UNIVERSITI SAINS MALAYSIA

R ConfeRence 2024

Spatial Epidemiology

Using R

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https://github.com/drhazlienor/R-Conference-2024.git

Overview

Epidemiology

Epidemiology is the study of the **distribution** and **determinants** of health-related states or events in specified populations, and the application of this study to the control of health problems (CDC).

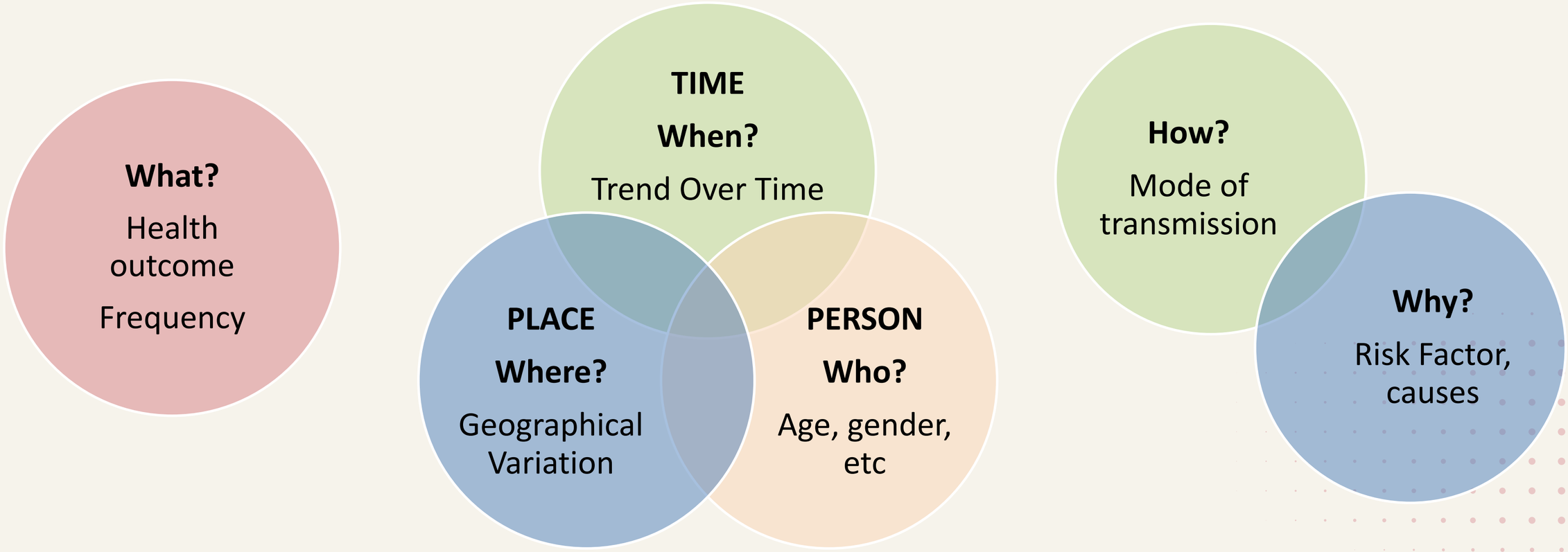
Overview

Spatial Epidemiology

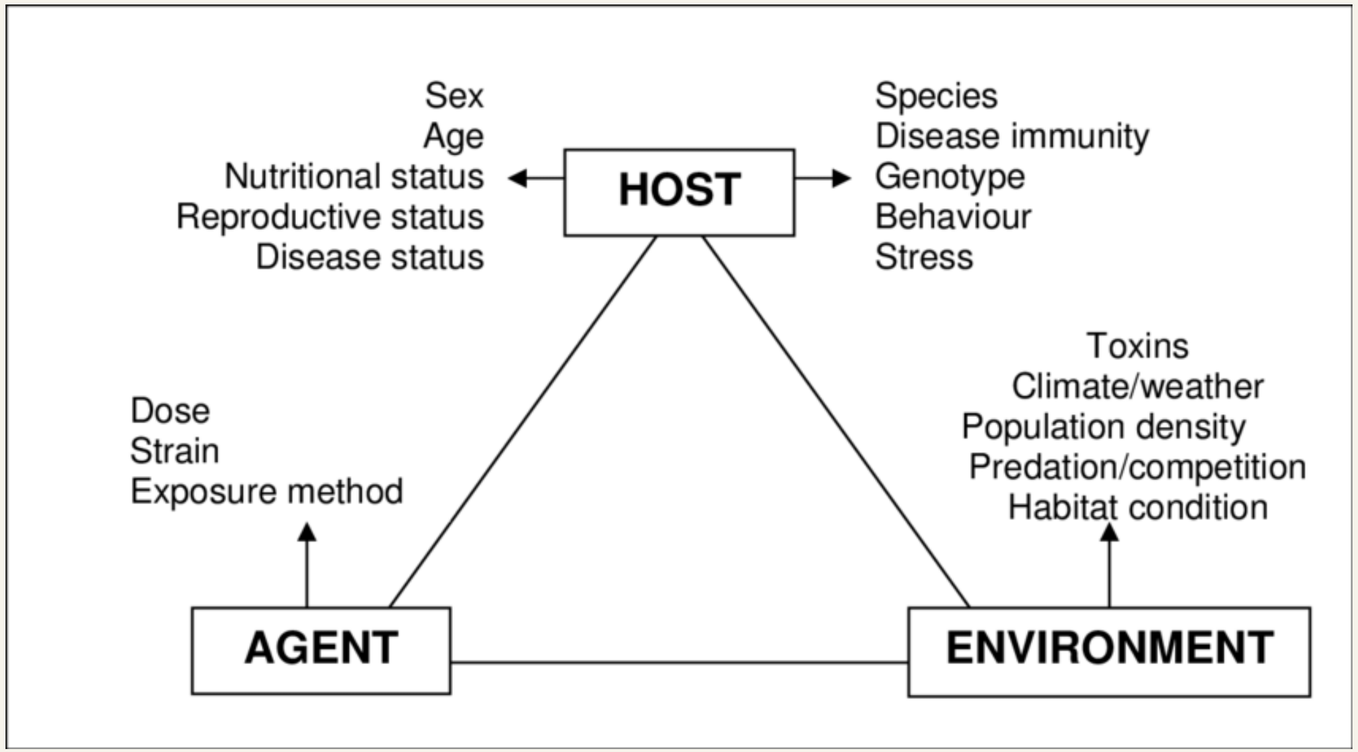
Spatial epidemiology is the description and analysis of geographically indexed health data with respect to demographic, environmental, behavioral, socio-economic, genetic, and infectious risk factors (Elliot, 2004).

Overview

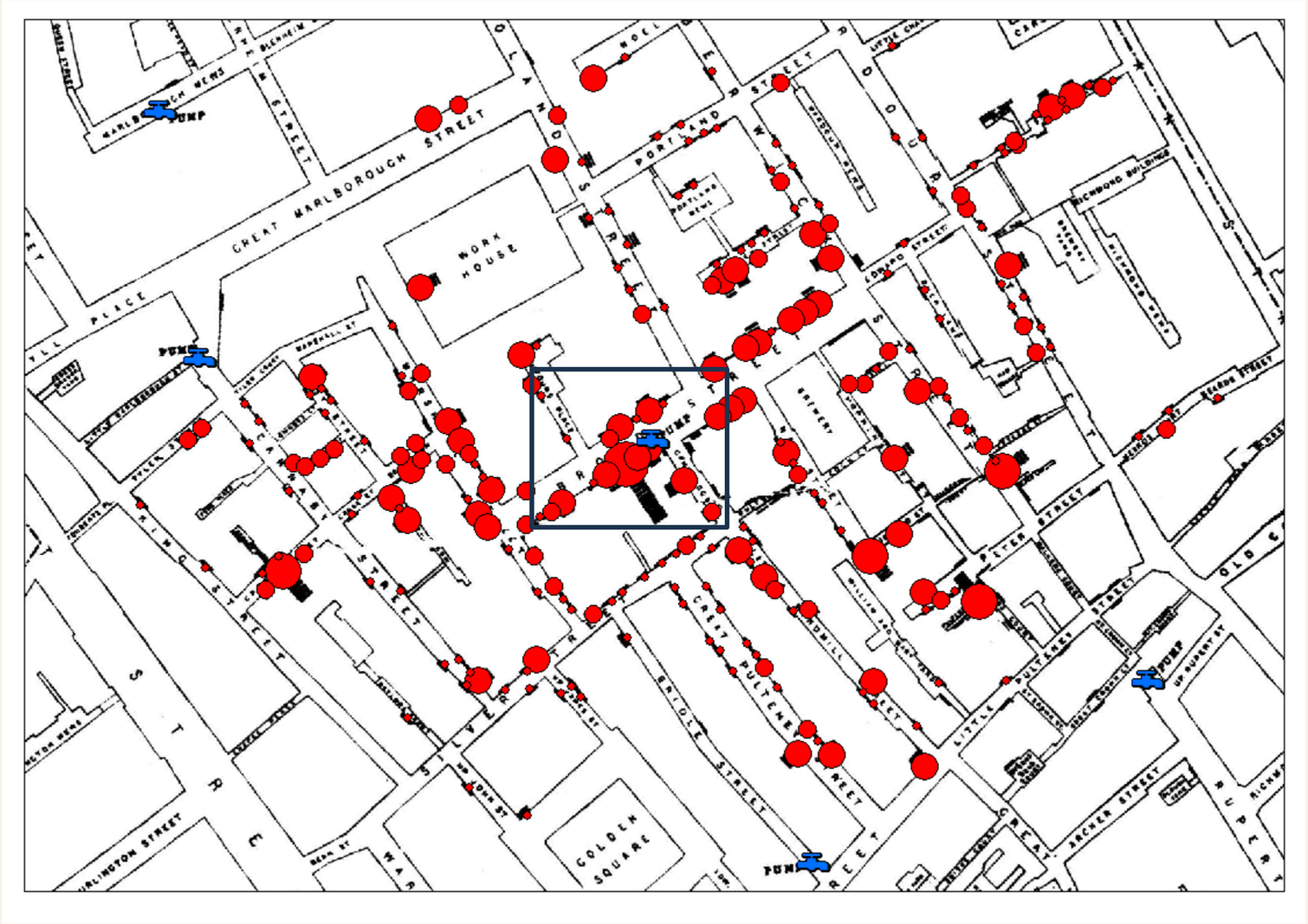
Epidemiology focuses on the triad of person, place, and time.



Learning Spatial Epidemiology?



Spatial Epidemiology



ROLE OF SPATIAL ANALYSIS IN PUBLIC HEALTH

Spatial Analysis

Identify hotspot & high risk areas

- helps identify areas with higher-than-expected disease rates or unusual clusters of cases.

Identifying Local Risk Factors

- Conventional non-spatial regression methods are not suitable for spatial disease data for two reasons: spatial dependency and spatial heterogeneity.

Modeling Disease Spread Based on Spatial Data

- Spatial Regression can forecast future disease outbreaks based on historical data and current risk factors.

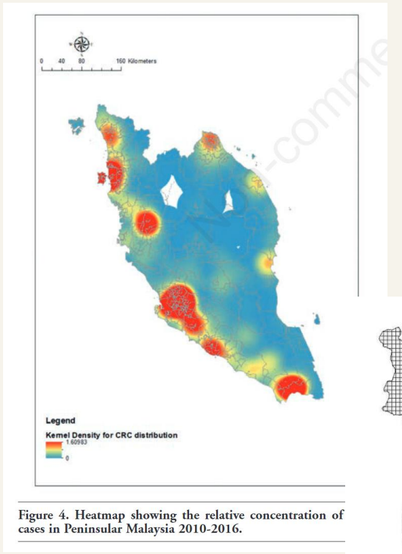
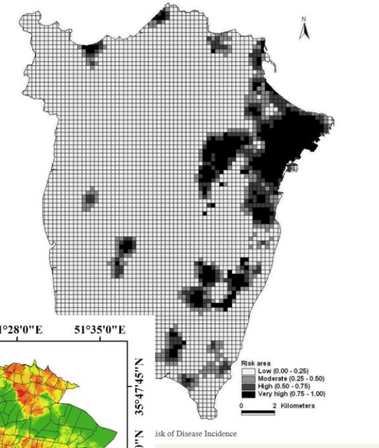
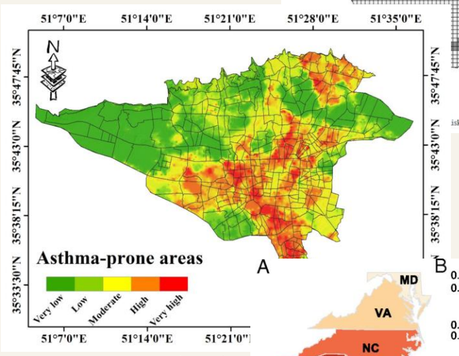
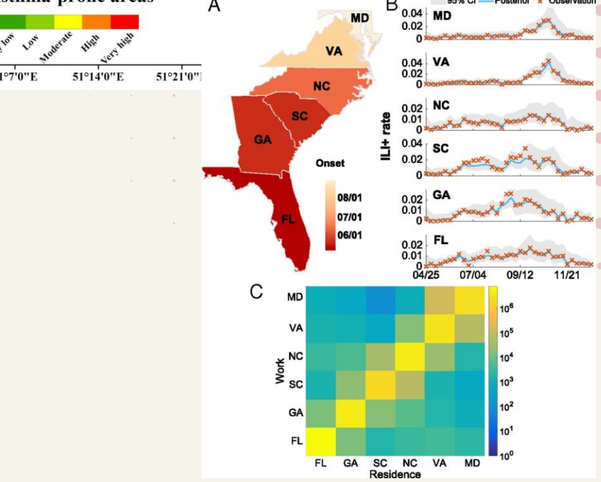


Figure 4. Heatmap showing the relative concentration of cases in Peninsular Malaysia 2010-2016.







Spatial Analysis

Targeting Vulnerable Populations

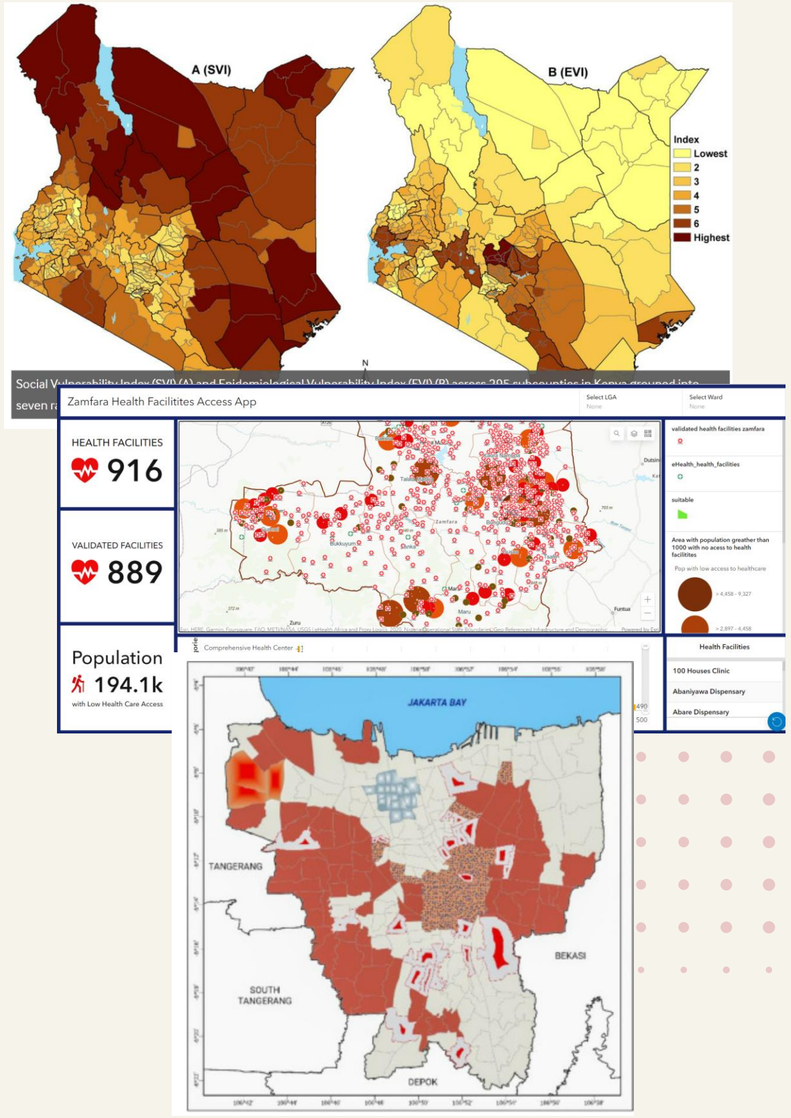
- Spatial epidemiology helps to locate populations most at risk, such as communities with limited healthcare access or poor living conditions.

Enhanced Surveillance Systems

- Incorporating spatial epidemiology improves the sensitivity and representativeness of disease surveillance systems.

Hypothesis Generation and Testing

- Spatial-temporal approaches allow investigators to generate and test hypotheses during outbreak investigations.



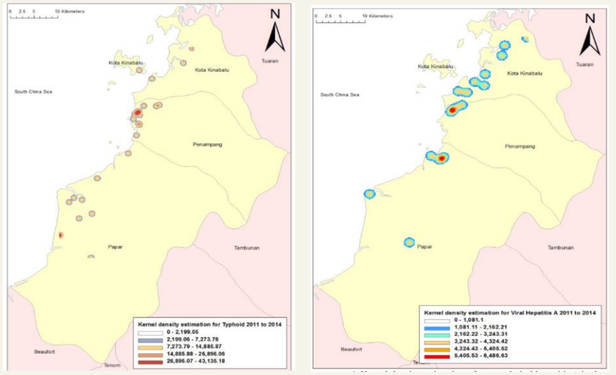
Spatial Analysis

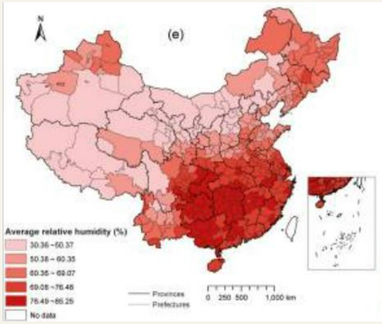
Identify Spatial Interaction Between Diseases

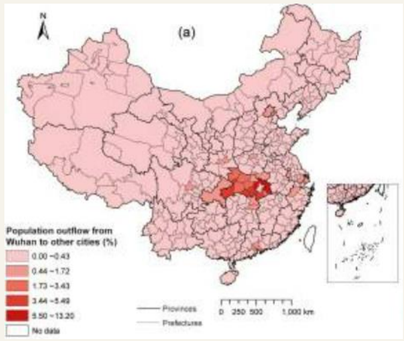
- Identify emerging outbreaks or co-clustered diseases, reveal areas where multiple diseases cooccurrence, multiple outbreaks.

Informing Prevention and Control Strategies

- Understanding spatial-temporal transmission helps to design more effective prevention measures.







SPATIAL ANALYSIS

Spatial Analysis

Elliott et al (2000) identified four types of spatial analyses in epidemiology:

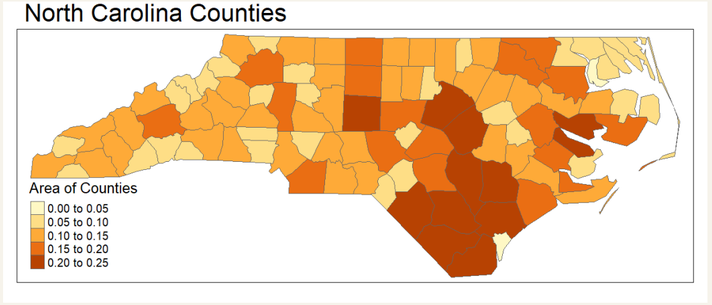
1. Disease mapping.
2. Geographical correlation studies.
3. Risk assessment in relation to point or line sources.
4. Cluster detection and disease clustering.

Types of Spatial Data

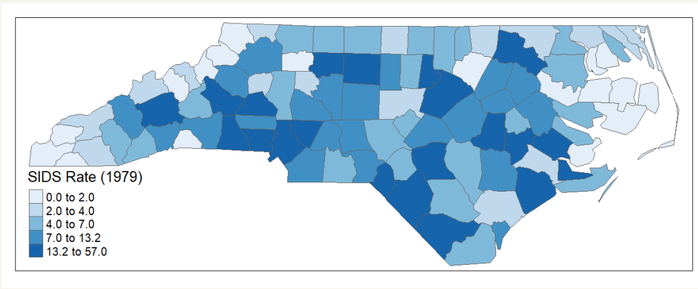
- summarizing individual-level data into broader geographic units or time
- Examples: Incidence rates or fatality rates aggregated by region or country.

Areal data

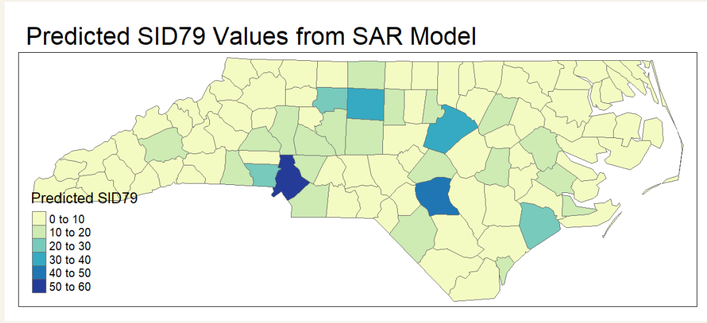
Population Mapping



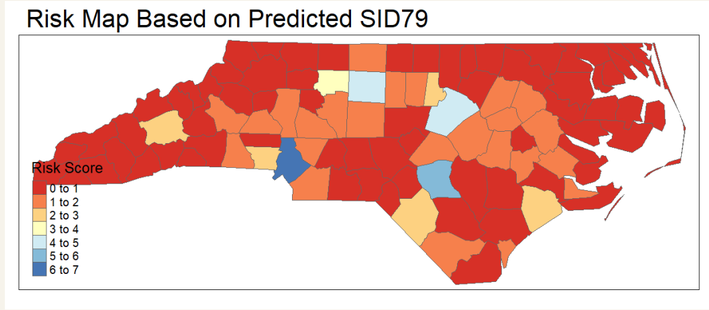
Incidence Mapping



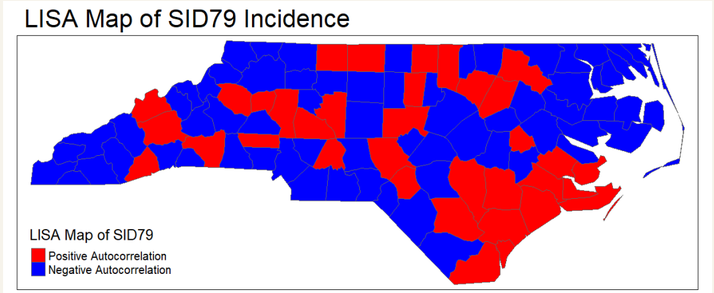
Prediction Analysis & Mapping



Risk Analysis & Mapping



Spatial Autocorrelation Analysis

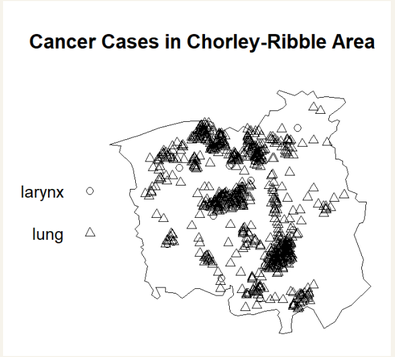


Types of Spatial Data

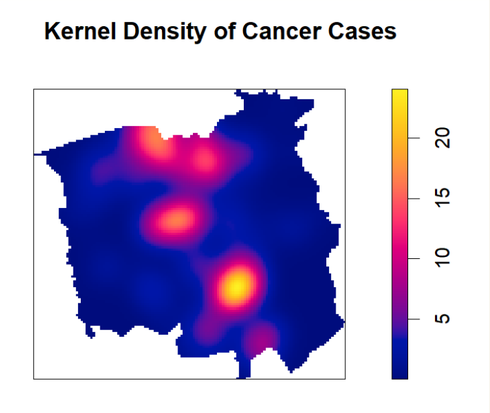
- Raw, individual-level data that represents specific events
- Examples: Health events such as disease or deaths

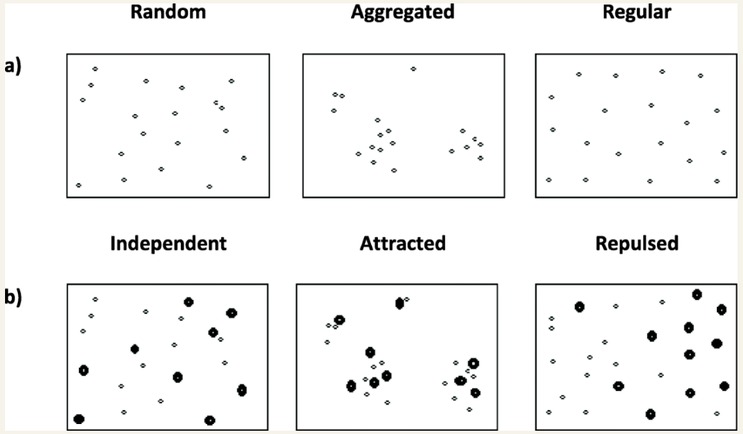
Point data

Disease/Event Mapping

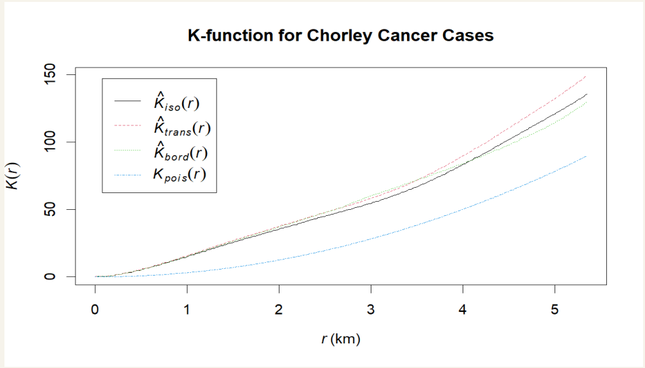


Spatial Intensity

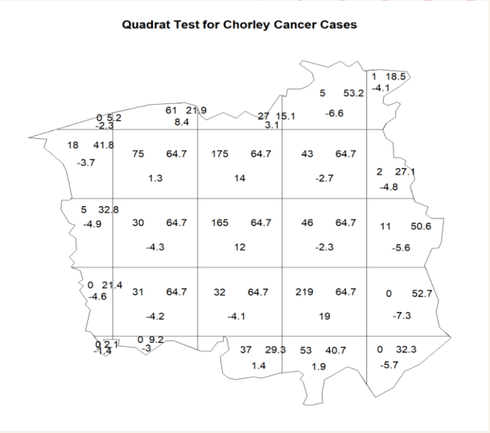




Spatial Clustering



Quadrat Analysis

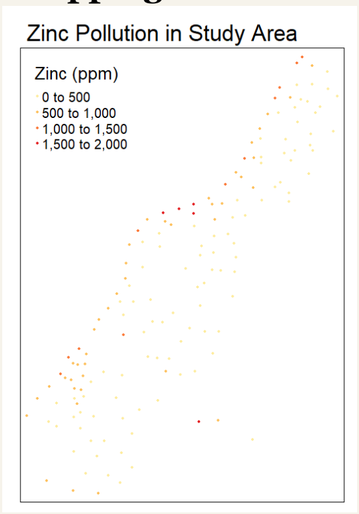


Types of Spatial Data

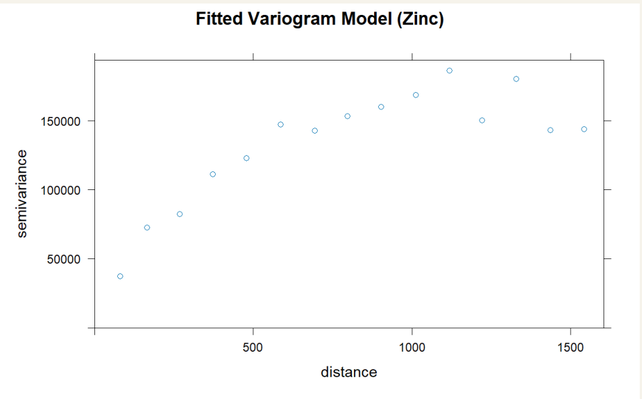
- involves data collected at specific points or over continuous areas
- uses a model fitted using the distances between observations to interpolate values observed at point to unobserved points
- Examples: Air pollution measured at different station, sentinel sampling for influenza

Geostatistical data

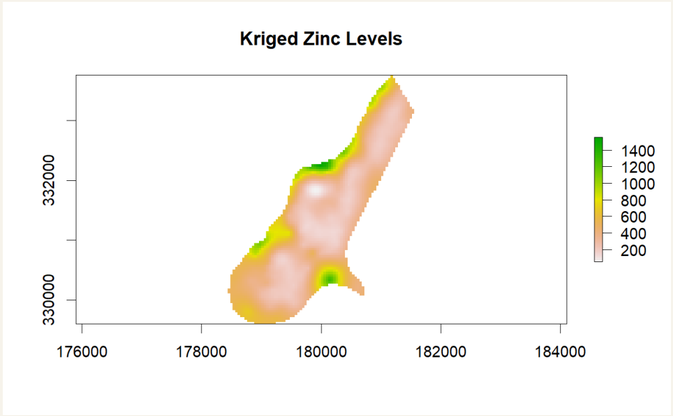
Mapping



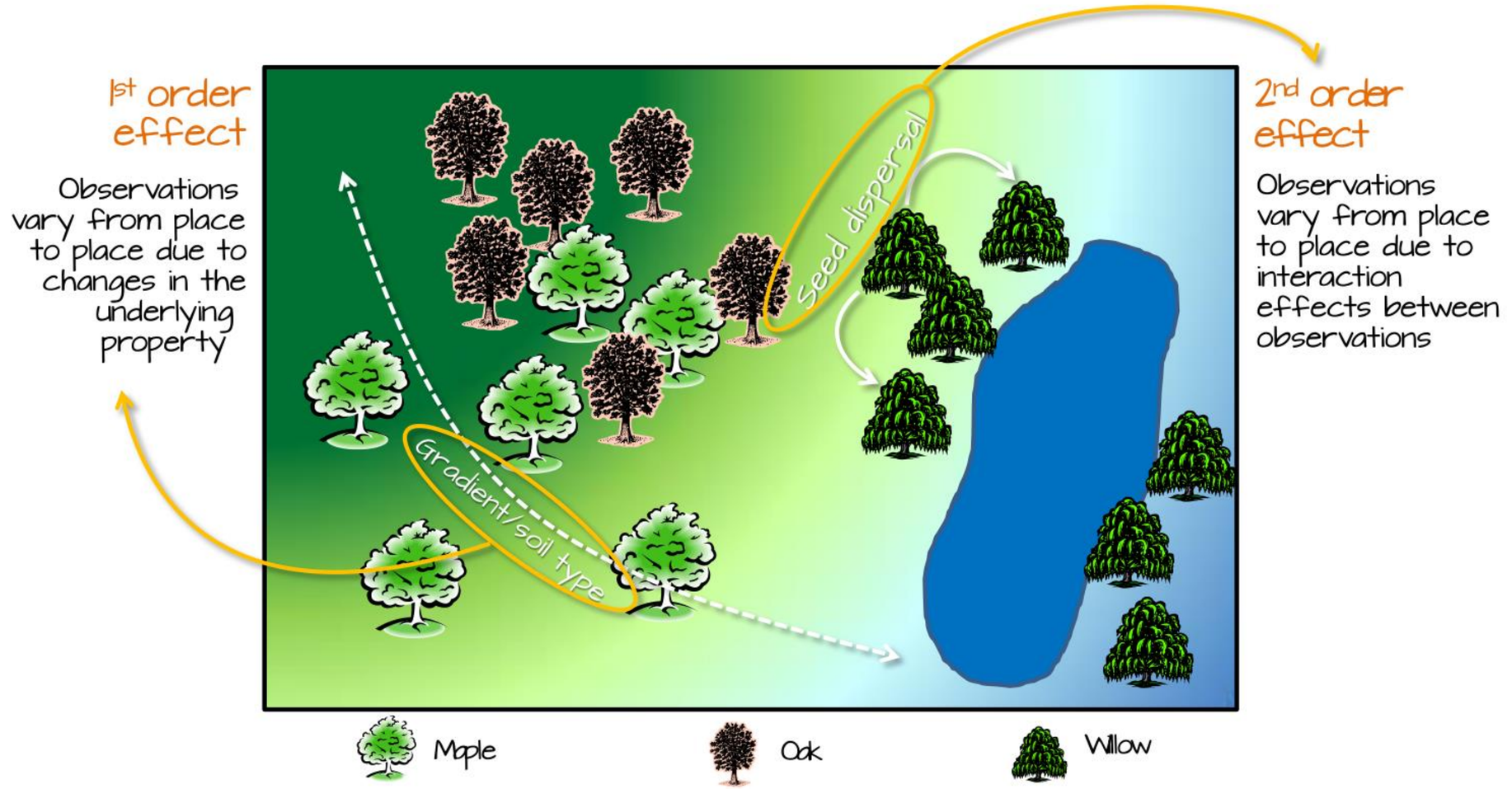
Variogram



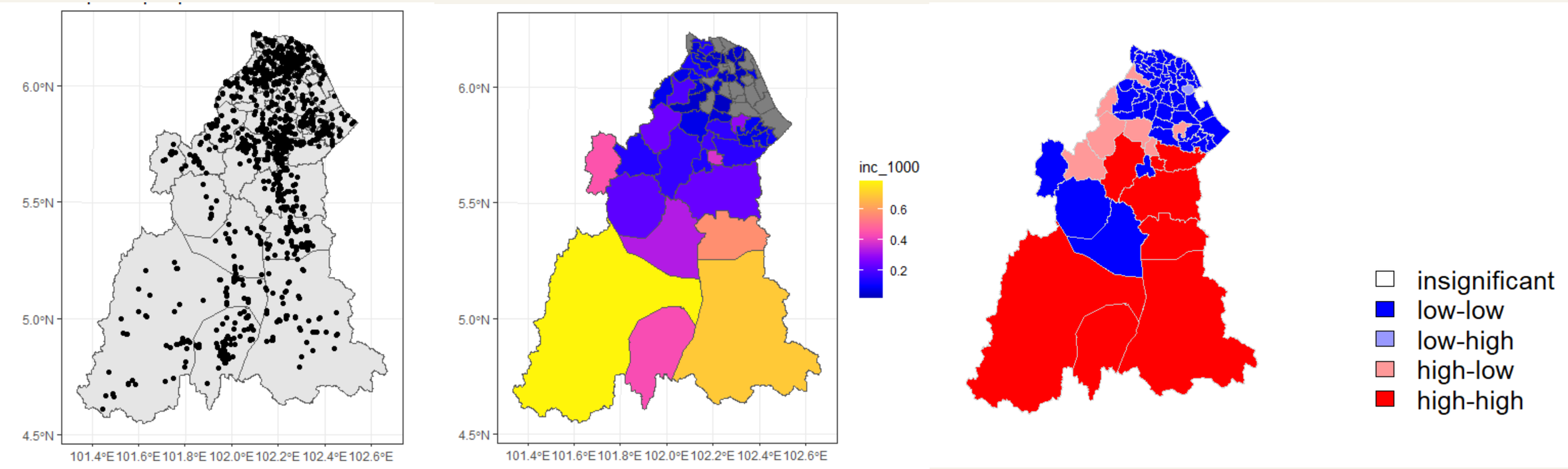
Kriging



PROPERTIES


1st order effect
Observations vary from place to place due to changes in the underlying property
Seed dispersal
Gradient/soil type
2nd order effect
Observations vary from place to place due to interaction effects between observations
Maple
Oak
Willow

Spatial Analysis



SPATIAL ANALYSIS USING R

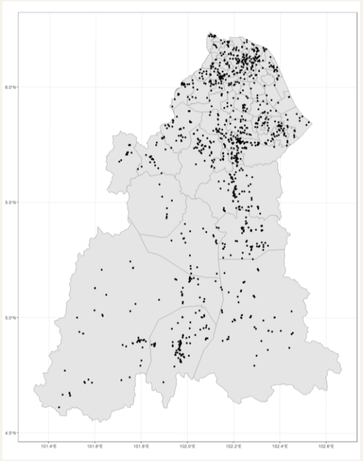
Why R for spatial analysis?

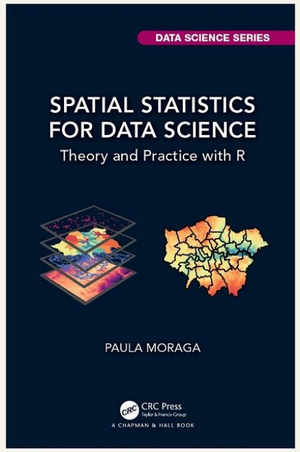
- **Increased Functionality**: Over the past decade, R has gained a growing number of packages for spatial data analysis, improving its capabilities and integration.
- **Standardized Approach**: The sp package was developed to provide standardized classes and methods for spatial data, making it easier to organize, store, and analyze spatial information consistently.
- **Data Compatibility**: The sp package facilitates compatibility and data movement across different spatial statistics packages by adopting a unified set of classes and methods.
- **Enhanced Methods**: It includes well-tested methods for plotting, summarizing, and combining spatial data types, as well as interfaces with GIS systems for reading, writing, and projecting spatial data.
- **Advanced Visualization**: The package supports advanced plotting techniques, including Lattice plots and combining various spatial elements with map features, enhancing the visualization and interpretation of spatial data.

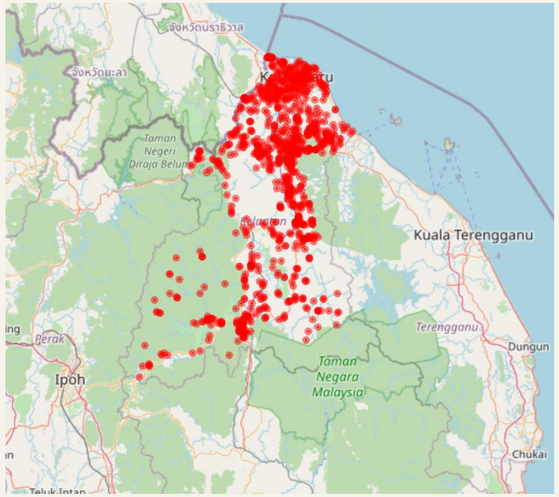
Geospatial Data Sources

- **Department of Statistic Malaysia (DOSM)**
- **MET Malaysia**
- **R packages**
  - **rnaturalearth :** facilitates interaction with Natural Earth map data including cultural (e.g., country boundaries, airports, roads, railroads) and physical (e.g., coastline, lakes, glaciated areas) datasets.
  - **OpenStreetMap:** gives access to open street map raster images
  - **cshapes:** Historical country boundaries (1886-today)
  - **Elevatr:** provides access to elevation data
  - **mapme.biodiversity:** open datasets related to biodiversity conservation including WorldClim and NASA FIRMS.

https://www.paulamoraga.com/book-spatial/r-packages-to-download-open-spatial-data.html







R Packages

https://cran.r-project.org/web/views/Spatial.html

Handling Spatial Data

- **sf:** Handles simple features (points, lines, polygons), asy integration with tidyverse packages.
- **terra:** high-performance operations on both raster and vector data

Point Pattern Analysis

- **spatstat:** is a family of R packages for analysing spatial point pattern data. It has extensive capabilities for exploratory analysis, statistical modelling, simulation and statistical inference.

  http://www.spatstat.org/
- **spatialEco**: Nearest neighbor analysis

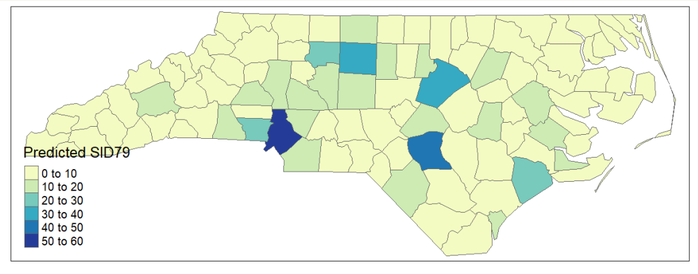
Geostatistical Data Analysis

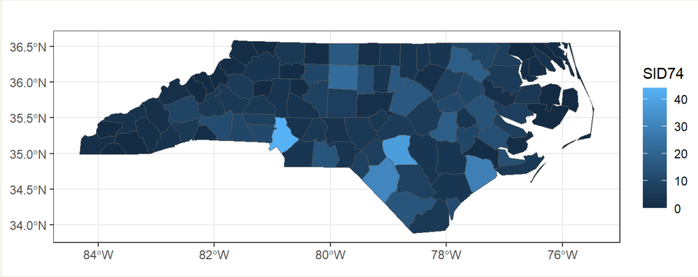
- **gstat:** Used for geostatistical modeling (e.g., kriging, variogram analysis).

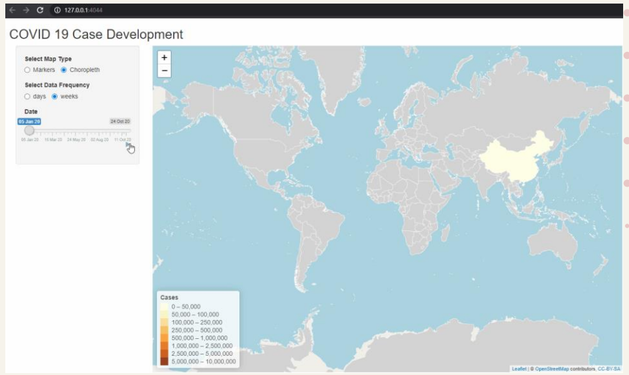
R Packages

Visualizing Spatial Data

- **tmap package:** thematic mapping, allows for interactive spatial data mapping
- **ggplot2 package:** has a built-in support for sf objects with the geom_sf function, spatial visualization capabilities can be further extended with **ggspatial**
- **mapview and leaflet packages:** provide methods to view spatial objects interactively, usually on a web mapping base



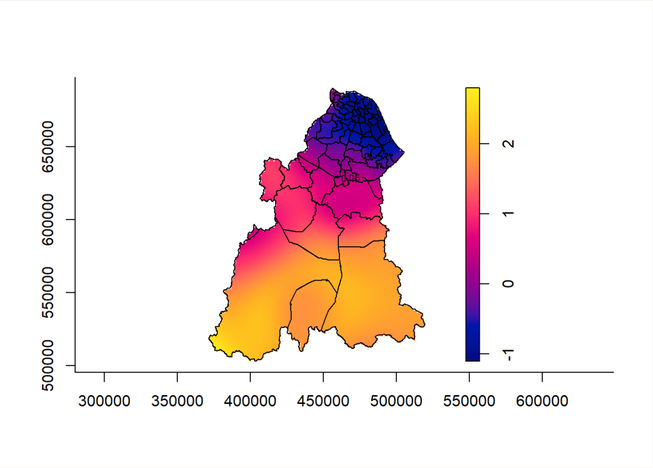


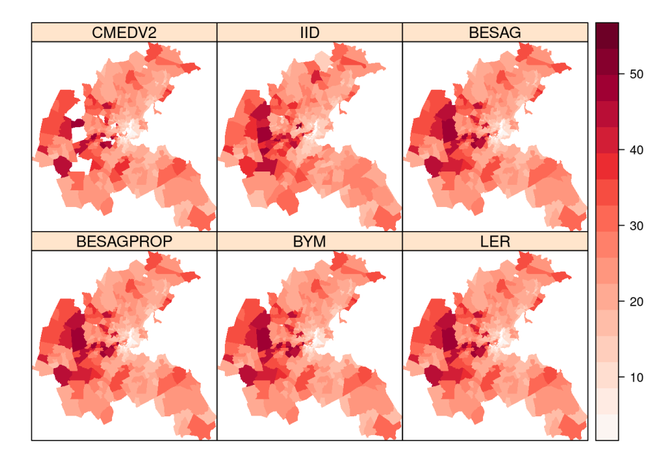


R Packages

Areal data analysis and risk mapping

- **spdep:** provides global and local tests for spatial autocorrelation, including join-count tests, Moran's I, Geary's C, Getis-Ord G and others
- **GIStools:** Visual tools for spatial analysis (e.g., hotspot maps, choropleth maps)
- **spatialEpi:** provides implementations of cluster detection and disease mapping functions, including Bayesian cluster detection, and supports strata
- **sparr:** provides approach to relative risks
- **INLA:** Supports Conditional Autoregressive (CAR) and Stochastic Partial Differential Equation (SPDE) models, ideal for disease mapping.





References

- https://cran.r-project.org/web/views/Spatial.html
- Brunsdon, C., & Comber, L. (2018). An introduction to R for spatial analysis and mapping.
- Gimond M. Intro to GIS and Spatial Analysis. 2023.
- Haining, R., & Maheswaran, R. (2016). Geographic Information Systems in Spatial Epidemiology and Public Health. In Handbook of Spatial Epidemiology (pp. 87-116). Chapman and Hall/CRC.
- Lawson, A. B., Banerjee, S., Haining, R. P., & Ugarte, M. D. (Eds.). (2016). Handbook of spatial epidemiology. CRC press.
- Lin CH, Wen TH. How Spatial Epidemiology Helps Understand Infectious Human Disease Transmission. Trop Med Infect Dis. 2022 Aug 2;7(8):164. doi: 10.3390/tropicalmed7080164. PMID: 36006256; PMCID: PMC9413673.
- Moraga P. Spatial Statistics for Data Science: Theory and Practice with R. CRC Press; 2023.

THANK YOU

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