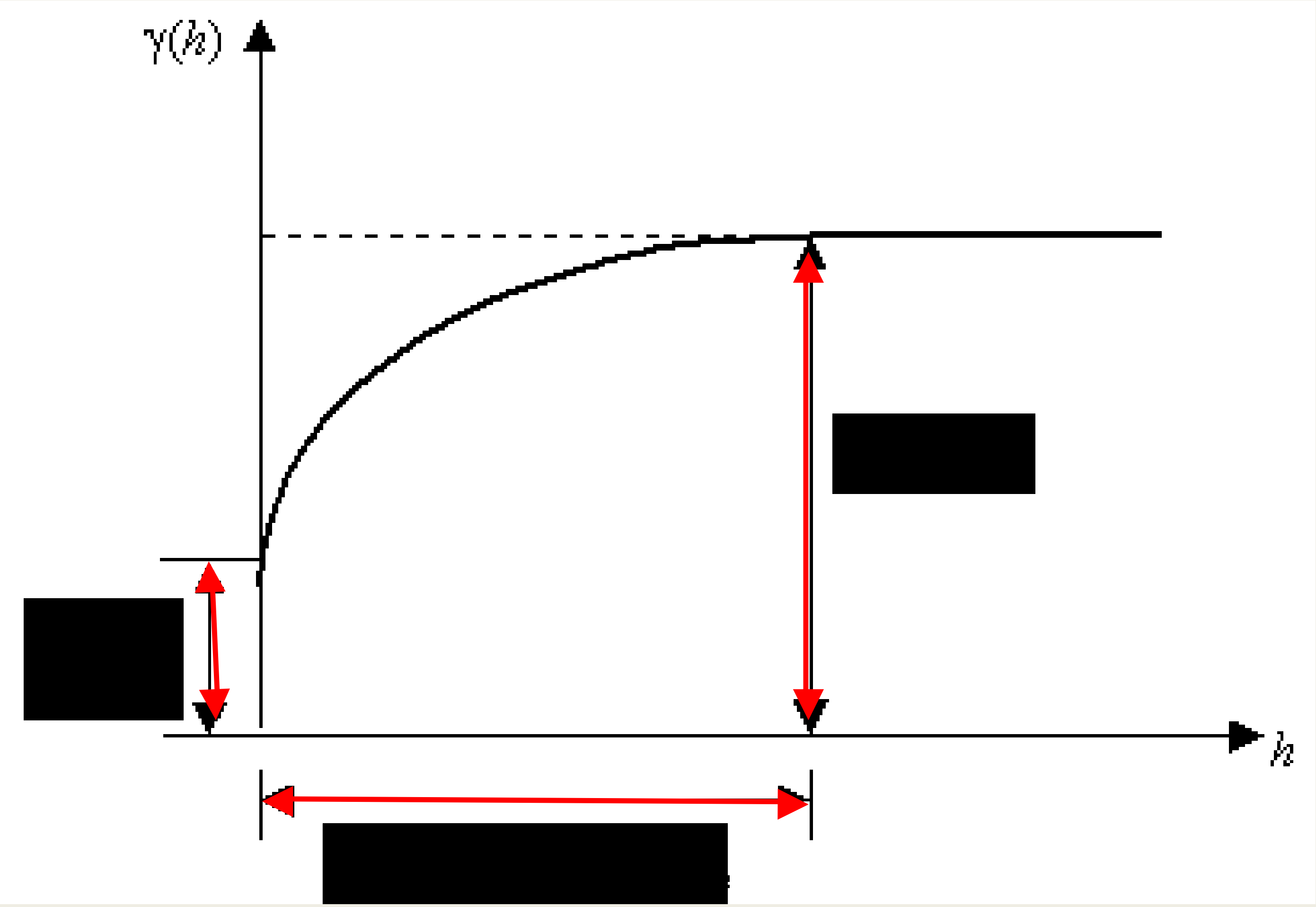
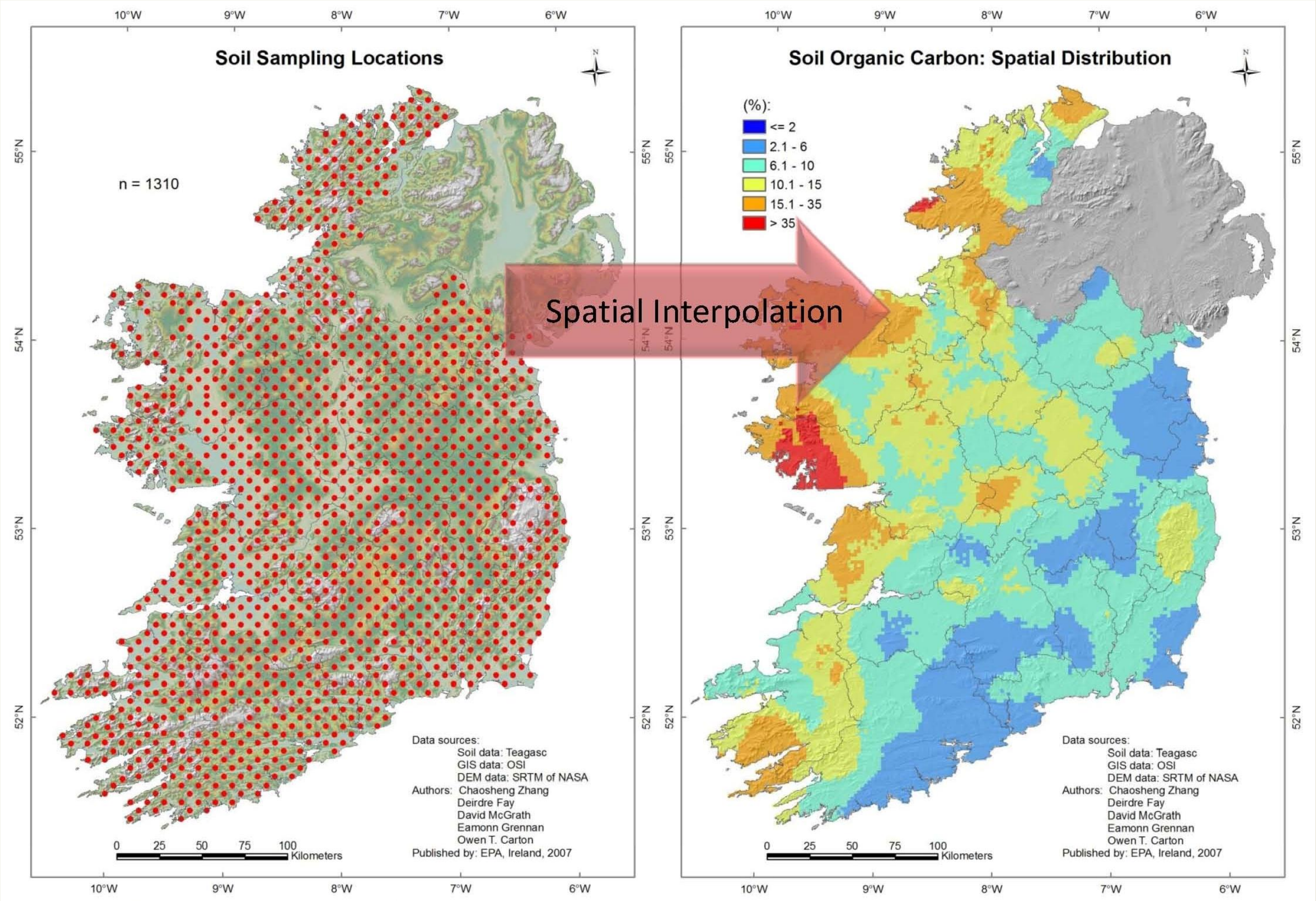


Review



Spatial Interpolation

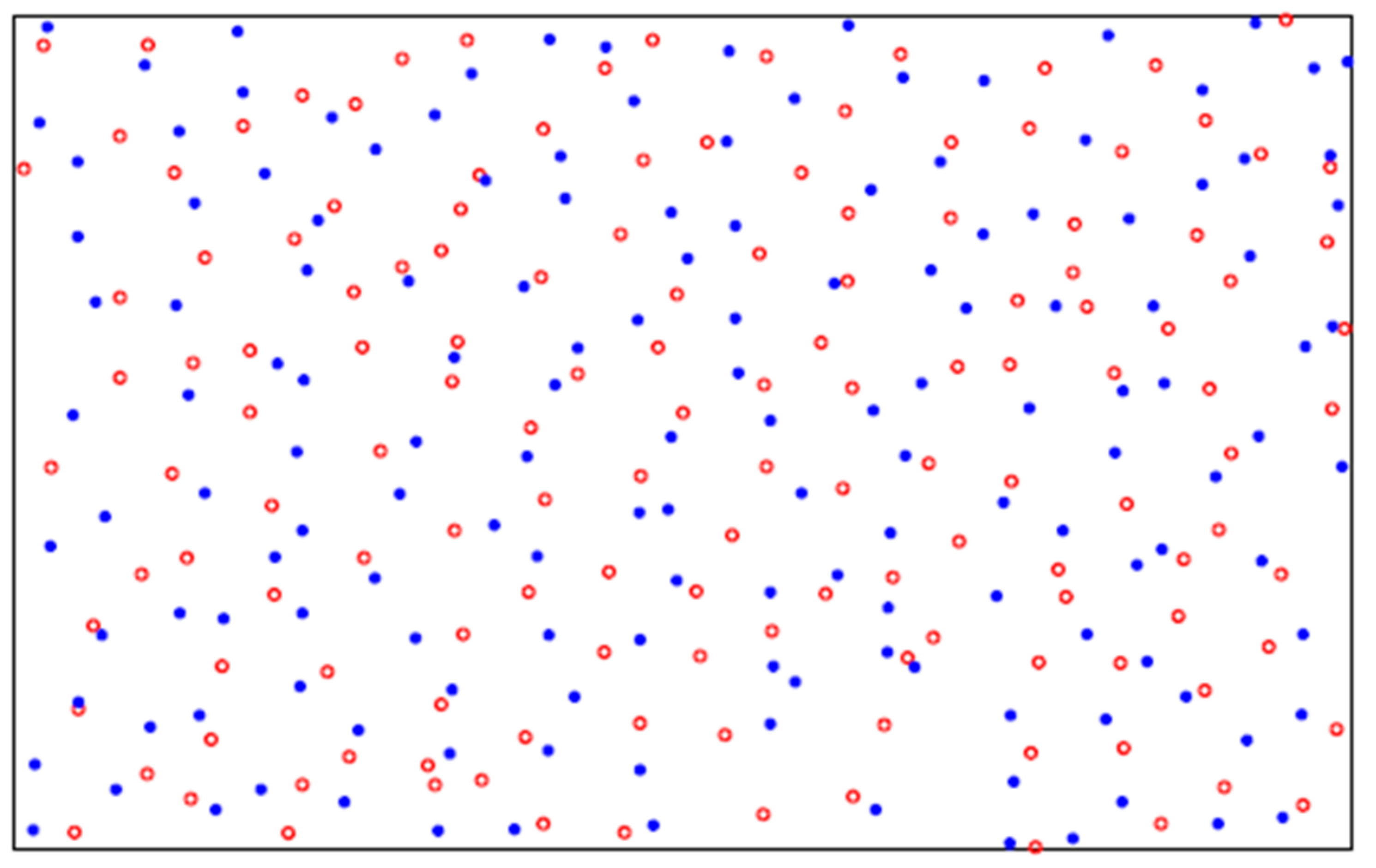


Properties of point patterns

Set of events in a study region where each event identifies the location of one point object.

1. Coordinate values should be in a 2-D planar (Cartesian) system – (Longitude/Latitude are not a distance value so should not be used).
2. Study region should be objective and not imposed.
3. The pattern should be a complete enumeration or one-to-one census of all points - not a sample of events.
4. Event locations must not be approximated.

Example marked point pattern

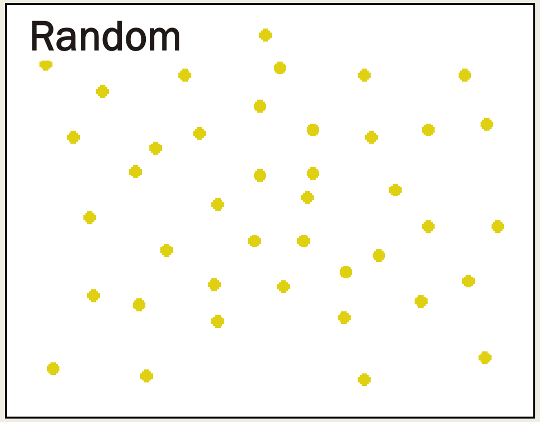


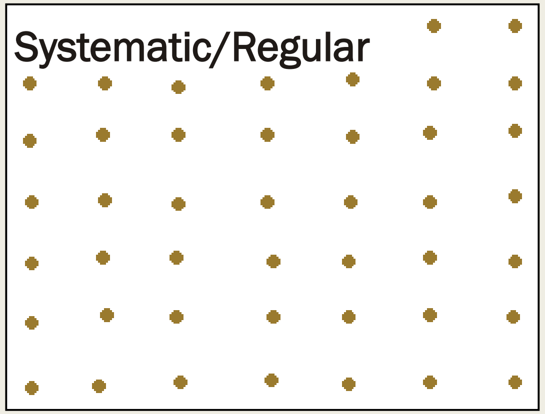
Point pattern types

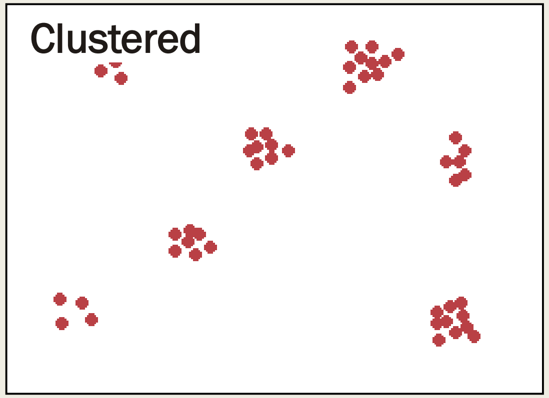
Random, Systematic or Clustered?

To test whether the observed pattern is a likely realization of a hypothesized process means creating a NULL hypothesis:

- H_o: The spatial point pattern is no different from a pattern derived from a CSR process.
- H_1: The spatial point pattern is significantly different from that produced by a random process.

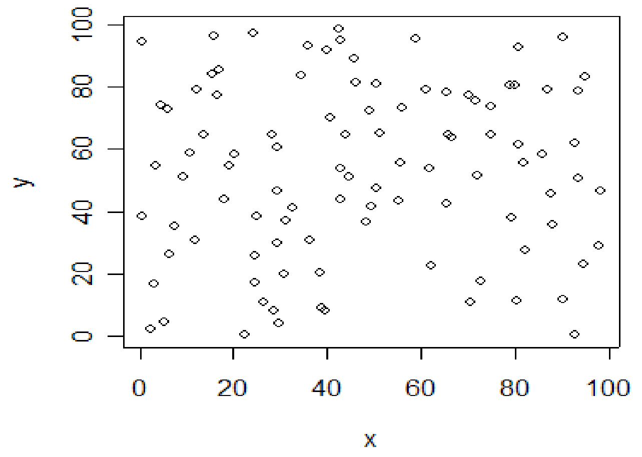


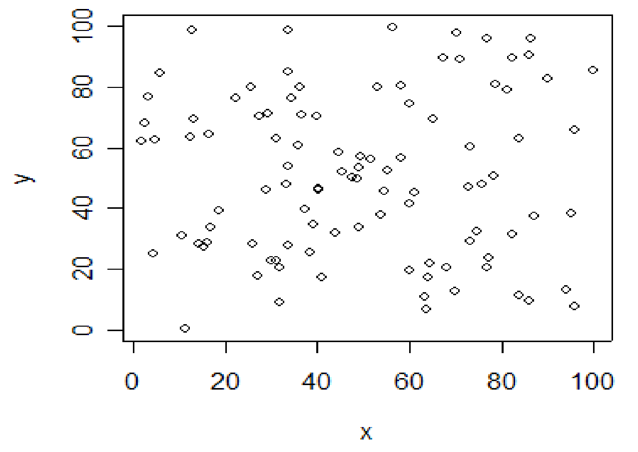




Complete Spatial Randomness - CSR

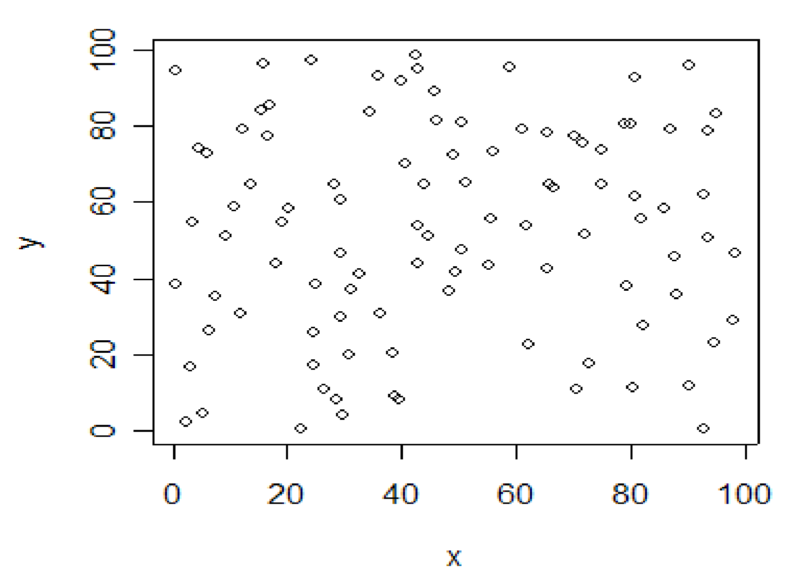
- Random describes the process of locating the points but NOT the pattern
  - WRONG: The pattern is a random pattern
  - CORRECT: The pattern conforms to a random process of x,y coordinate selection
- Could a CSR produce clustering?
- This does not mean that a similar geographically produced pattern is a chance occurrence and there is usually a reason why something exists where it exists.





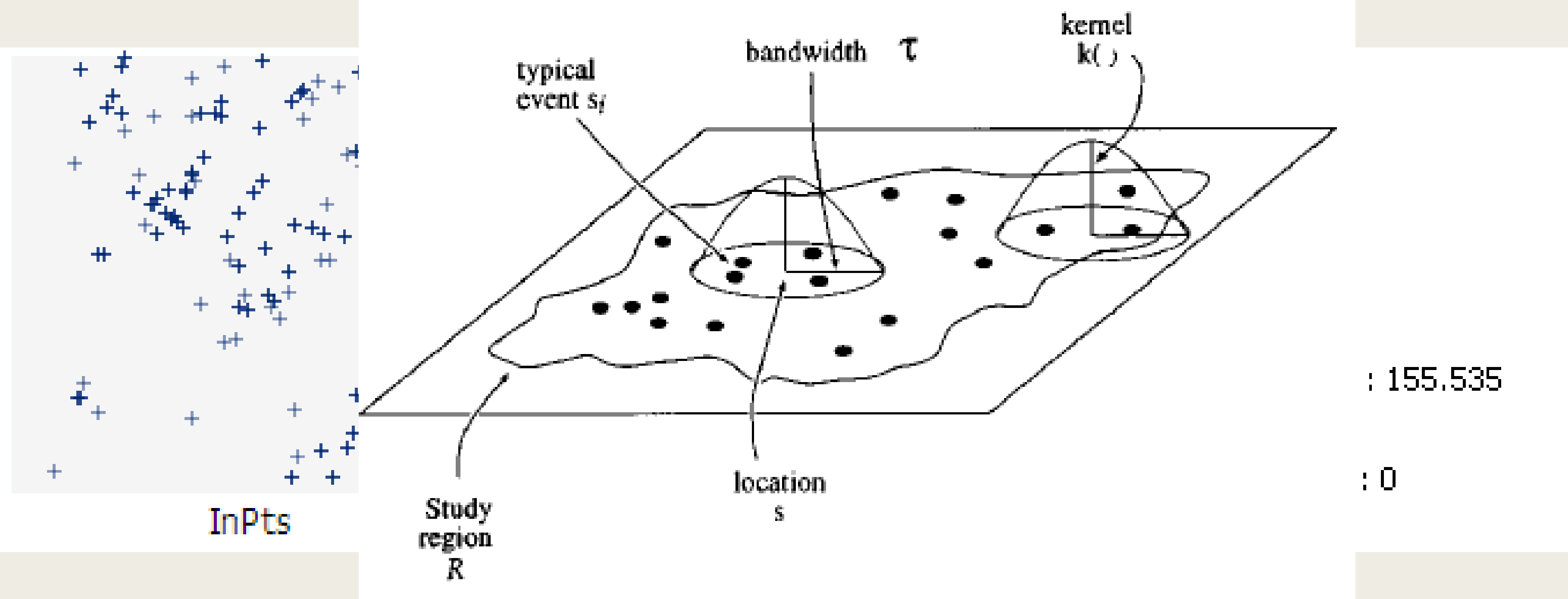
First order properties

- Intensity – count of points within area
- Quadrat analysis – count of points within quadrats of predetermined size
- Kernel density estimation
- Nearest neighbor analysis
  - G-function and F-function



Kernel estimation

- Calculates a magnitude-per-unit area from point or polyline features using a kernel function to fit a smoothly tapered surface to each point
- Crime analysis

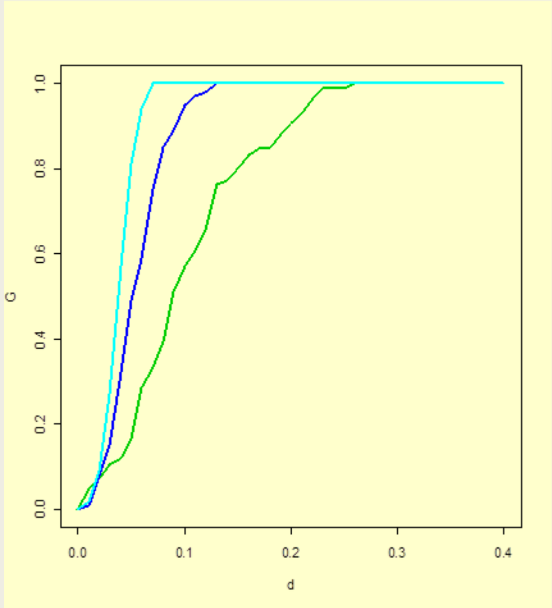


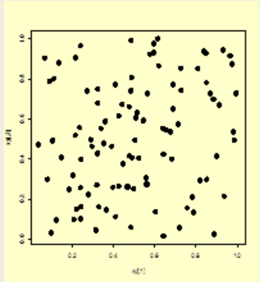
G vs. F

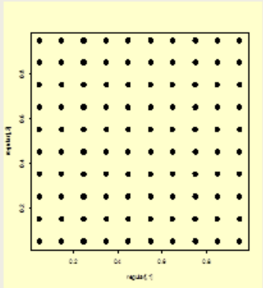
G-hat relates how close events are from each other.

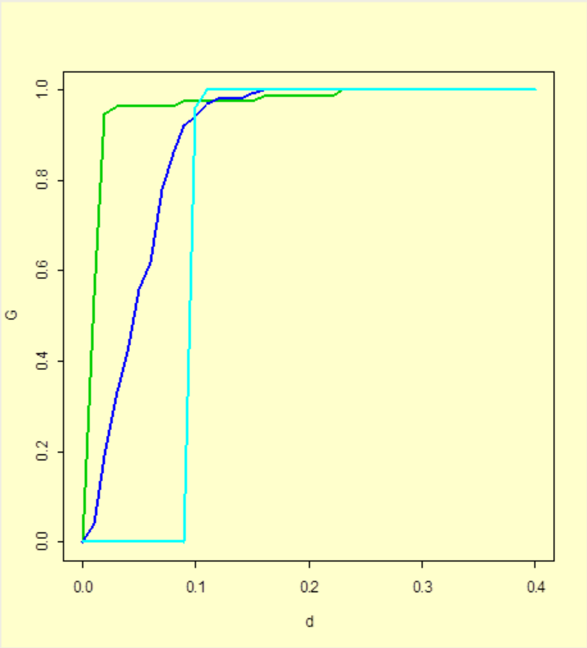
- **Shallow or slow rise to maximum means regularity.**
- **Quick rise to maximum means clustering.**

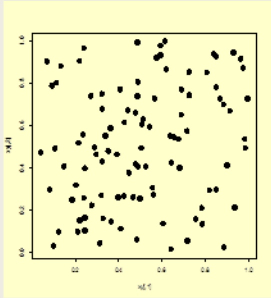
$\hat{F}(d)$

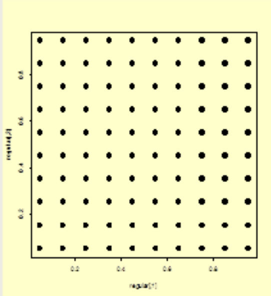












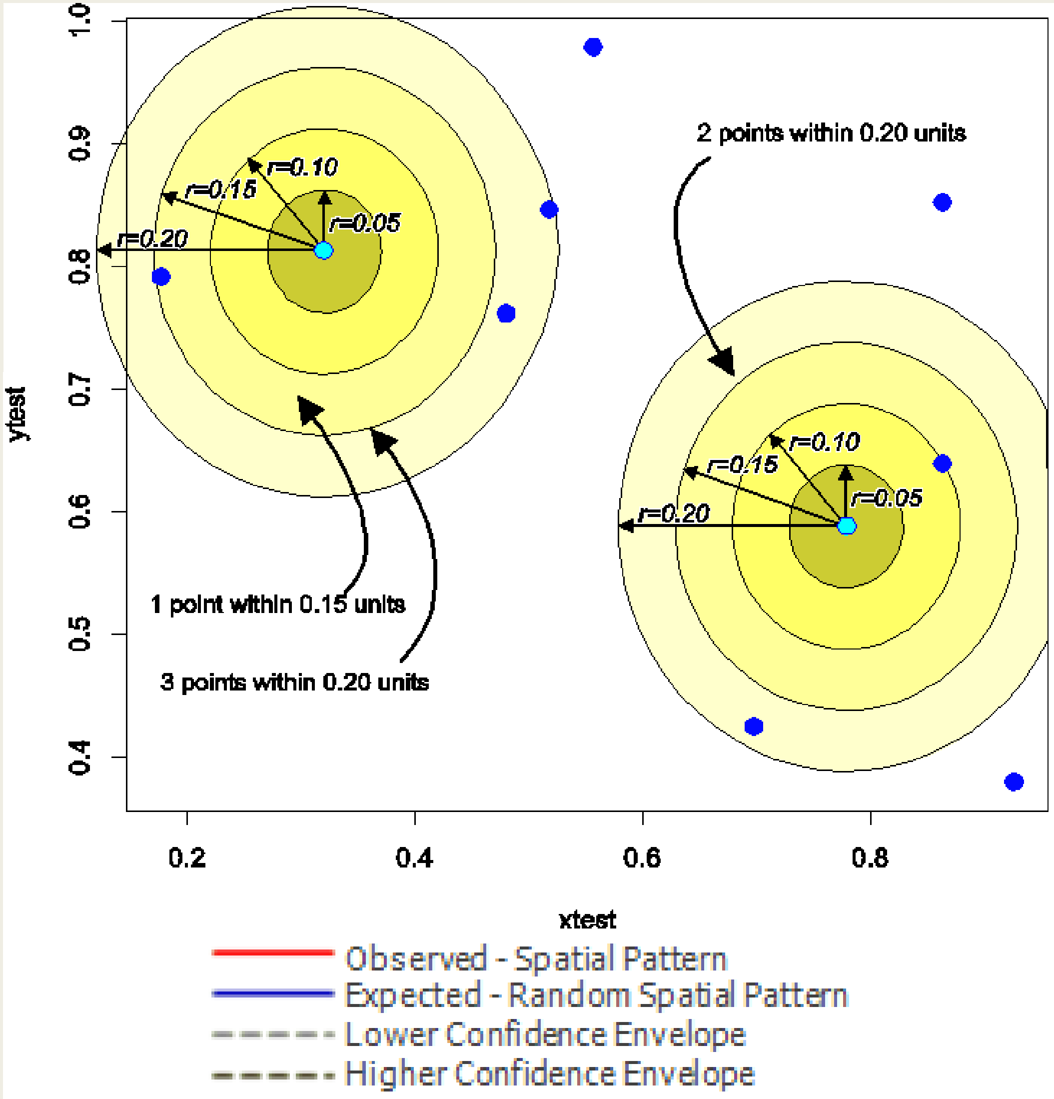
$\hat{G}(d)$

F-hat relates how far events are from randomly selected points.

- **Shallow or slow rise to maximum means clustering**
- **Quick rise to maximum means regularity.**

Second order properties

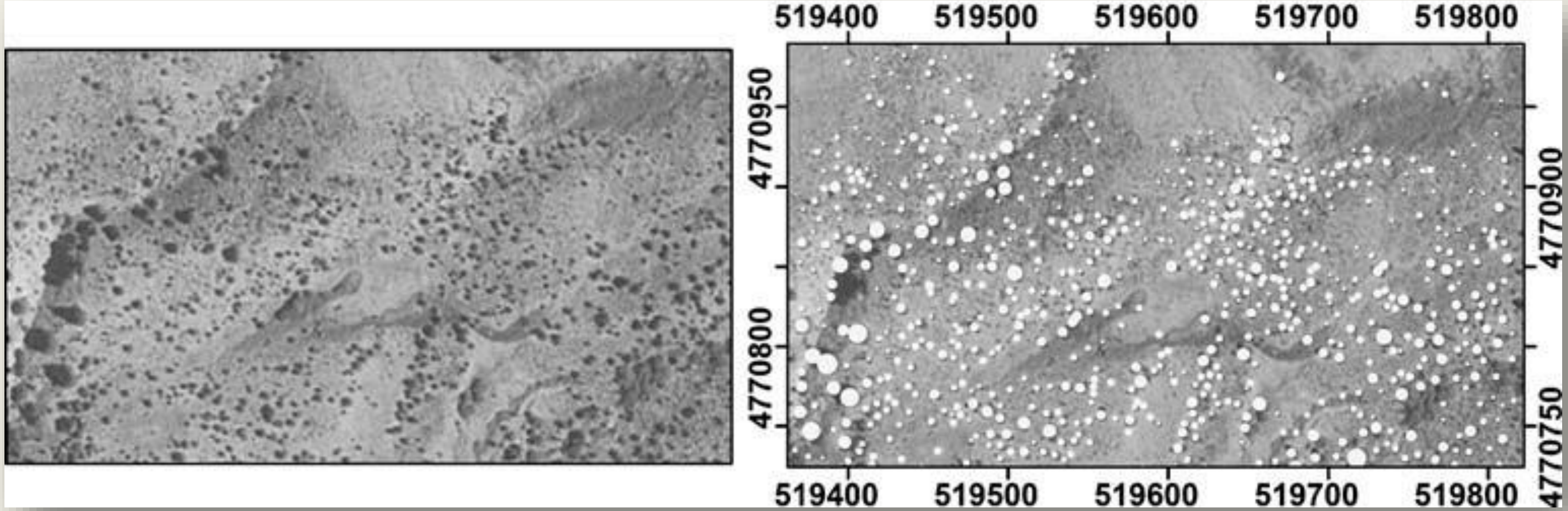
- Measuring spatial dependence –based on distances of points from one another
- K-function (Ripley's K, Ripley 1976)
  - Developed due to limitations with nearest neighbor distances
  - K is based on all the distance between points



Application: Woodland development

Evaluation of ecological processes shaping woodland expansion in the Great Basin USA.

- Observed inhibition between woody plants at short distances, indicating competition for resources between plants.
- Observed clustering within 30-60 m, attributed to the seed dispersal by birds with small territories



Strand et al. 2007