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Health on maps

Introduction to health geography

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Presenting information on health

Epidemiology

- Occurrence and distribution of health and disease in the population

			Disease, N (%)		
		N	Yes		No
Overall		60,000	10,000 (20 %)		50,000 (80 %)
Gender	Male	30,000	7,000 (23 %)		23,000 (77 %)
	Female	30,000	3,000 (10 %)		27,000 (90 %)
Age (years)	30-39	10,000	100 (1 %)		9,900 (99 %)
	40-49	20,000	500 (2.5 %)		19,500 (97.5 %)
	…				
	≥80	500	200 (40 %)		300 (60%)

Presenting information on health

Epidemiology

- Occurrence ... ase in the popula...

Overall					80 %)
Gender					77 %)
					90 %)
Age (years)					99 %)
	40-49	20,000	500 (2.5 %)		19,500 (97.5 %)
	…				
	≥80	500	200 (40 %)		300 (60%)

Results in a table

Results on a map → health geographics

John Snow - Deaths from cholera

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1854: Cholera outbreaks in London

Visualiazed the location of deaths on a map

→ Disease transmission
A water pump as the source

Early example of spatial epidemiology

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Overview

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Health geographics - Spatial epidemiology

Geographical distribution of health and disease

- What is geographical data
- Spatial/statistical methods and analyses
    - Vizualization
    - Disease mapping
    - Clustering
    - Exposure assessment
    - Associations and spatial regression
- Examples

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What is geographical data

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Geographical data

- Location
- Information (features, attributes)

Location

→ Address, municipality, school area

Information

→ Demography, health, building characteristics, SEP, …

What is geographical data

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Geographical Information System (GIS)

- Database and software system for storing and handling different data layers – i.e. locations and information/variables at each location (e.g. ArcGIS, Quantum-GIS)
- Applications for geographical, spatial and statistical analysis

What is geographical data

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Geographic coordinate systems

- A unique set of coordinates for each location (x, y)
- Different systems
  - UTM – Universal Transverse Mercator

    Grid-based coordinate system

    Easy to use, unit is a meter
  - Latitude/longitude (Degrees)

    Degree-based coordinate system

    Unit is a degree

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What is geographical data

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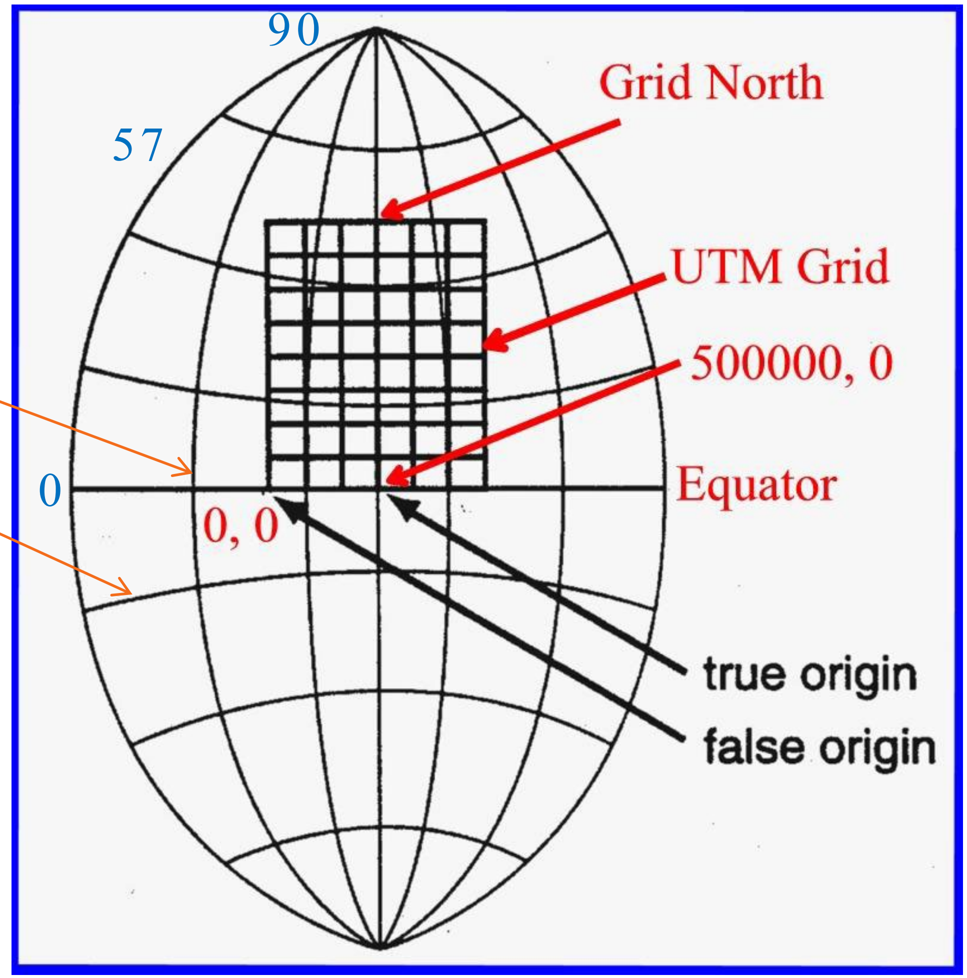
Latitude/Longitude grid



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What is geographical data

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Geocoding of locations

- Identify coordinates of a position

- Geocoding an address – apply a unique set of coordinates to the address

- Exact locations of all buildings know (e.g. in DK)
  - Exact linkage
  - Current addresses of all citizens
  - Historical addresses of all citizens

What is geographical data

Location - Point versus areal (polygon) data

Points

- Exact location – a set of (x,y) coordinates
- E.g. of buildings/addresses

Areal data (polygons)

- Data aggregated in polygons
- Administrative boundaries (e.g. municipality)

What is geographical data

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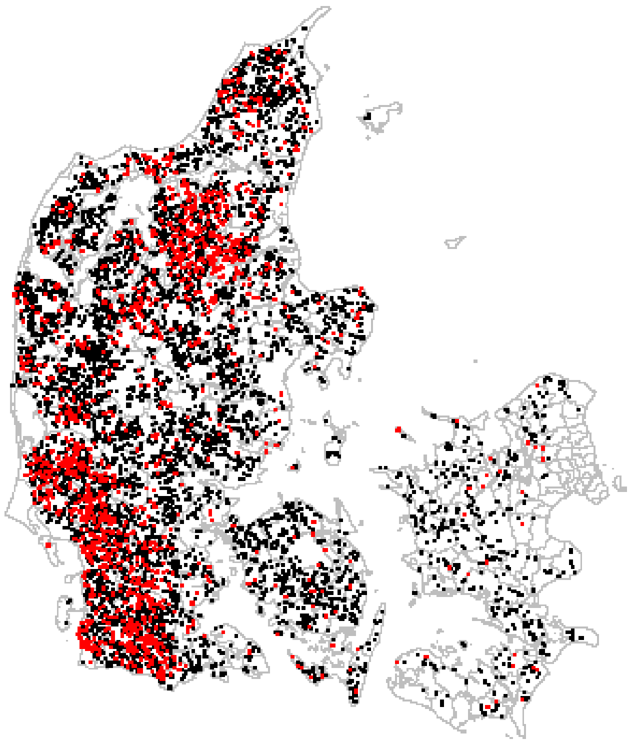
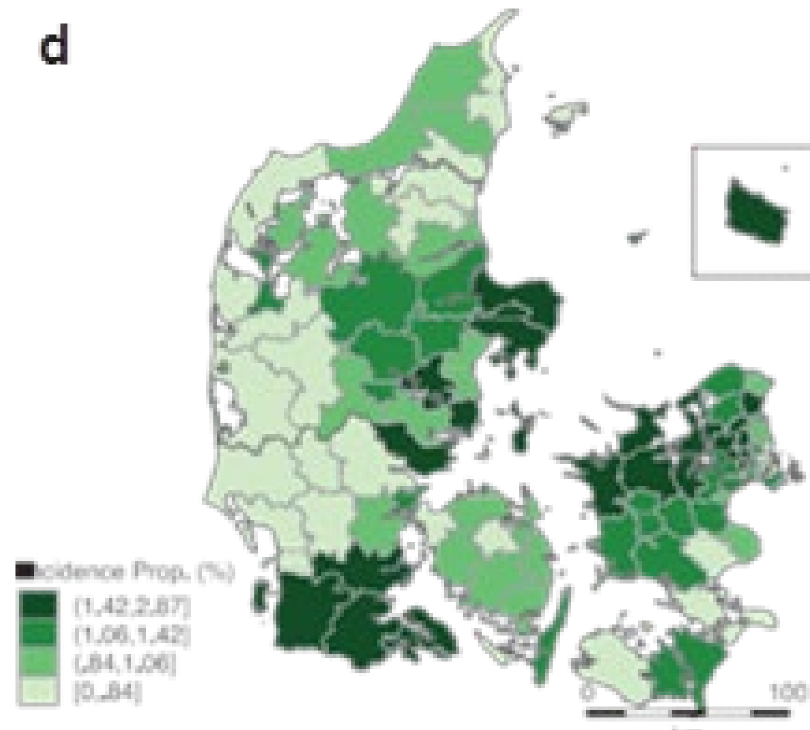
Salmonella in dairy herds



Ersbøll et al (2010) PVM

Incidence of ADHD



KB Madsen et al. (2015) Int J Health Geogr

What is geographical data

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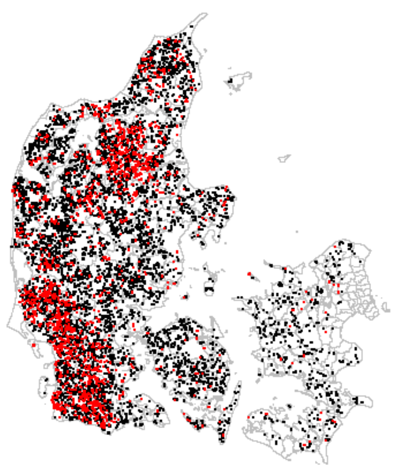
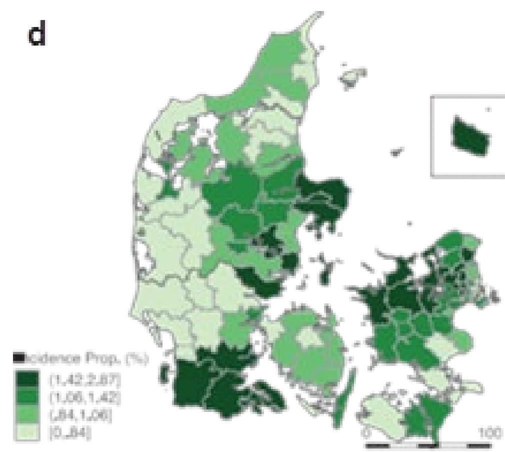
Areal data vs point data

- Modifiable areal unit problem (MAUP)
- Ecological fallacy – association estimated at an aggregated level may not apply to individual level
- Methods used for analysis depends on type of data





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Danish registers - History

Long tradition for registers of the Danish (and Nordic) population

Births and deaths have been registered in church records since 1645

1968: Civil Registration System (CPR)
Unique personal identification number (given at birth or immigration)

National Patient Register in 1977

National Prescription Register in 1995


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Optegnelse

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Danish population registers

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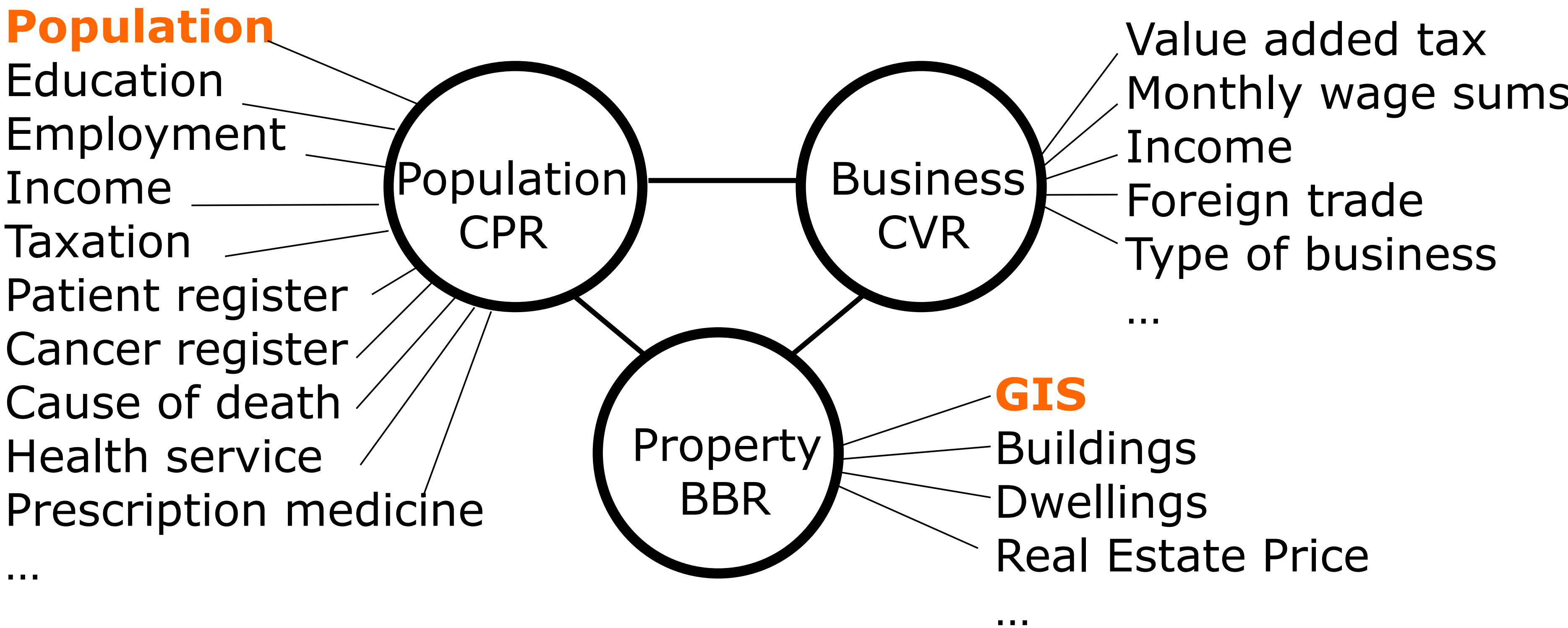

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Scandinavian Journal of Public Health, 2011, Suppl 7

Geographical data

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Combining register-based health data and information about geographical location

Addresses in Denmark

→ Approx. 2.5 mill addresses

→ Geocoded, coordinates in Building and Housing Register (BBR), publicly available dataset

Geographical location

→ Place of work

→ Place of residence

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Geographical analysis

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Purposes

- Visualization
- Disease mapping
    - Deriving smooth maps
- Clustering
    - Identifying areas with hot/cold spots
- Exposure assessment
- Spatial regression and associations
    - Association between exposure and outcome taking the spatial correlation between individuals into account

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Visualization of data

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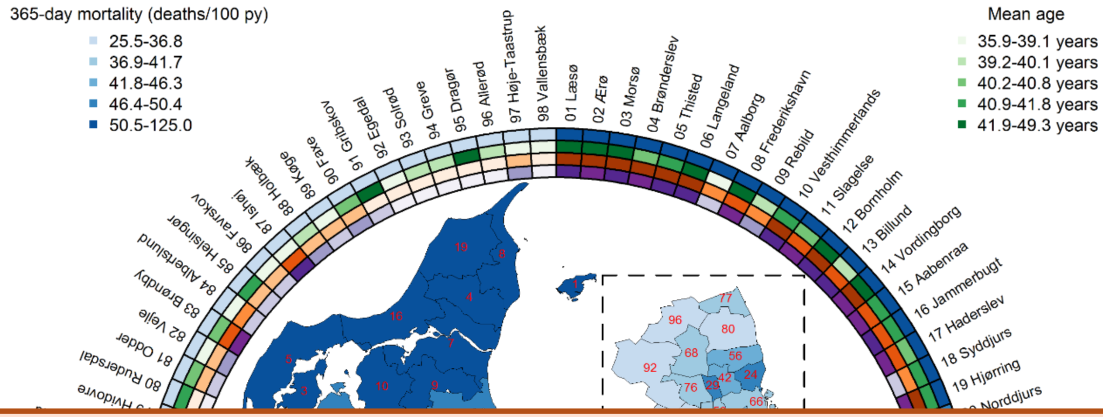

Visualizing geographical data on a map

RINGMAP

Map of Denmark visualizing the correlation between AMI mortality and neighbourhood characteristics

Central map: Mortality among individuals with incident AMI

Rings: Neighbourhood characteristics

Visualization of data

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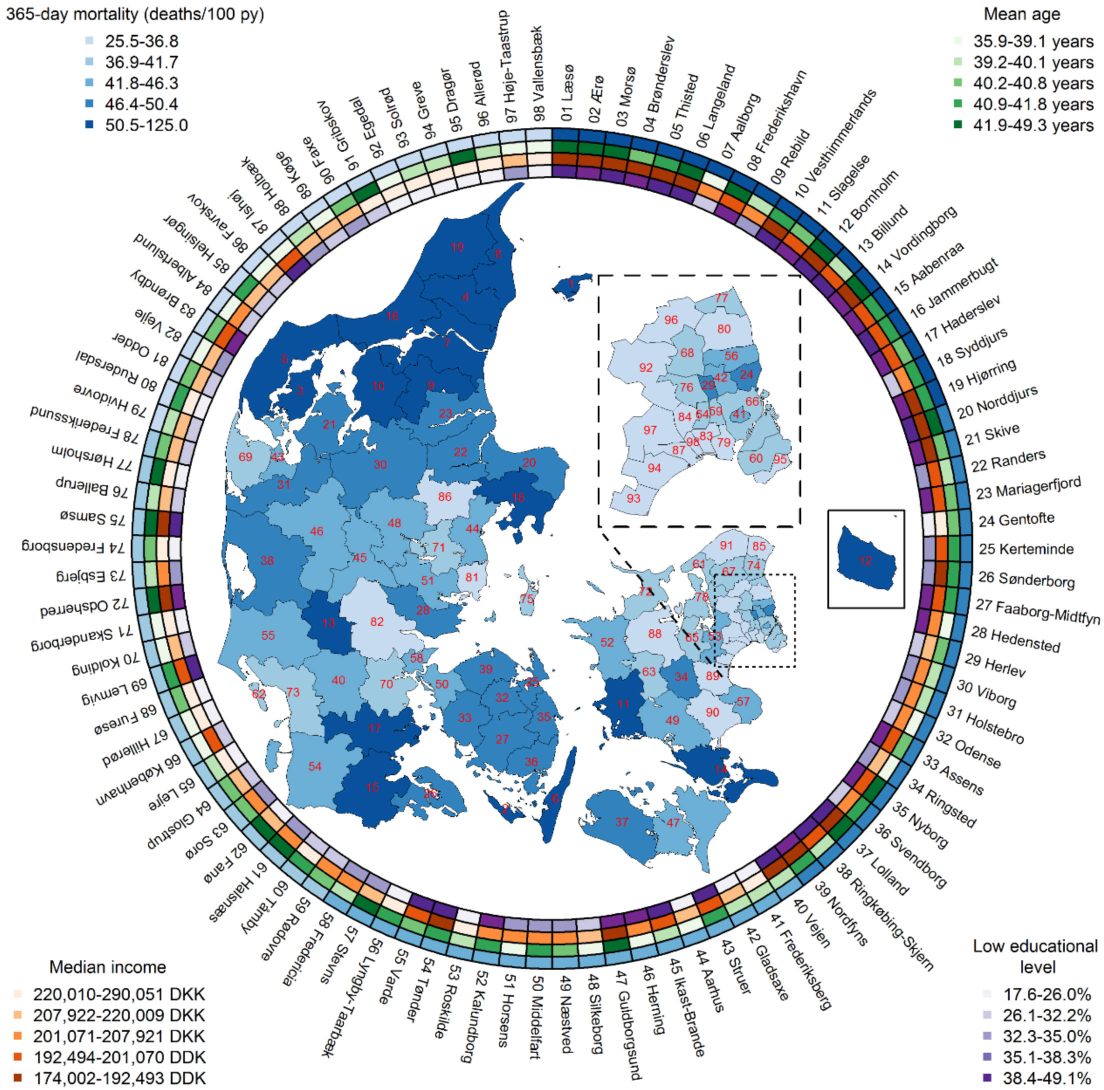

Visualizing geographical data on a map

Disease mapping

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Deriving smooth maps based on point data

Binary variable

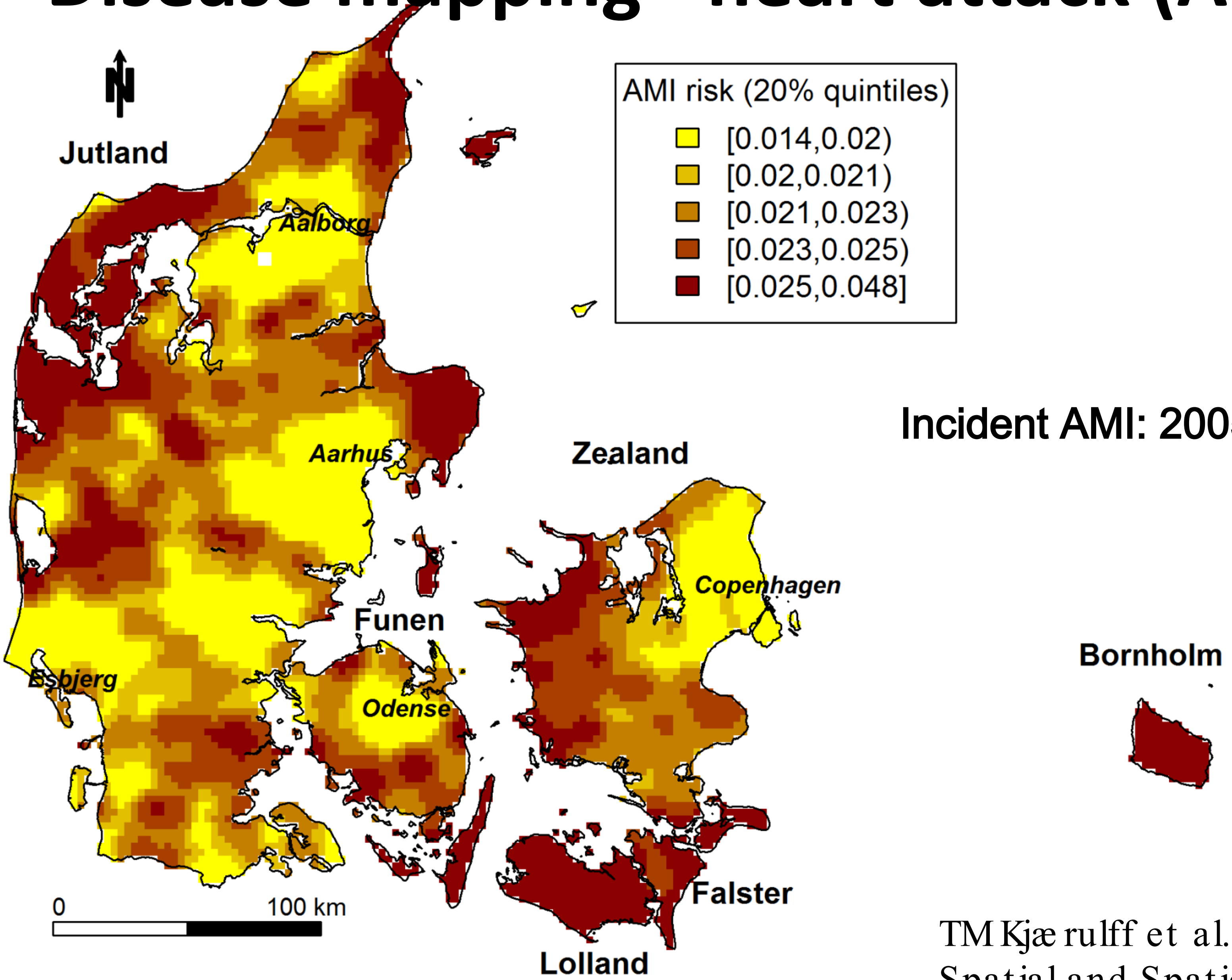
- Kernel density estimation (KDE)

Continuous/quantitative variable

- Inverse distance weighting (IDW)
- Kriging (geostatistical analysis)

Disease mapping - heart attack (AMI)

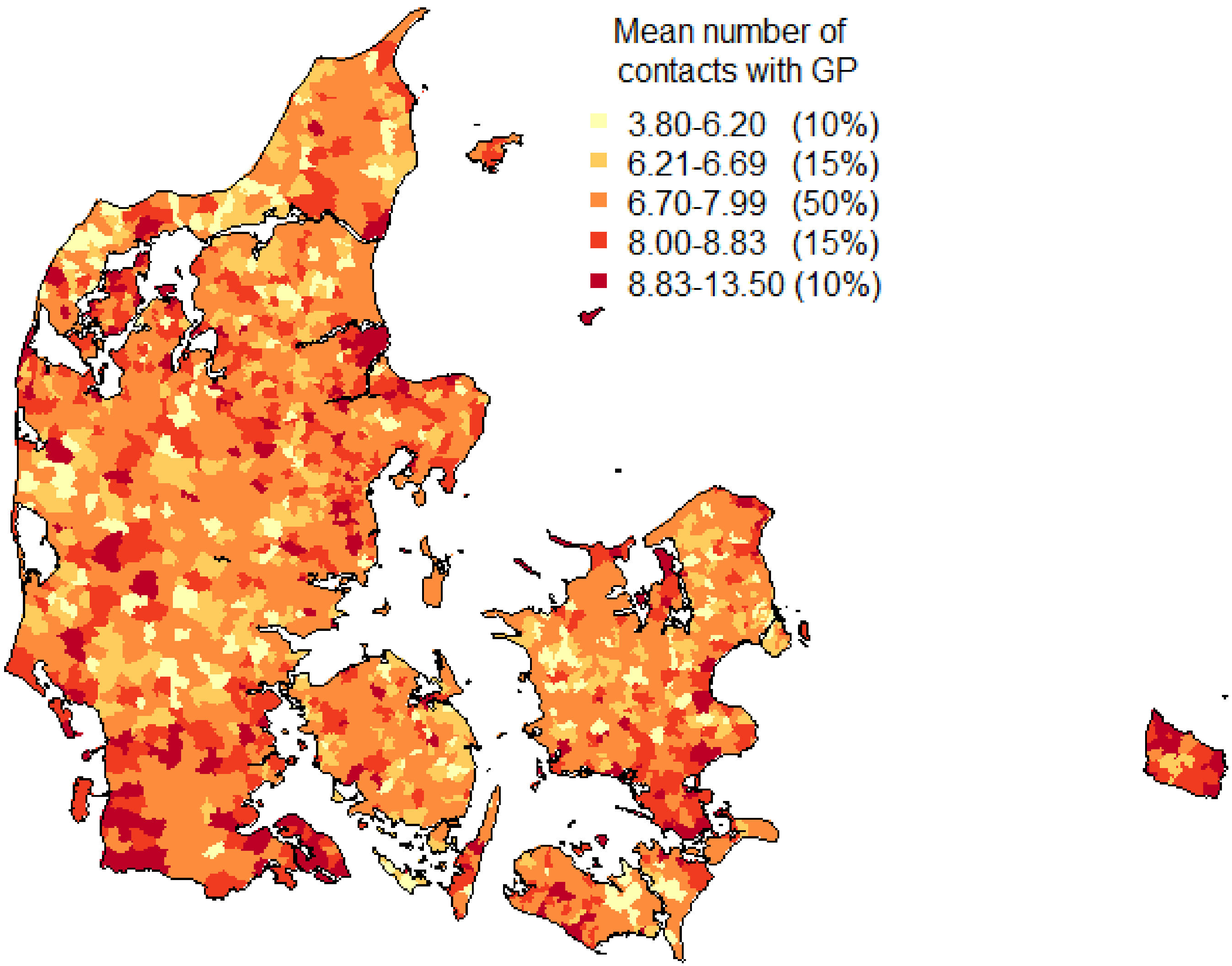
c Health



Incident AMI: 2005 -2011

TM Kjærulff et al. (2016)
Spatial and Spatio-temporal Epi

Annual number of contacts with GP



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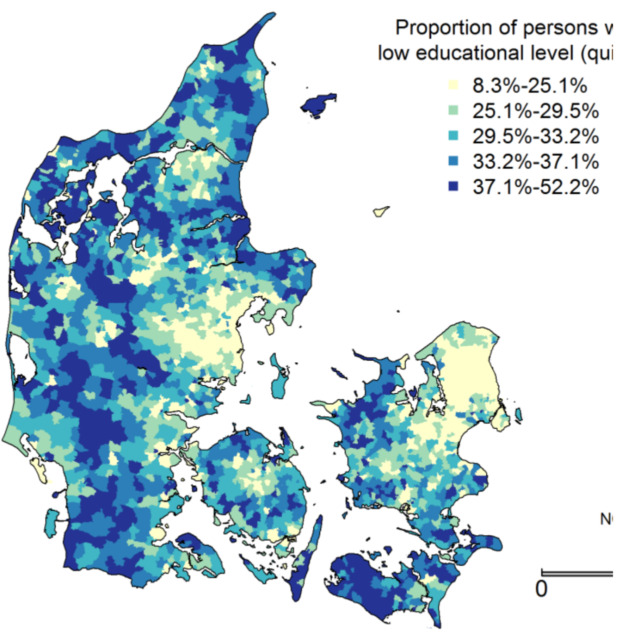
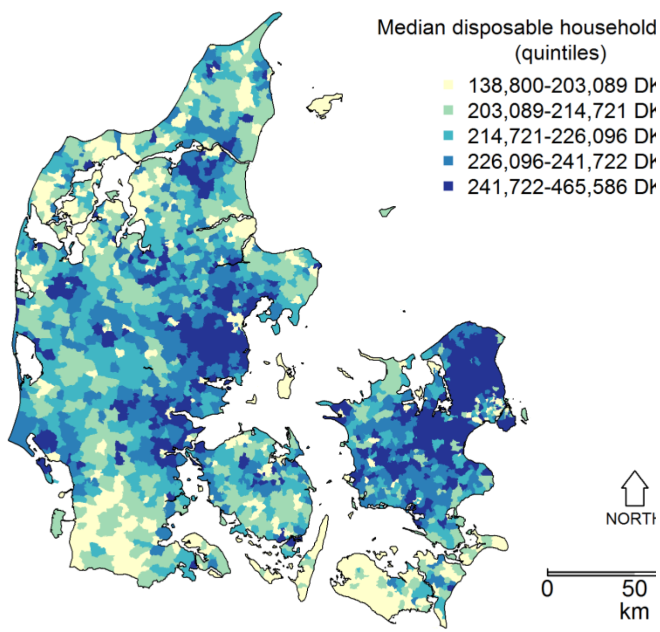
Geo dist of socio-economic position

Proportion of population with

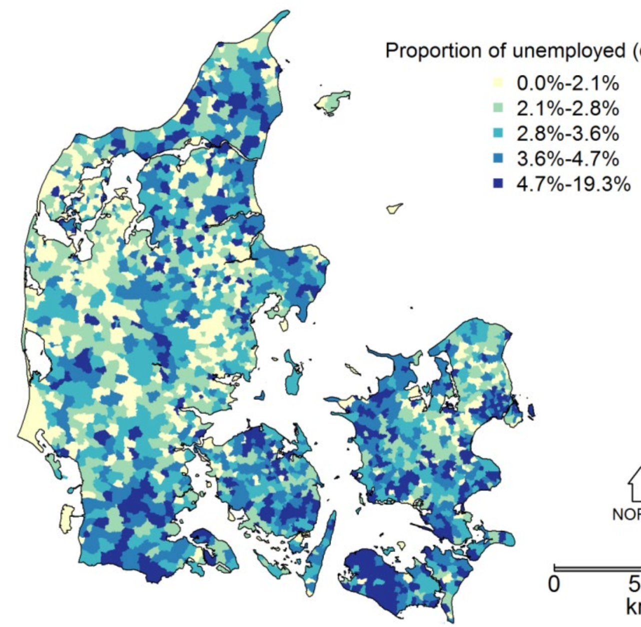
Short education



Low income



Unemployed



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Clustering

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Identifying spatial patterns in disease

i.e. identify areas with increased or decreased risk of disease (hot and cold spots)

Point data

- *K*-function
- Spatial scan statistics

Areal data

- Moran's I

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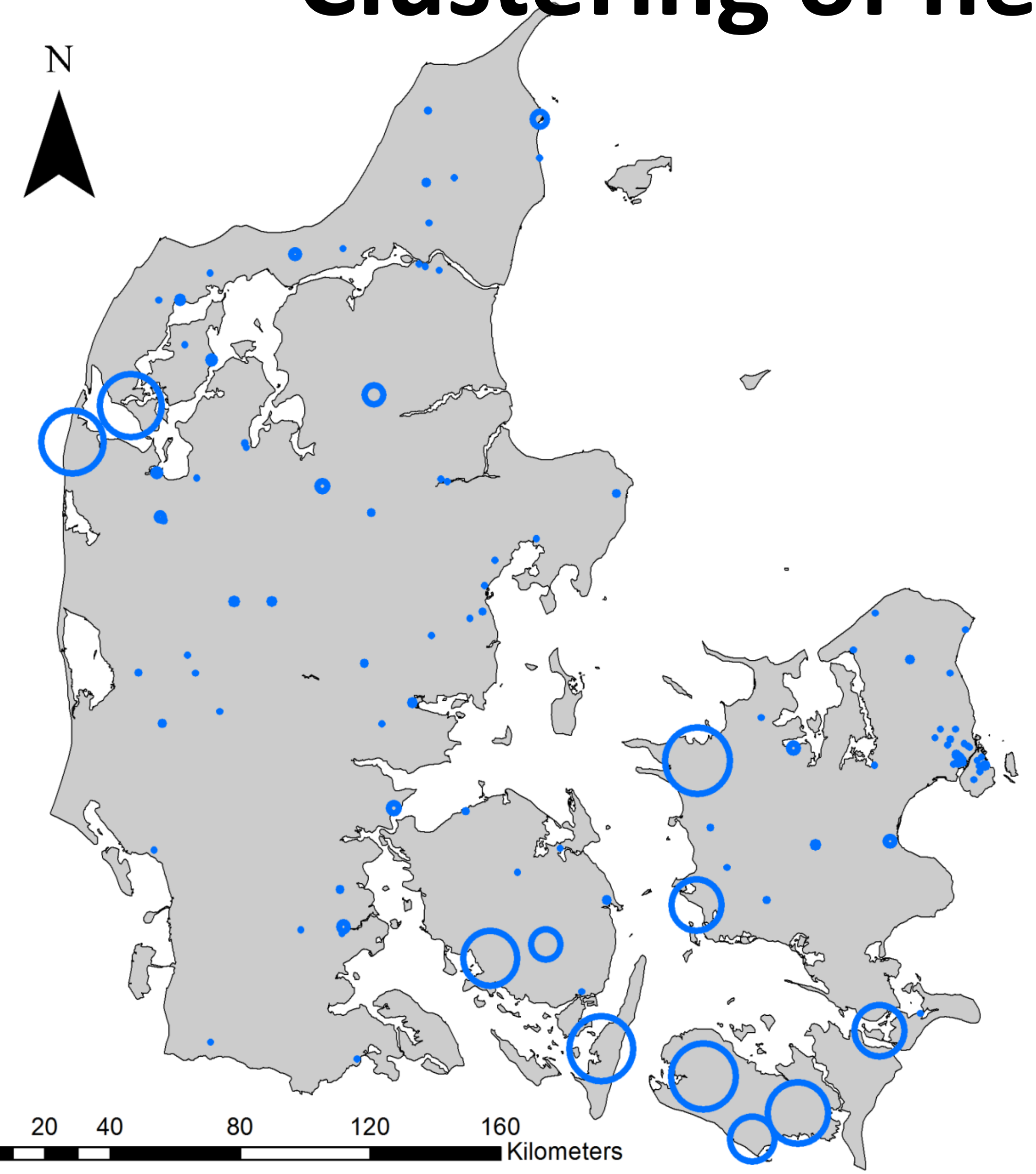
Clustering of heart attack



Legend

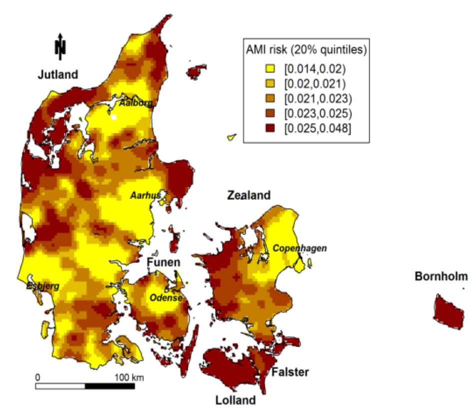
Clusters with high risk of incident AMI

Spatial clusters

Scan statistics

- High risk clusters
- Significant clusters

- SaTScan software



Clustering of multiple sclerosis

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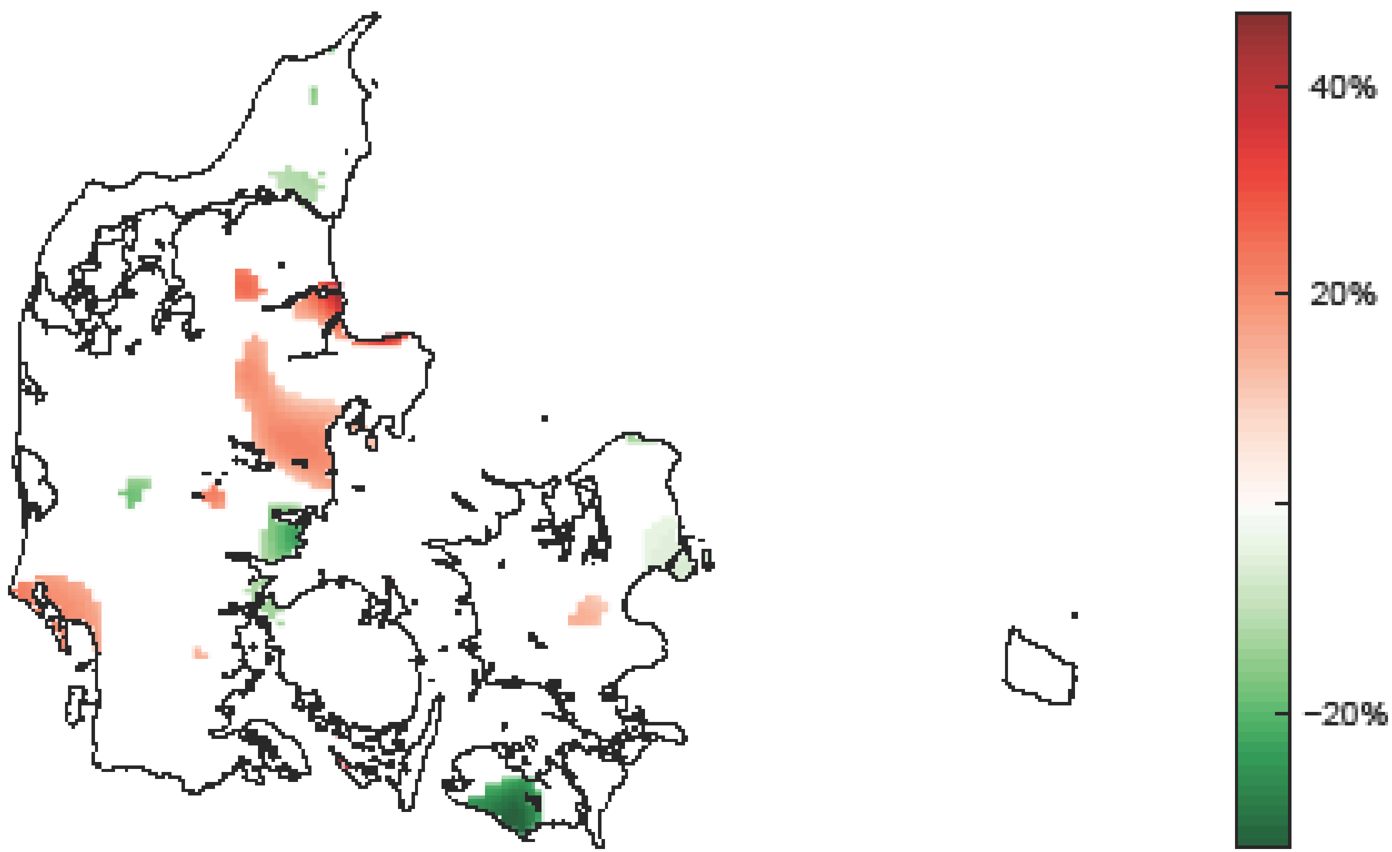
Focus at unknown exposures at age 10-18 years

- Addresses at age 15 years of individuals who later were diagnosed with MS



Exposure assessment

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Based on geographical data

- Drinking water quality (Mg, As, Li)
- Distance to health care (GP, hospital, AED)

1. Linking geographical data to an individual/address
2. Derive exposure variable for the individual

Exposure assessment

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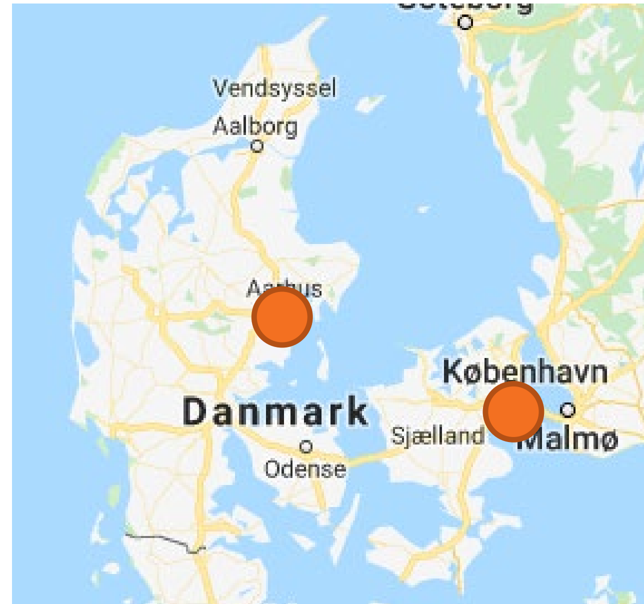
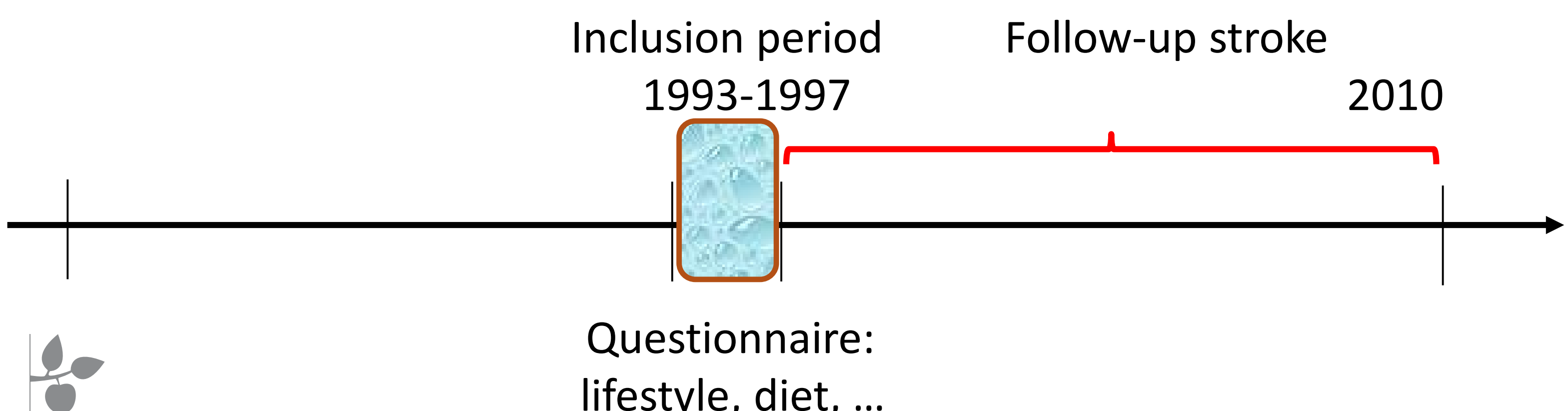
N = 57,053 participants
Age at inclusion: 50-64 years

Individuals included in Copenhagen and Århus





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Exposure assessment

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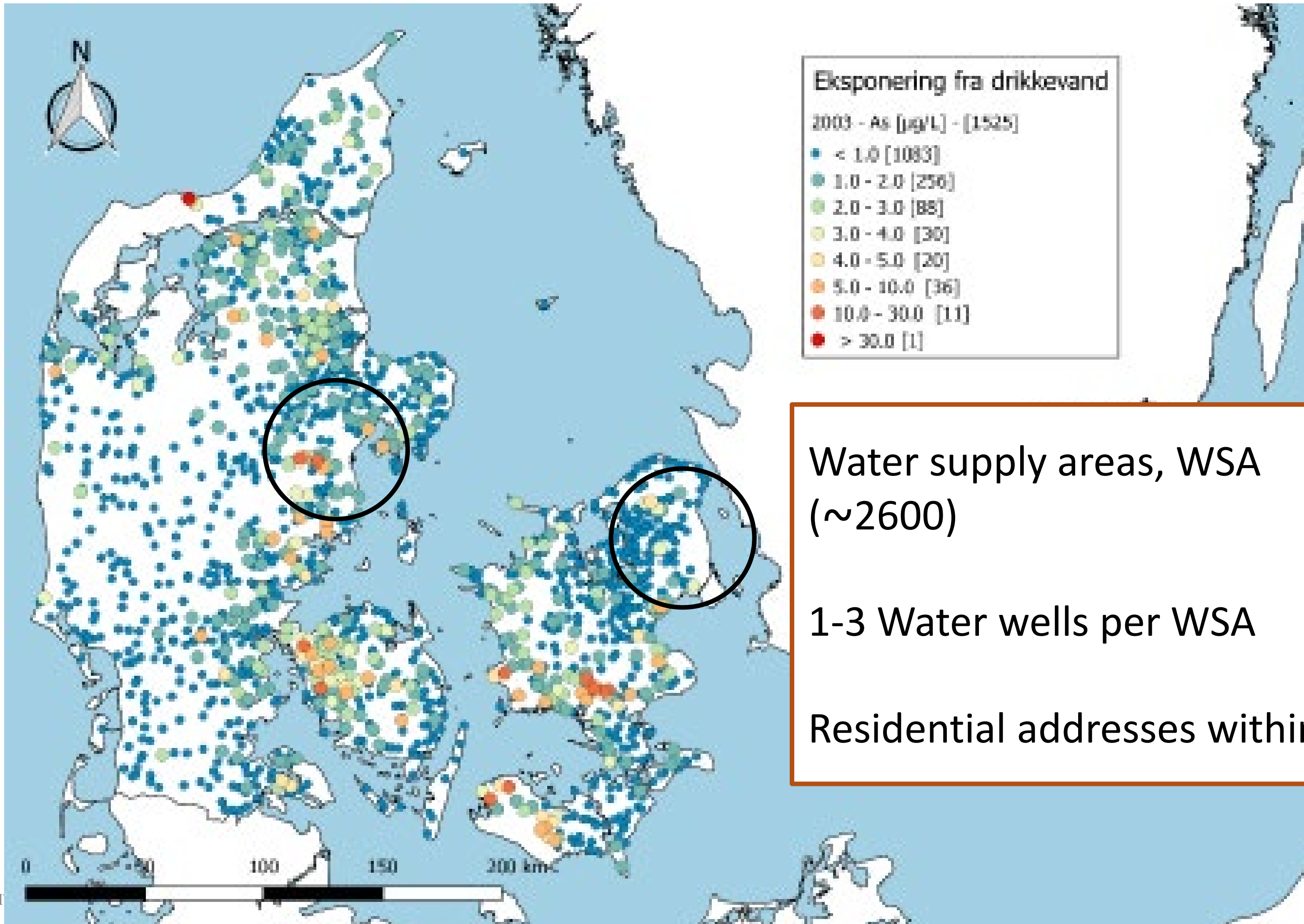
Arsenic distribution in Denmark – Arsenic exposure and risk of stroke



Water supply areas, WSA (~2600)

1-3 Water wells per WSA

Residential addresses within WSA

Exposure assessment

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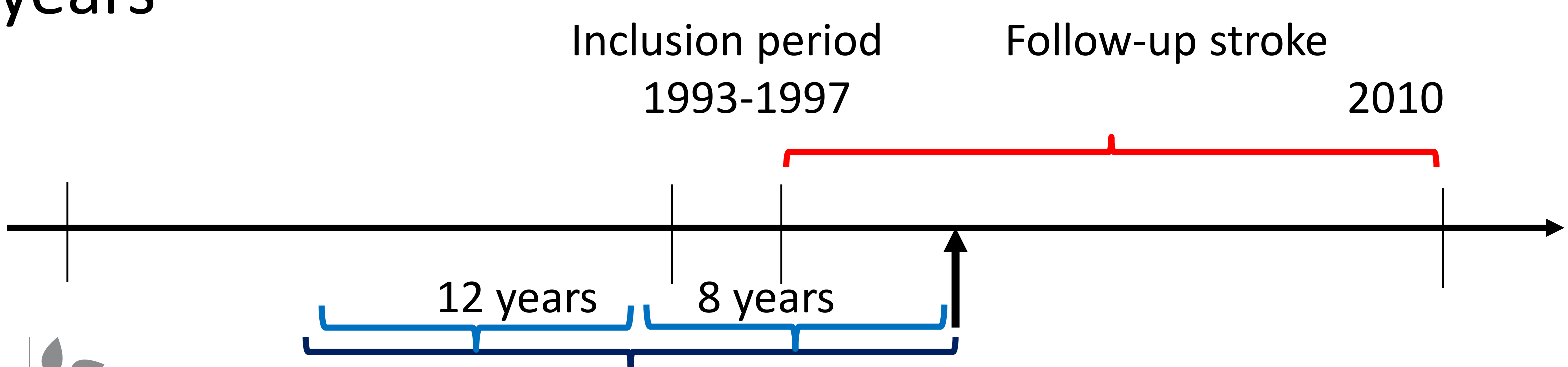
Exposure

- Long-term exposure to As:
  20-year time-weighted average of As
- As in drinking water at residential addresses
- Mobility of the population
- Changes in As concentration at same WSA across years



As concentrations →20-year TWA As

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Exposure assessment

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- Long-term exposure to high concentrations:
  20-year time-weighted average of As

- As in drinking water at residential addresses
- Mobility of the population

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Exposure assessment

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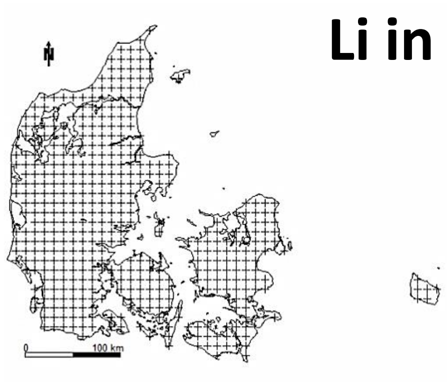
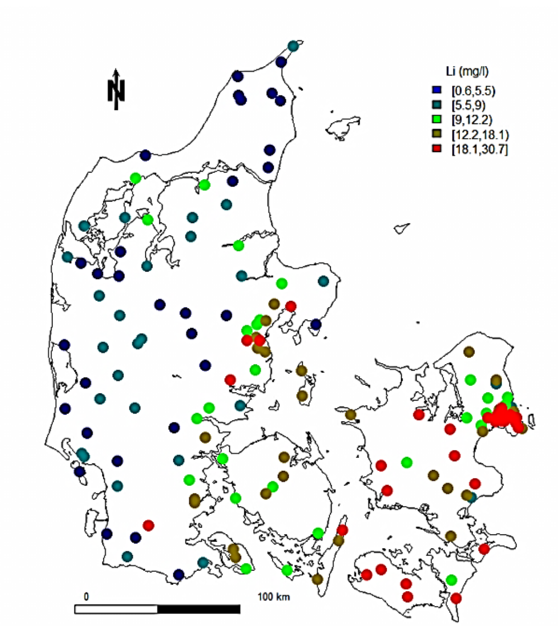
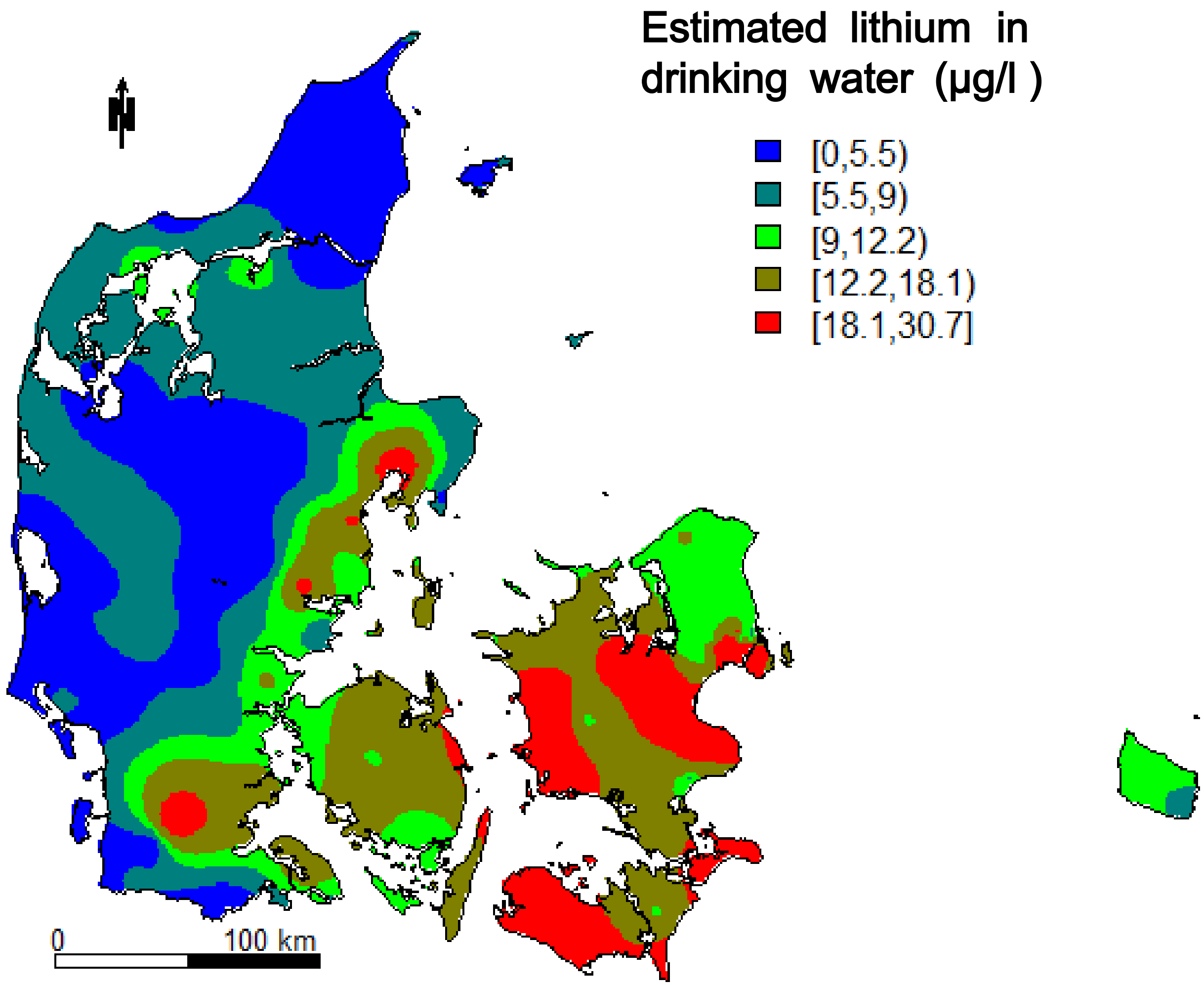
Li in drinking water and risk of suicide







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Spatial regression analysis

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Spatial regression and association

Association between exposure and outcome taking into account the spatial correlation between individuals

- Conditional autoregressive model (CAR)

  Modelling the correlation between individuals (point data) or between municipalities (areal data)

Fatal outcome of a heart attack

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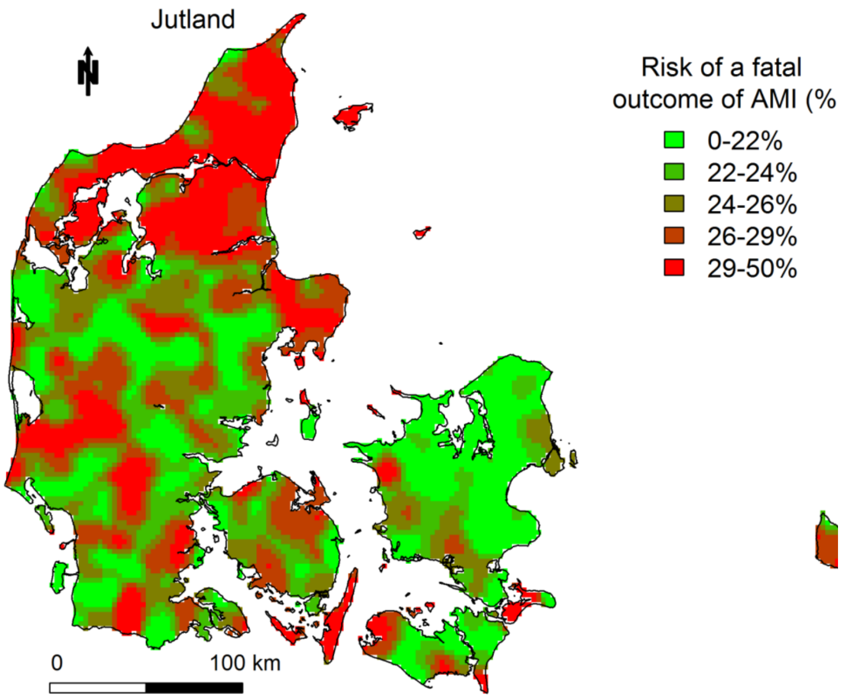
OUTCOME

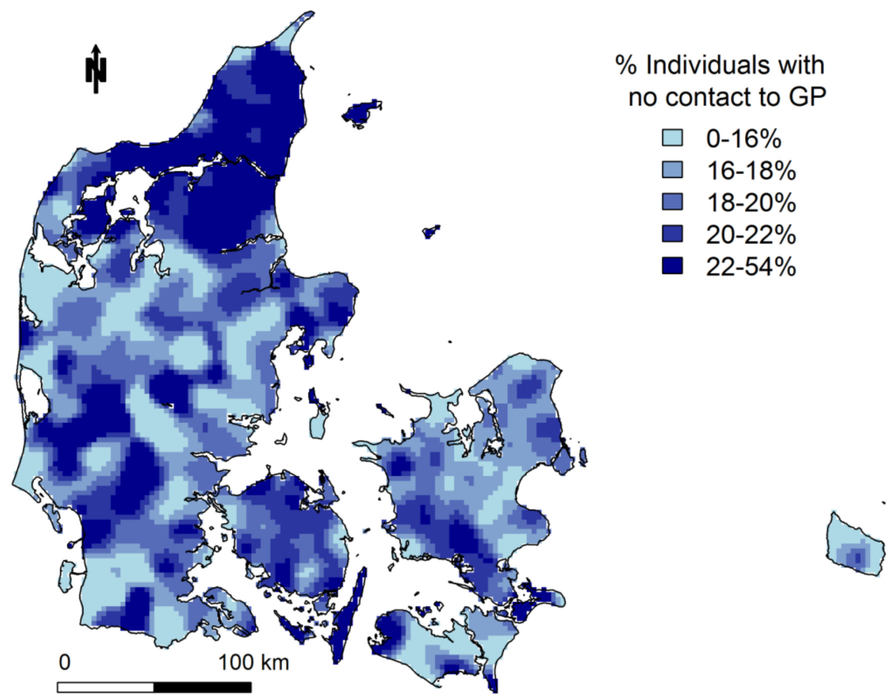
24,7% fatal outcome of AMI

EXPOSURE: Contact to GP

Individuals with contact to GP: 12% had a fatal outcome

Individuals with no contact to GP: 78% had a fatal outcome





AK Ersbøll et al. (2016)
Spatial and Spatio-temporal Epi

Spatial patterns in fatal AMI

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Association between contact to a GP and a fatal outcome of a heart attack

$$\boxed{\text{logit}(p_i) = \beta_0 + \boldsymbol{\beta X_i}} + \boxed{W(s_i)}$$

p_i: Risk of a fatal outcome of a heart attack

$\boldsymbol{\beta X_i}$: Covariates and parameters: age and sex

$W(s_i)$: Spatial dependence beween locations

$W \sim (0, \boldsymbol{\Sigma})$ $\boldsymbol{\Sigma}$:Matern covariance

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Spatial regression analysis

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Generalized linear model – individual-level data

→ Outcomes: Post-AMI mortality (immediate, days 1-28, 1-year)

Mortality	Analysis	Regression model
Immediate (+/-)	1	Logistic
Days 1-28 (+/-)	2	Logistic
1-year (rates)	3	Poisson of rates

Random effect component	Fixed effects
Geographically structured (CAR)	Individual-level and neighbourhood-level socio-demographic characteristics

Spatial regression analysis

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Generalized linear model – individual-level data

Geographically structured random effect component

Conditional AutoRegressive model (CAR) – spatial autocorrelation

98 x 98 adjacency matrix – correlation between neighbouring municipalities

Neighbourhood-level characteristics derived at Parish level (approx 1700)

Bayesian inference using INLA

Residual relative risk (random effect) estimates for municipalities

➔ Does geographical patterns in mortality exist before and after accounting for sociodemographic characteristics?

Spatial regression analysis

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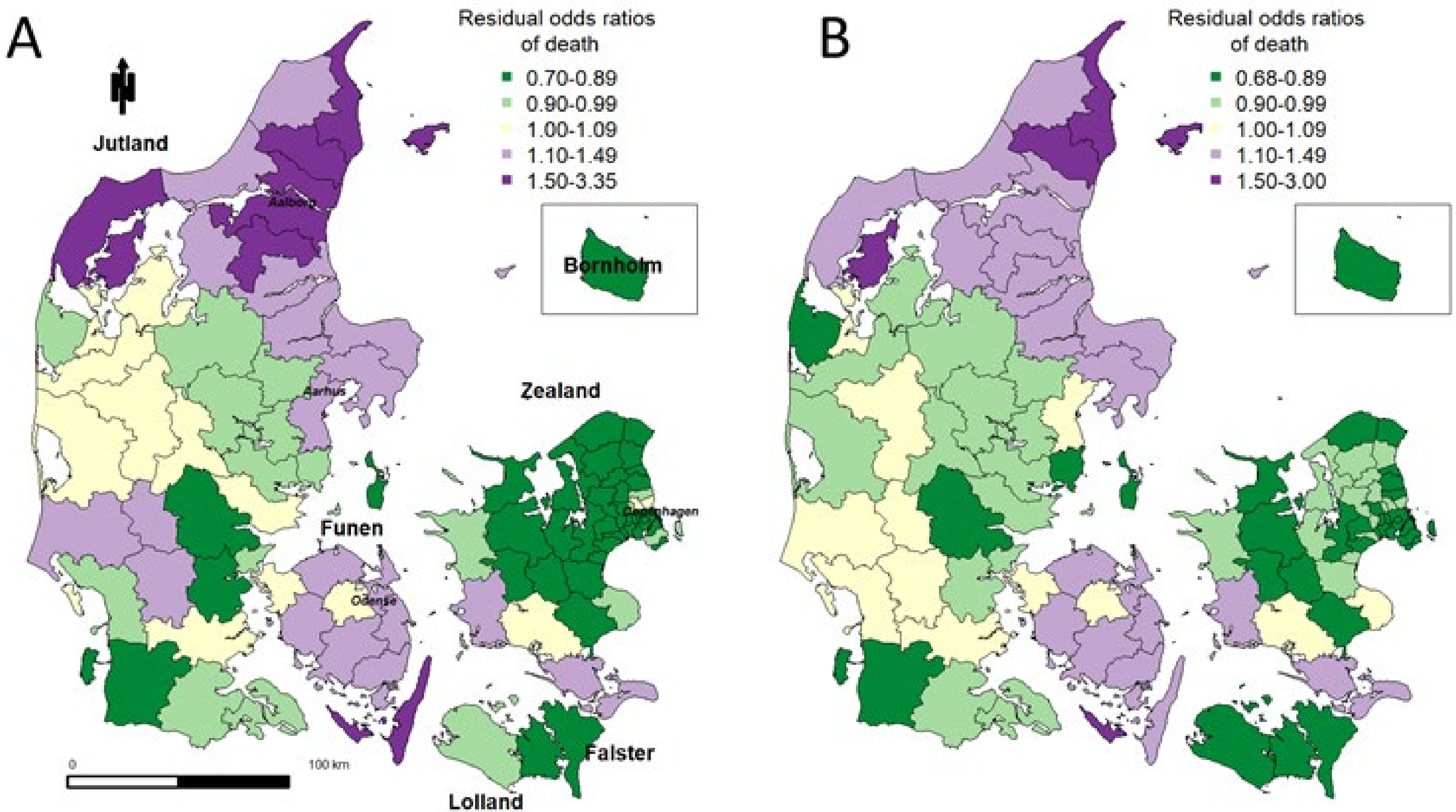


Random effect component (CAR)
No fixed effects

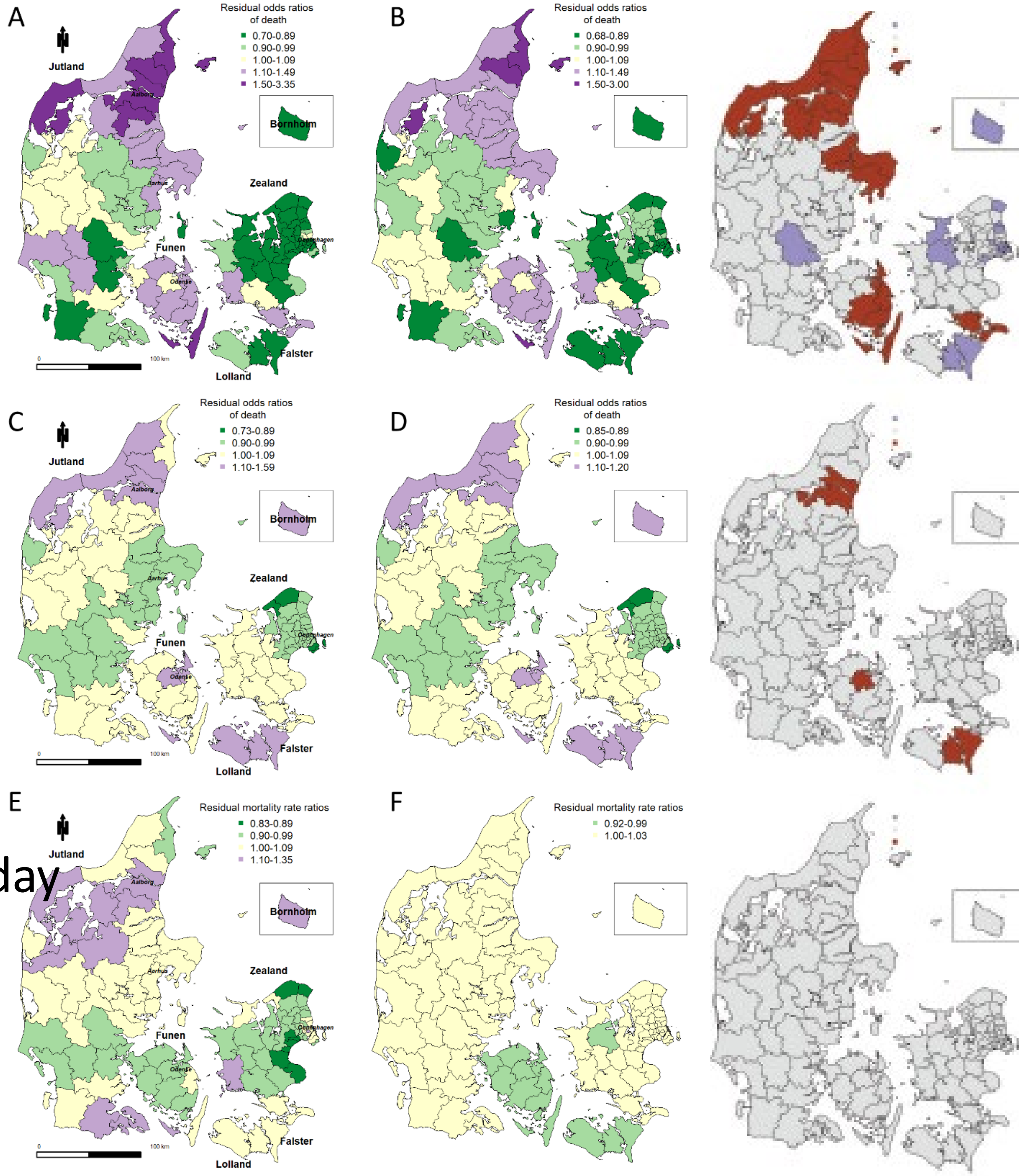
Random effect component (CAR)
Fully adjusted

Mortality

Immediate

Days 1-28

1-year among 28-day survivors



Healthcare

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Prehospital care

Patient awareness

Hospital stay

Rehabilition

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Concluding remarks

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Register-based data can be linked with geographical data

and used for epidemiological studies in public health

and can contribute to policy and decision making

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Thank you for your attention

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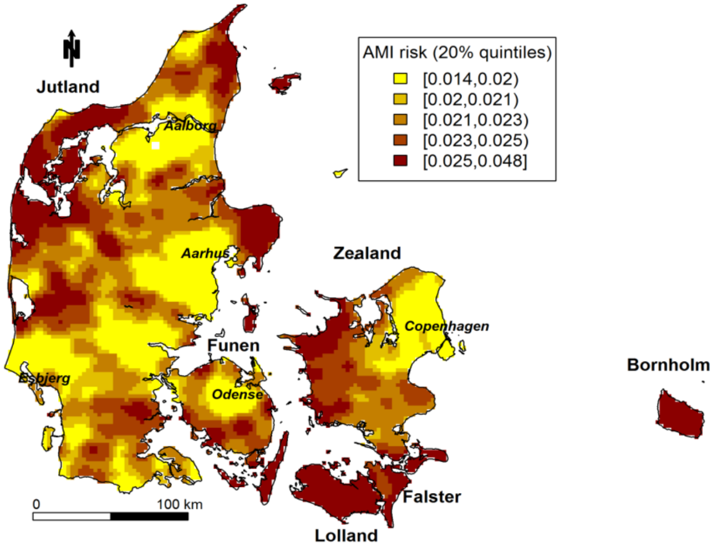

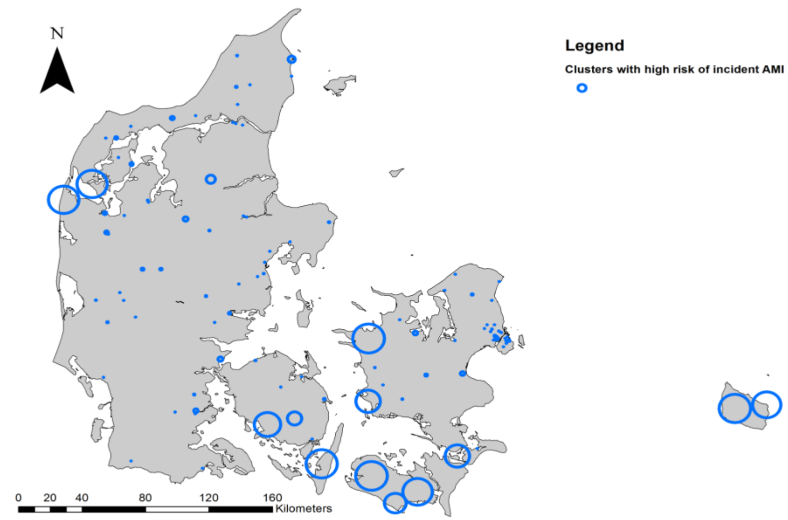

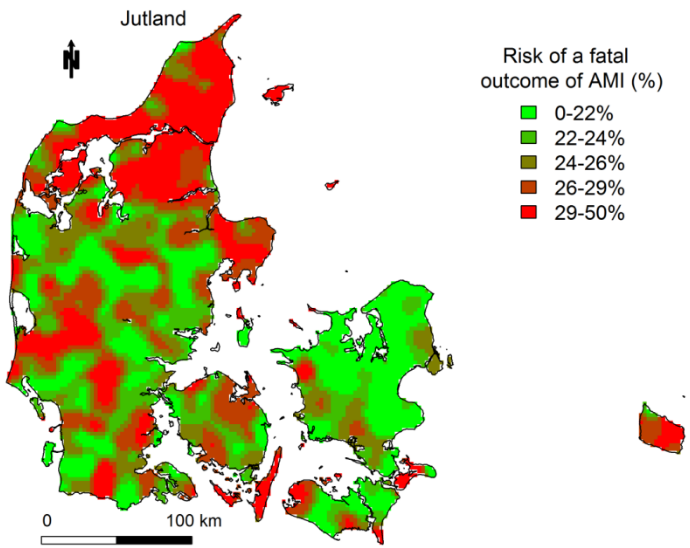

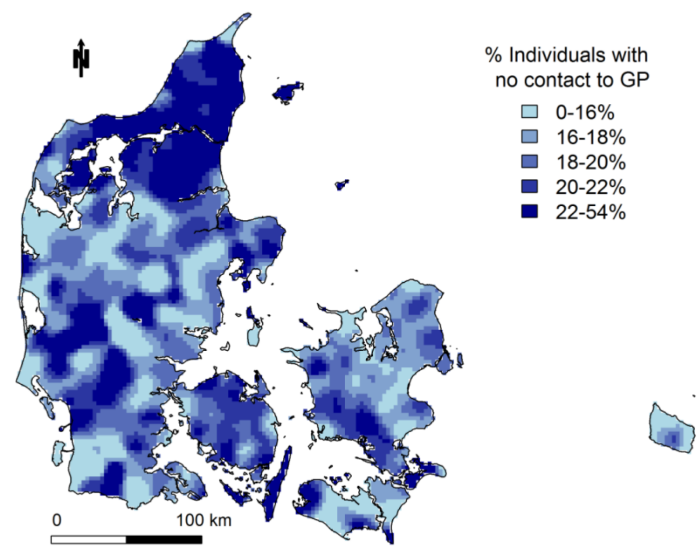

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