Day 1 – Spatial & Spatio-temporal Modelling

About me

- Completed a Bachelor's degree in Statistics at FUTA
- Master's in Mathamatical Sciences at AIMS-Tanzania
- PhD in Statistics and Epidemiology at University of Lancaster
- Postdoc at University of Manchester
- Lecturer in Statistics at the University of Manchester

Overview of the 3 days

- Spatial and spatio-temporal analysis (different likelihoods)
- Joint modelling of multiple malaria processes
- Non-stationary spatial processes
- Hybrid machine learning + geostatistical models

Linear Regression

- Goal: Model a continuous response variable as a linear function of predictors.
- Model $Y = X\beta + \epsilon$, where $\epsilon \sim N(0, \sigma^2)$
- Key Assumption
  - Linearity
  - Independence
  - Homoscedasticity (constant variance)
  - Normality of errors

Generalized Linear Models (GLMs)

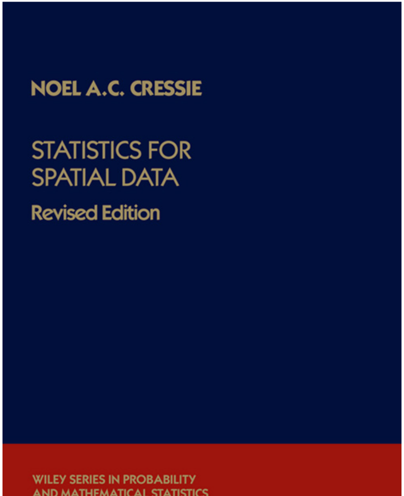
- Extension of linear models to handle non-normal response distributions.
- Three components:
  - Random component: Distribution from the exponential family (e.g., Binomial, Poisson).
  - Systematic component: Linear predictor $\eta = X\beta$.
  - Link function: Relates \$\mathbb{E}(Y) ~~~ \text{to} ~~~ \eta \$.
- Examples:
  - Logistic regression for binary outcomes – `logit link function`
  - Poisson regression for count data – `log link function`

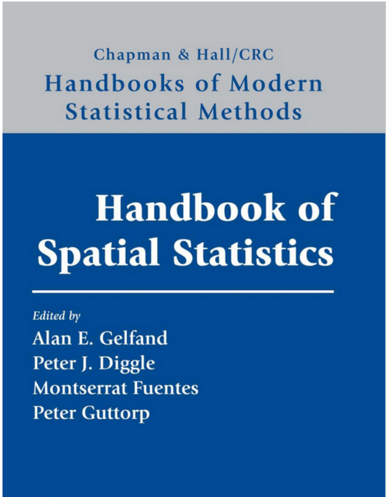
Why Spatial Statistics?

- **Spatial Dependence:**
  Observations collected at nearby locations are often more similar than those farther apart.
- **Ignoring Spatial Structure:**
  - Leads to biased parameter estimates.
  - Underestimates uncertainty.
  - Misses important spatial patterns.
- **Applications:**
  - Disease mapping
  - Environmental monitoring
  - Agricultural field trials
- **Goal:**
  Account for spatial correlation to improve prediction and inference.

Spatial Analysis

Spatial Statistics





Classification of spatial statistics

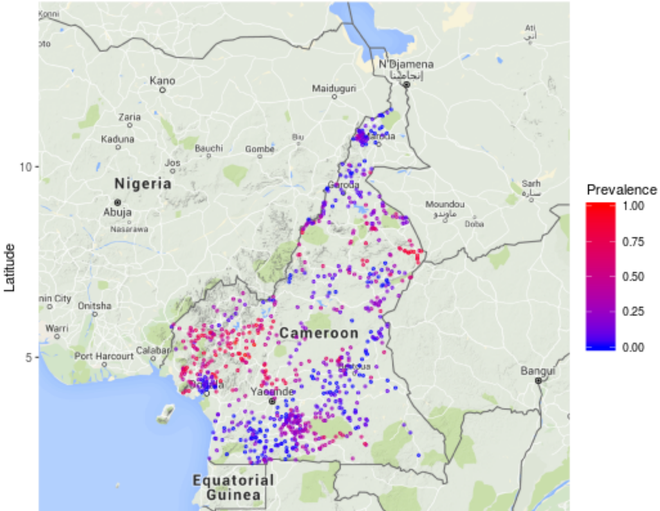
Cressie's book classifies spatial statistics according to **data format**:

1. Geostatistical data
2. Lattice data
3. Point patterns

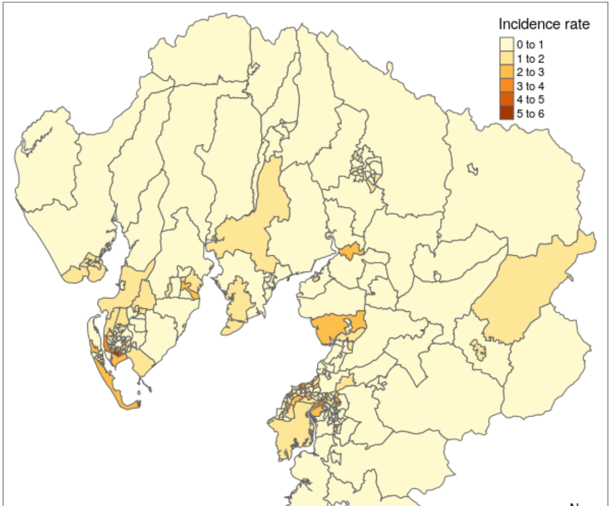
Gelfand's book classifies spatial statistics according to **spatial variation**:

1. Discrete spatial variation
2. Continuous spatial variation

Geostatistical data: River blindness in Cameroon



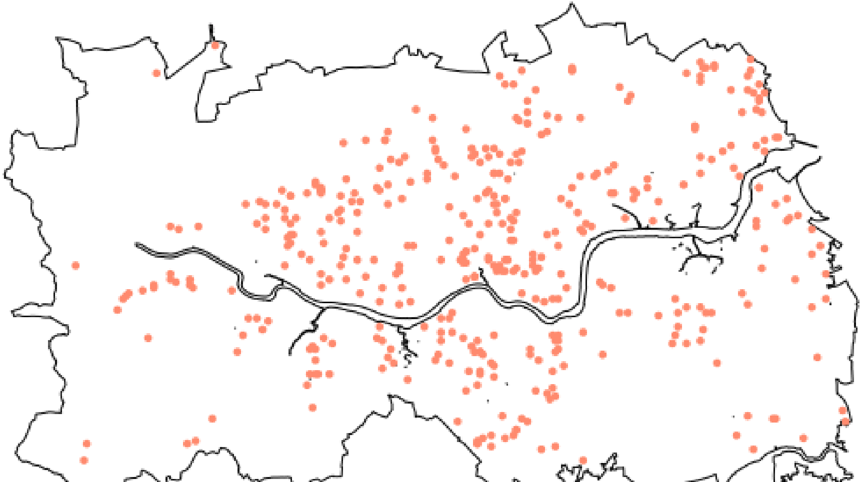
Lattice Data: COPD emergency admission



The University of Manchester

MANCHESTER 1824

Point pattern: Primary biliary cirrhosis data



Model-based Geostatistics

Modelling Geostatistical Data – Model-based Geostatistics

- The term **Model-based Geostatistics (MBG)** was coined by Peter Diggle in 1998 (Diggle, Tawn, and Moyeed 1998; Diggle and Giorgi 2019).
- MBG applies general principles of statistical modelling and inference to the analysis of geostatistical data.
- It emphasises the use of likelihood-based inference.
- `and the use of a latent spatial process (Gaussian or stochastic process)`

References

Diggle, Peter, and Emanuele Giorgi. 2019. *Model-Based Geostatistics*. CRC Press.

Diggle, Peter, Jonathan Tawn, and Rana Moyeed. 1998. "Model-Based Geostatistics." *Journal of the Royal Statistical Society: Series C* 47: 299–350.