Swiss TPH
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Schweizerisches Tropen- und Public Health-Institut
Institut Tropical et de Santé Publique Suisse

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arpae emilia-romagna

The use of GIS in modelling exposure (theory)

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Dispersion models

ADMS-Urbanis a commercial product you have to purchase(http://www.cerc.co.uk/environmental-software/ADMS-Urban-model.html)

AERMOD is free but it is not very user friendly (https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models).

European papers on satellite data modelling

Kees de Hoogh, Harris Héritier, Massimo Stafoggia, Nino Künzli, Itai Kloog, Modelling daily PM2.5 concentrations at high spatio-temporal resolution across Switzerland, Environmental Pollution, Volume 233, 2018, Pages 1147-1154,ISSN 0269-7491, https://doi.org/10.1016/j.envpol.2017.10.025

M. Stafoggia, J. Schwartz, C. Badaloni, T. Bellander, E. Alessandrini, G. Cattani, F. de' Donato, A. Gaeta, G. Leone, A. Lyapustin, M. Sorek-Hamer, K. de Hoogh, Q. Di, F. Forastiere, I. Kloog Estimation of daily PM10 concentrations in Italy (2006–2012) using finely resolved satellite data, land use variables and meteorology Environ. Int., 99 (2017), pp. 234-244 https://doi.org/10.1016/j.envint.2016.11.024

Review of LUR modelling

Gerard Hoek, Rob Beelen, Kees de Hoogh, Danielle Vienneau, John Gulliver, Paul Fischer, David Briggs, A review of land-use regression models to assess spatial variation of outdoor air pollution, Atmospheric Environment, Volume 42, Issue 33, 2008, Pages 7561-7578, ISSN 1352-2310, https://doi.org/10.1016/j.atmosenv.2008.05.057 .

Learning outcomes

At the end of this lecture, you should be able to:

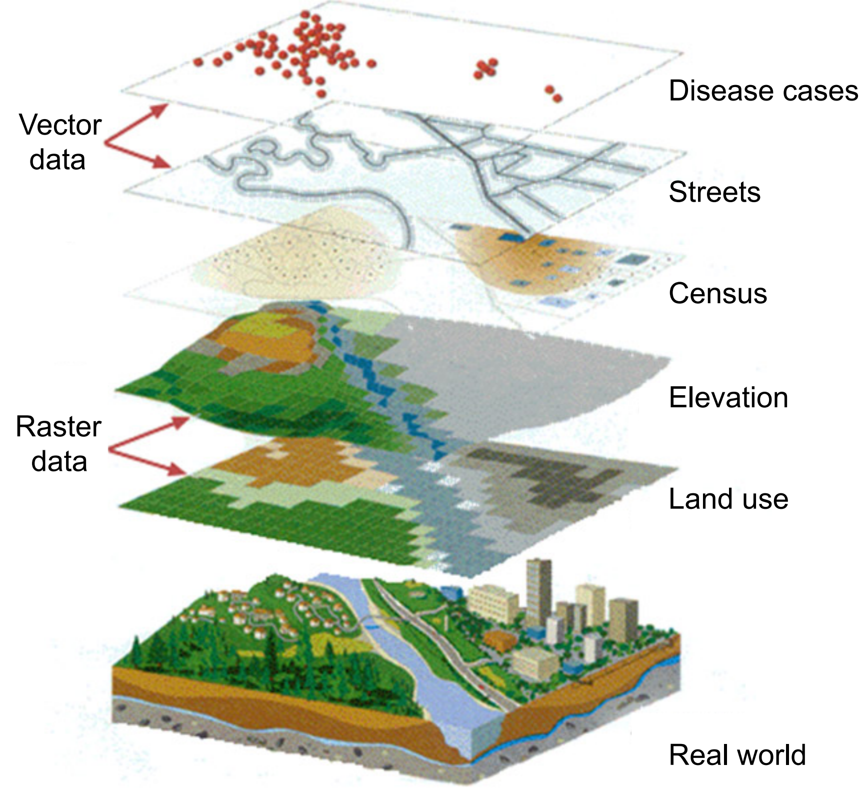
1. Understand the concept of GIS;
2. Understand what role GIS can play in exposure assessment.

Outline

- Short introduction to GIS.
- What role can GIS play in exposure assessment.
- Examples of GIS functionality – i.e. proximity, buffering.
- Example of use of GIS in exposure assessment studies

Geographic information system (GIS)

Google maps



Geographic information system (GIS)

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- **Managing spatial data**

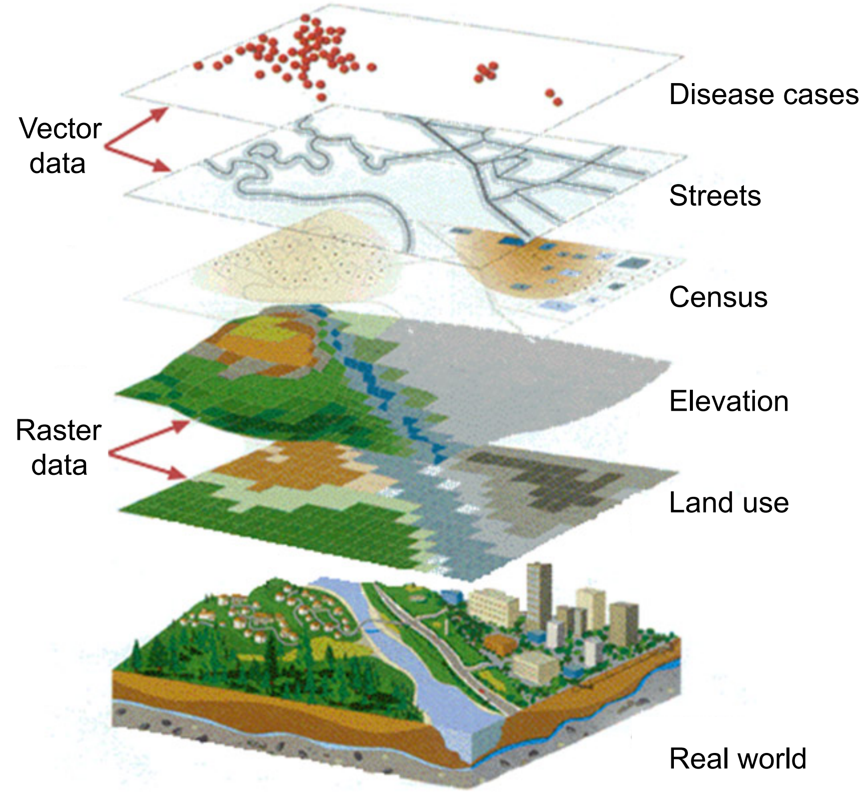
  capture, integration, validation and quality control

- **Mapping**

  disease, environmental hazards and socio-economic factors

- **Spatial modelling**

  linkage or integration of models



Why does geography matter?

Spatial variation in environmental hazards

+

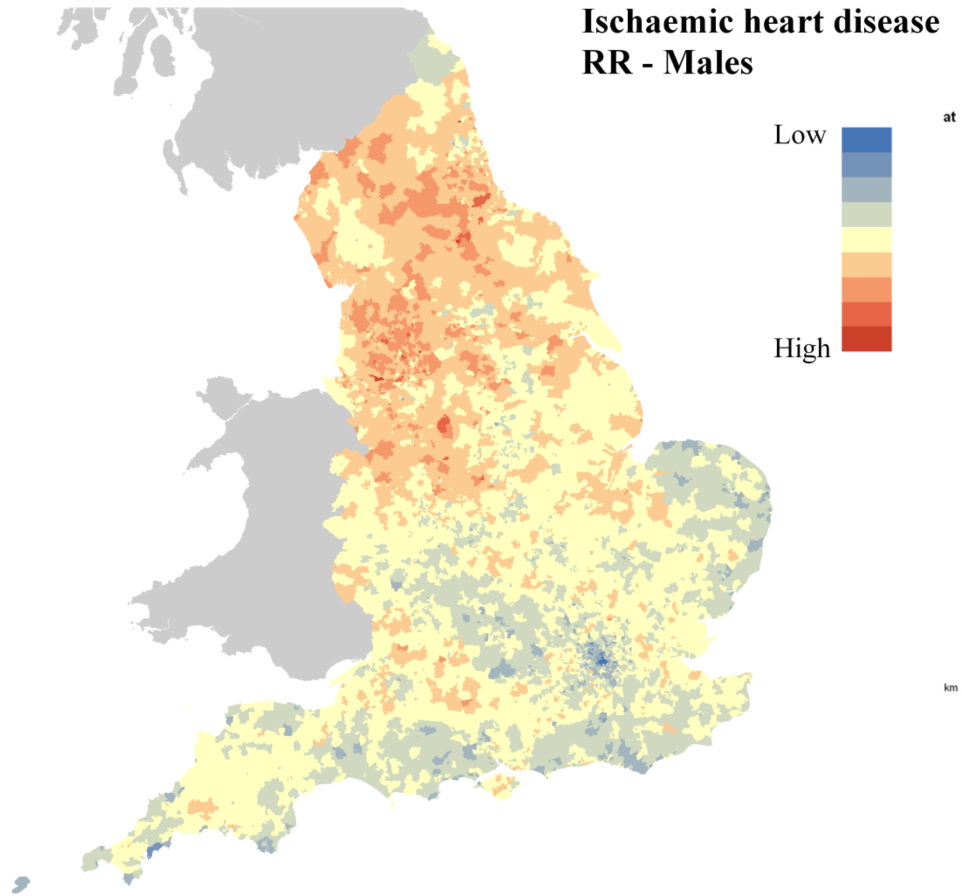
Spatial variation in population distribution

+

Spatial variation in population characteristics (susceptibility)

=

Spatial variation in health outcomes



Adding the spatial component

Databases help answer:

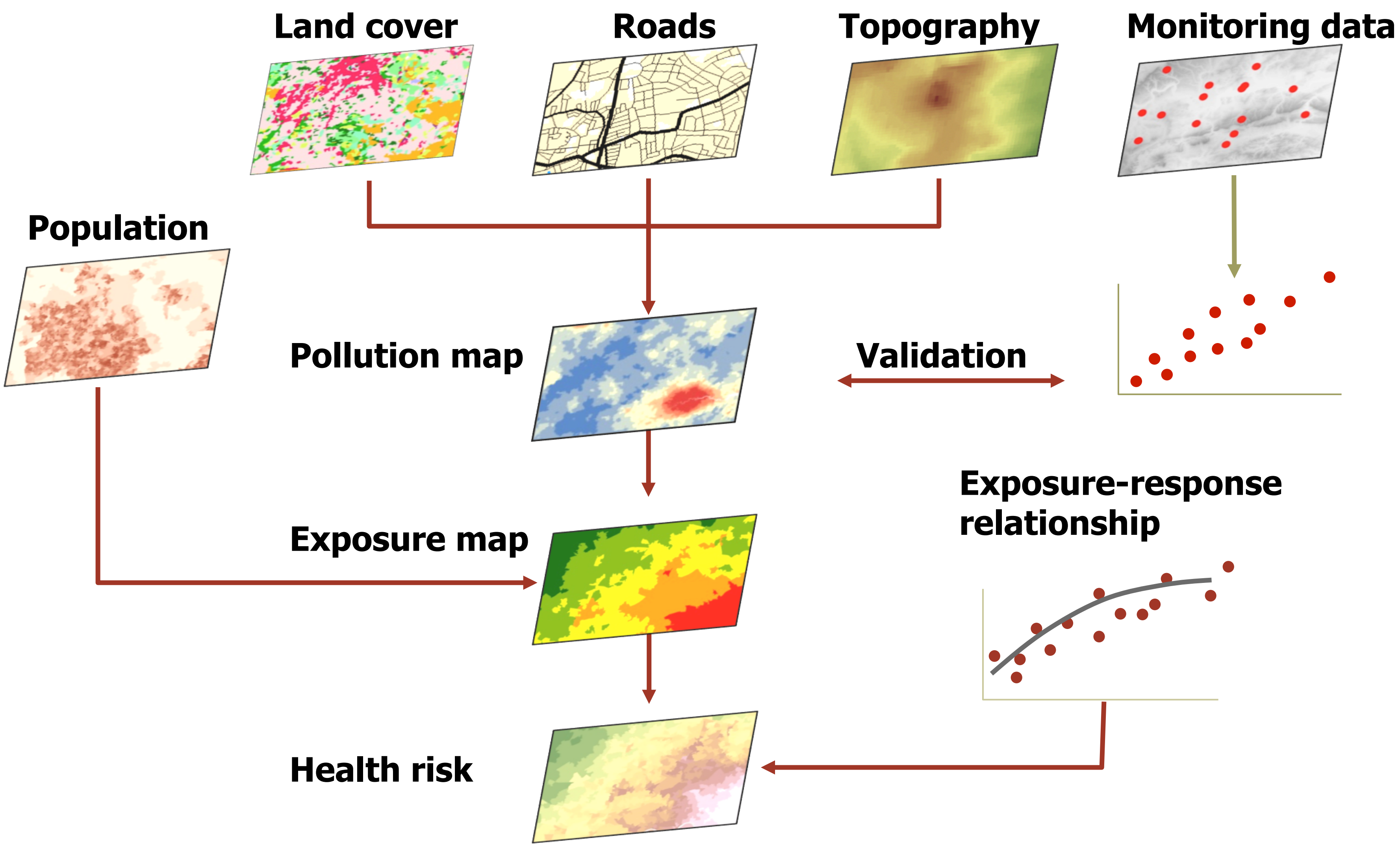
- Who? What? When? Why? And How?

A GIS helps answering questions about ***Where***?

- Location: Where is it at?
- Trends: What has changed since ....?
- Patterns: What spatial patterns exist?
- Modelling: What if ...?
- In disease rates

GIS allows us to view, understand, question, interpret and visualise data in many ways that reveal relationships, patterns and trends in the form of maps, reports and charts

GIS in Environment-Health Chain



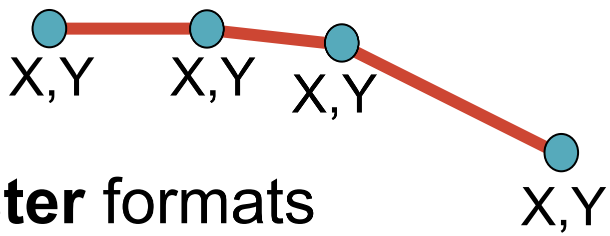
Sources of data

Description	Examples	Georeferencing
Existing maps	Topography, land use, administrative boundaries	Lat/long; national grid systems
Routinely collected enumeration data	Census, mortality, hospital admissions	Census tracts, postcodes, addresses
Satellite data	Land cover, pollution	Pixel
Routine monitoring data	Pollution	Monitoring sites (x,y)
Purpose-designed household surveys	Health, SES, self-reported exposure	Postcodes, addresses
Environmental surveys	Personal monitoring, field surveys	Map location (x,y), GPS

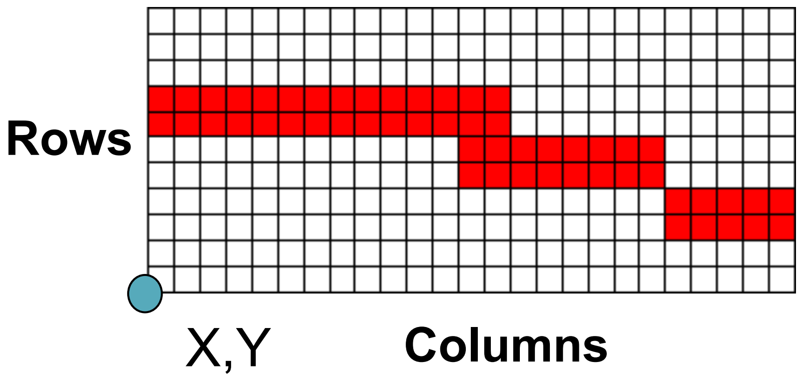
The key to using any data in GIS is by georeferencing (i.e. link to location)

Data formats

- **Vector** formats
  - Discrete representations of reality



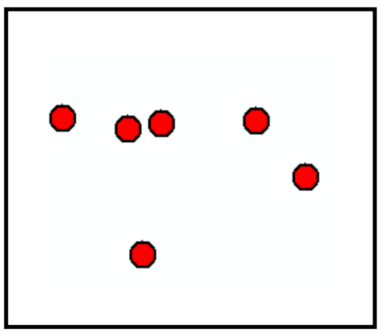
- **Raster** formats
  - Use square cells to model reality



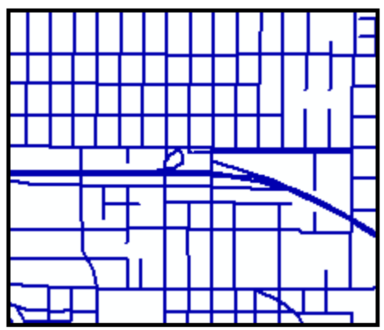
Reality
(motorway)

Vector data

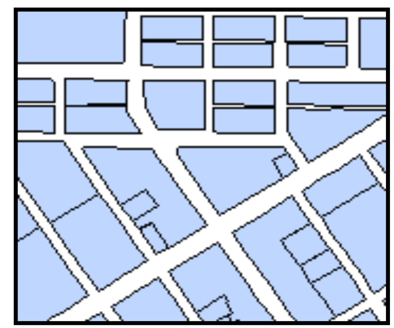
Real-world entities represented in three basic shapes



Points
(address locations, chimneys, pollution monitoring stations)



Lines (Arcs/Routes)
(roads, streams, disease vectors)

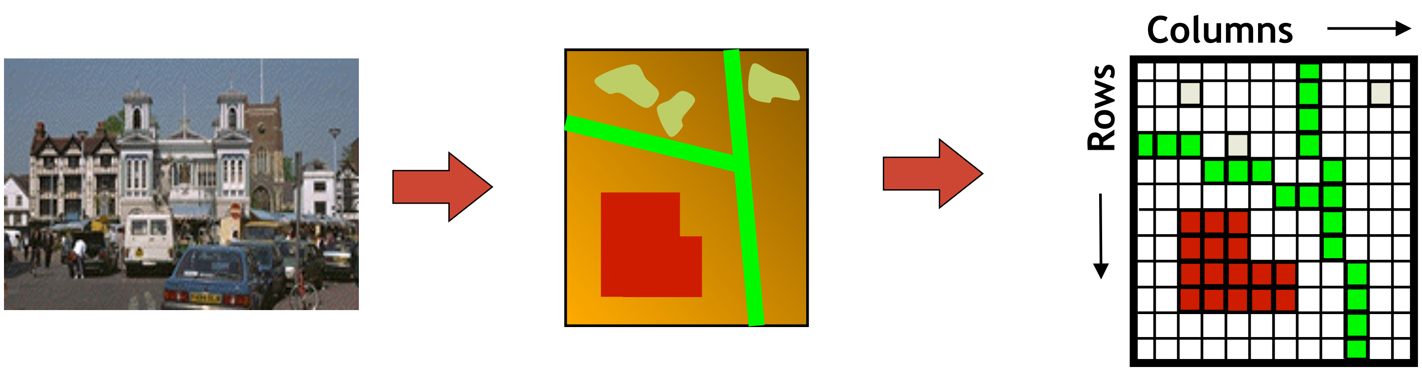


Polygons (Areas/Regions)
(administrative areas, land use zones, exposure zones)

Raster data

Real-world entities represented as regular grids

- The relationship between cell size and the number of cells is expressed as the resolution of the raster
- A finer resolution gives a more accurate and better quality image

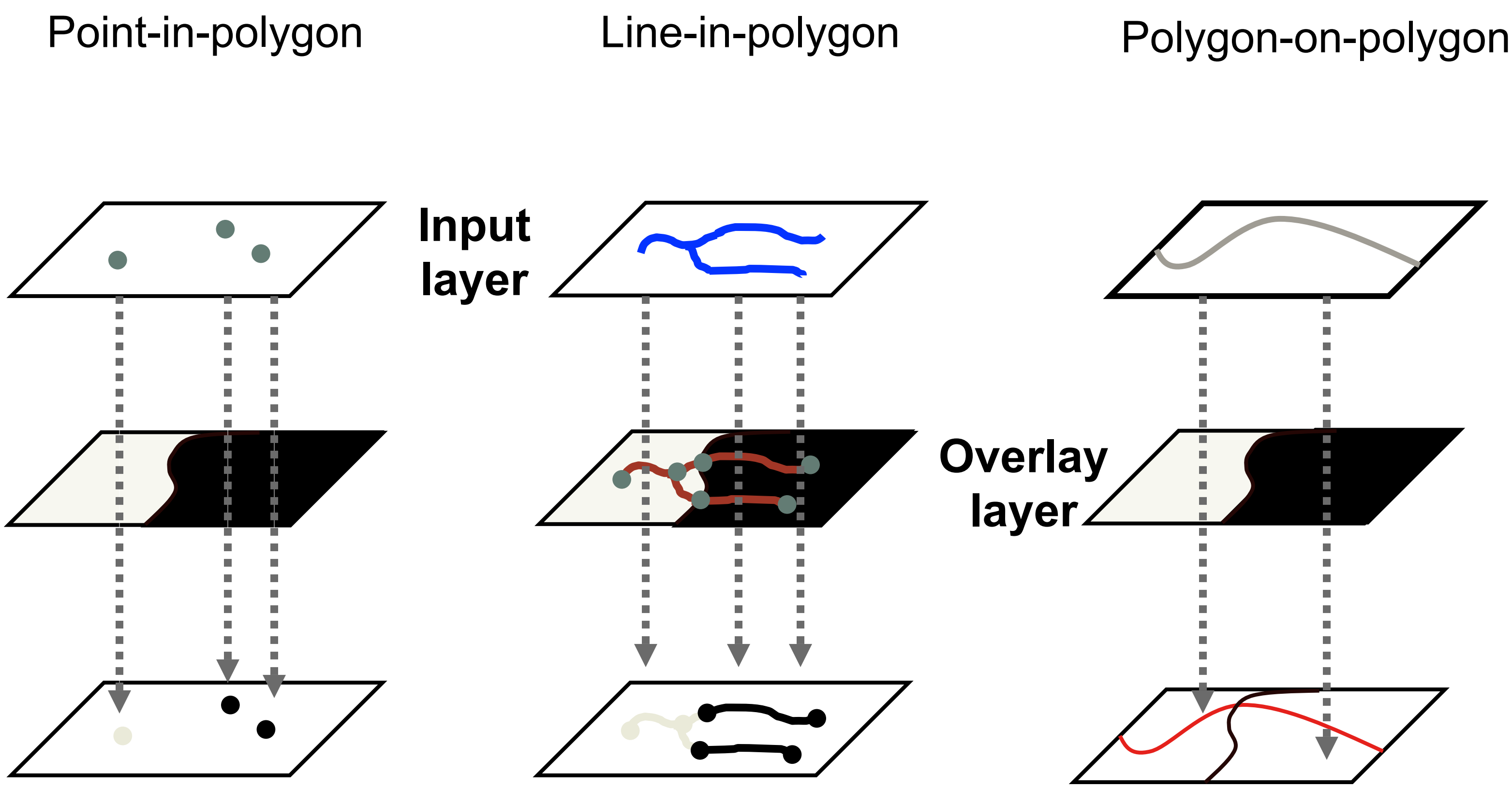


Attribute data

For each location attribute information can be attached

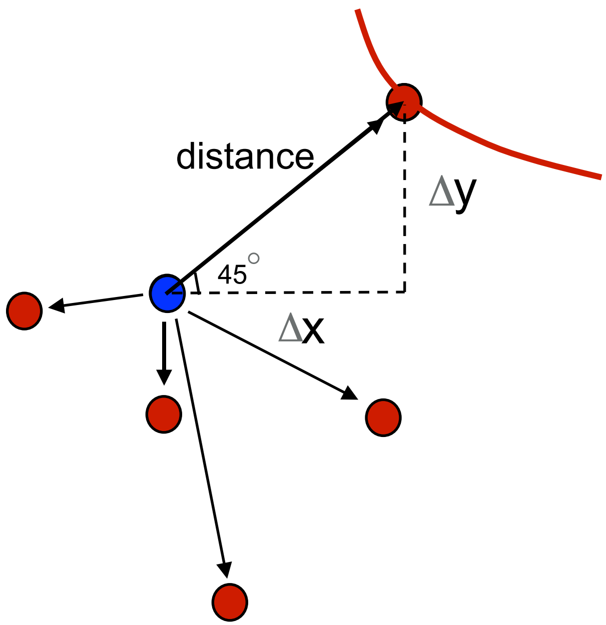
	area	perimeter	bldgs_id	subname
1	25051.960000	953.937600	1	Gooman's Industrial
2	1170.595000	147.109500	2	Rose Meadows
3	12.840320	48.297480	3	Rose Meadows
4	1356.333000	162.136400	4	Rose Meadows
5	39.084850	56.904610	5	Rose Meadows
6	1134.347000	138.024400	6	Rose Meadows
7	1817.636000	188.131900	7	Rose Meadows
8	1074.224000	140.601400	8	Rose Meadows
9	2072.033000	234.254900		
10	892.986800	122.200700		
11	1405.082000	171.598900		
12	833.528200	115.520200		
13	42.666470	62.084680		

Overlay analysis

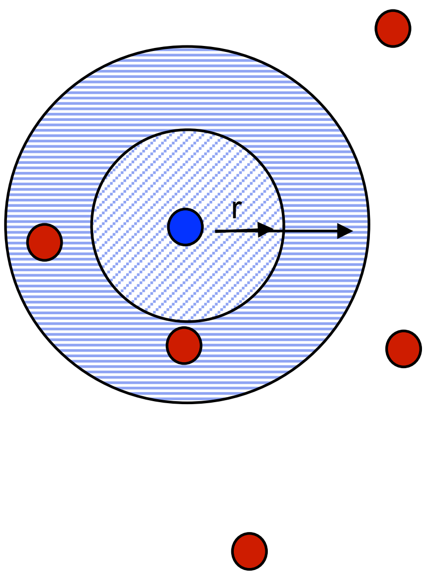


Output layer inherits overlay layer's attributes

Proximity analysis



Distances



Buffering

Tobler's first law of geography:

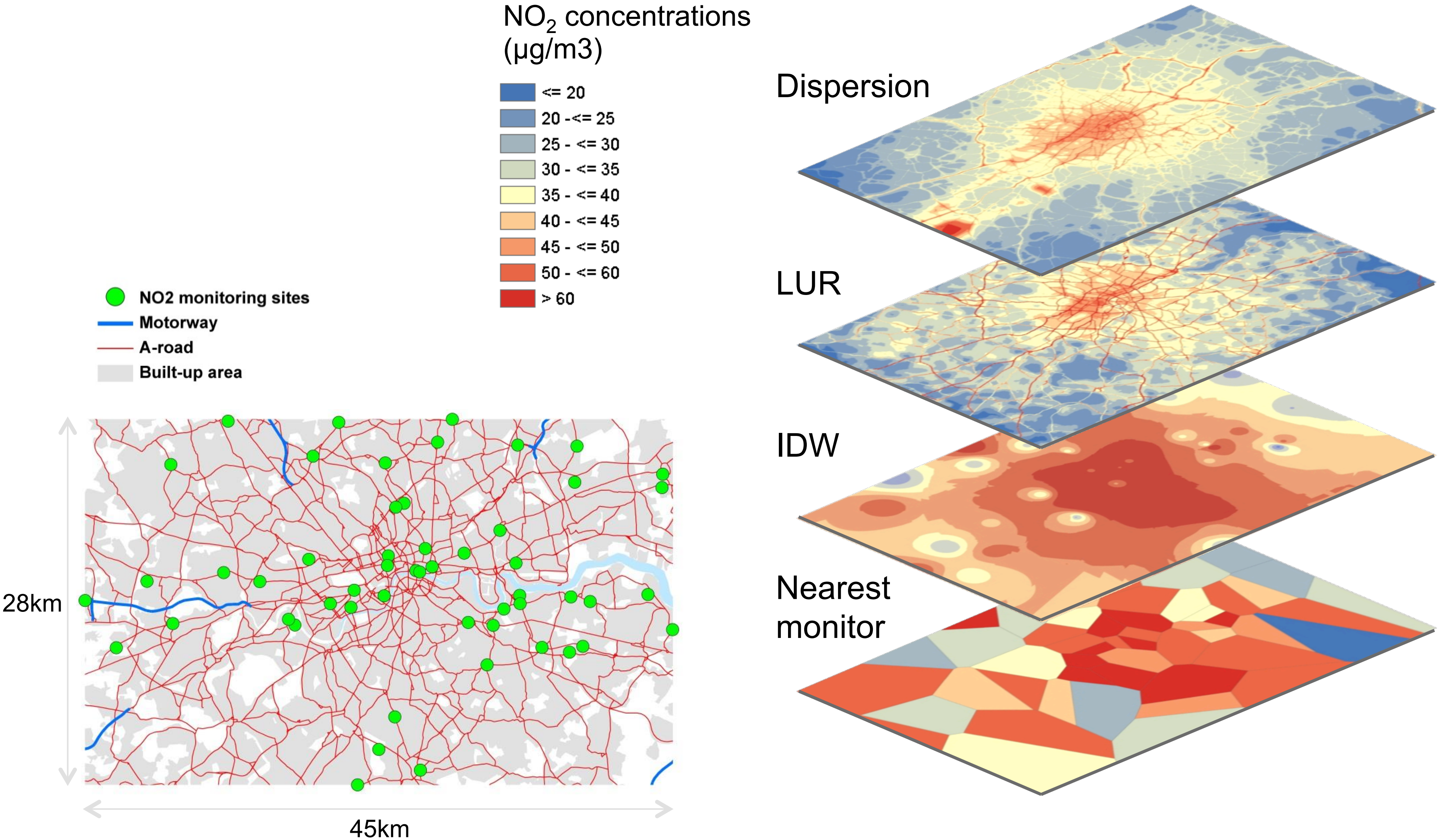
Everything is related to everything else

...but near things are more related than distant things

Modelling methods for point data

Approach	Example	Description
Proximity	Voronoi tesselation	Creates areas around each point containing locations nearest to that point
	Buffering	Creates zone (buffer) of specified distance around point
Distance functions	Inverse-distance weighting	Weights each location in terms of inverse distance from monitoring site
Global interpolators	Trend surface analysis	Fits global surface through data points
Local interpolators	Kriging	Fits series of local surfaces through data points

Air pollution modelling approaches



Air pollution modelling approaches

Type of model	Description	Application
Proximity models	measurement of the distance between the subjects and the source of pollution. Continuous or discrete.	used with any type of source, it supposes a direct relationship
Spatial interpolation	Geostatistical models (i.e. kriging, IDW) to reconstruct the pollution values in areas not covered by measurements	applicable in case of an adequate number of measurements.
Land Use regression	statistical models on the relation between land characteristics and pollutant concentrations in a specific point	useful for differences within urban areas, they require measurements campaigns
Dispersion models	mathematical models describing processes of pollutant diffusion	require detailed information, reconstruct temporal and spatial variation of pollutant due to specific sources
Remote sensing	Analyses on satellite images to estimate atmospheric pollution at ground level	required a calibration with measured data. Information both on spatial and temporal level
Source apportionment	statistical models to reconstruct the contribution of each emission source	applicable when detailed pollution measures and chemical profiles of each source are available

UK Municipal Solid Waste Incineration study

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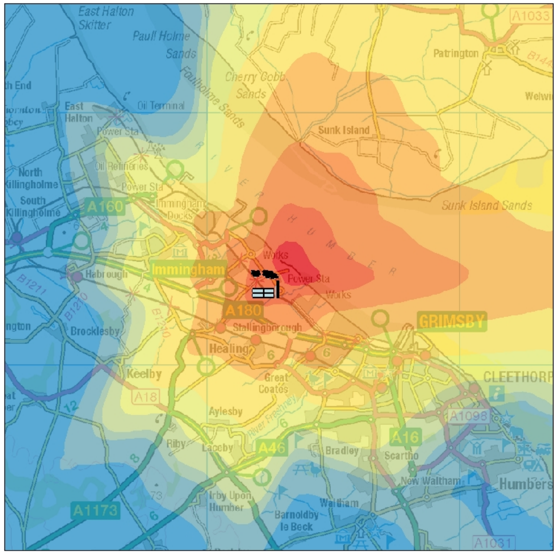
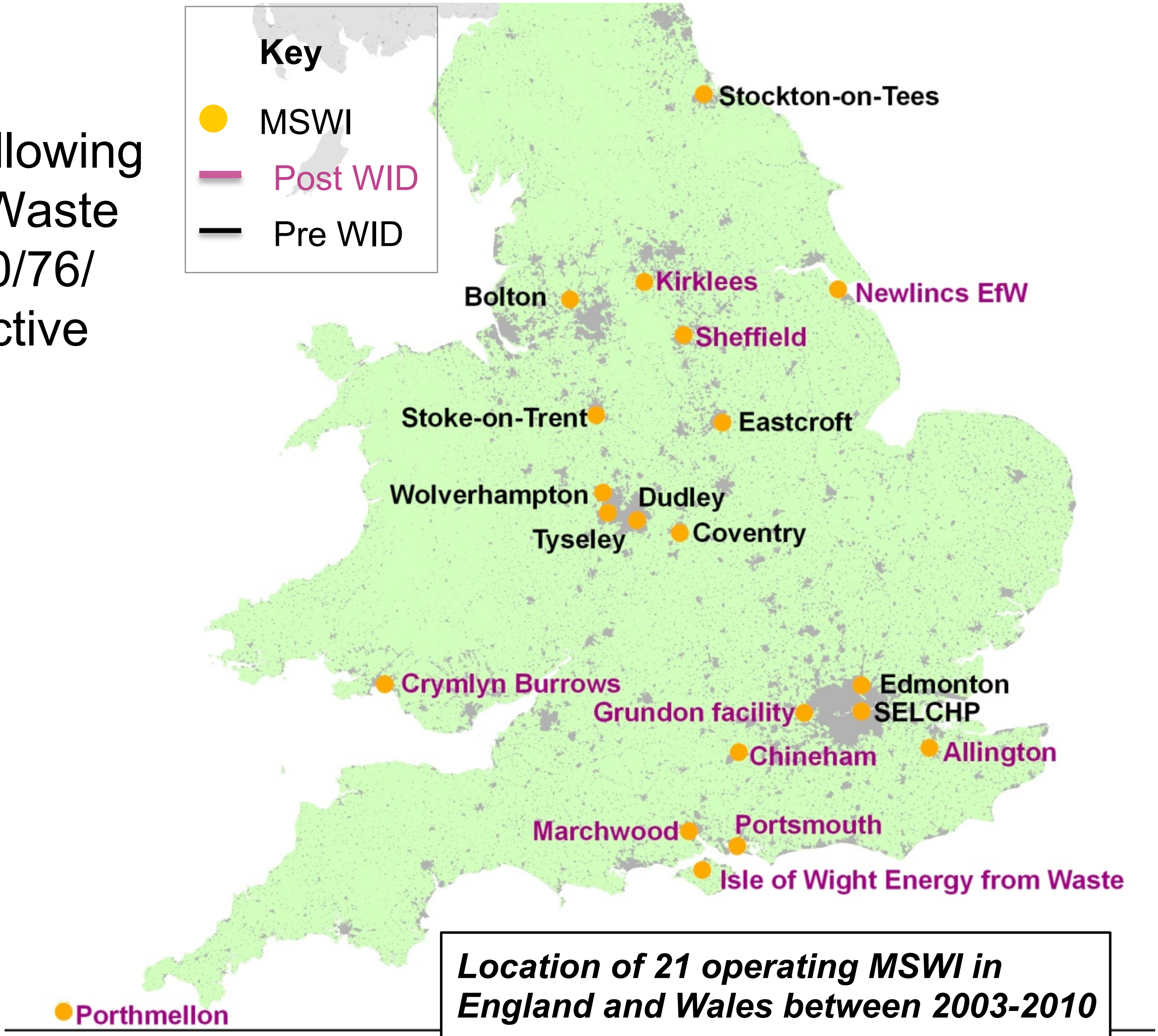
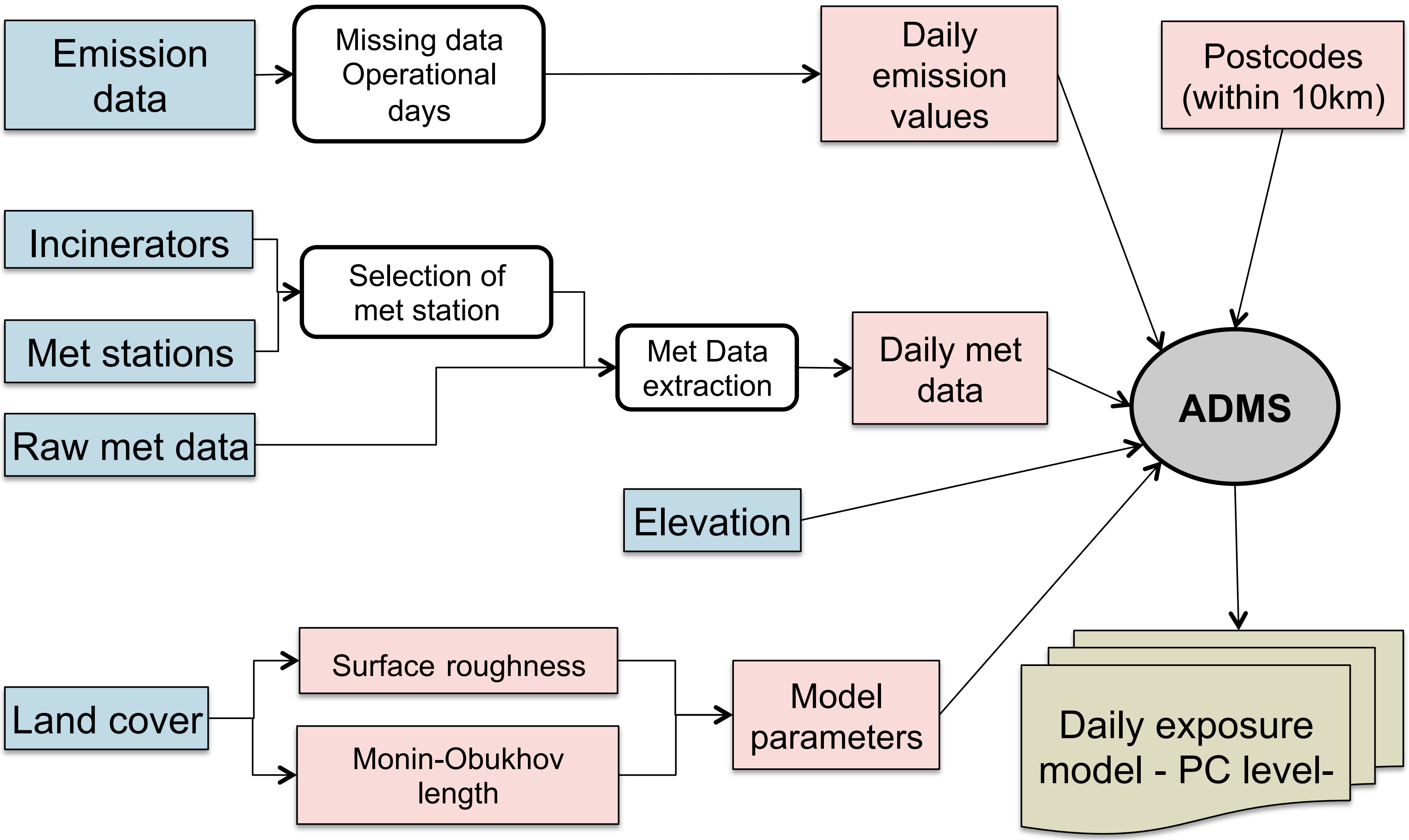
Do municipal solid waste incinerators in operation following implementation of the EU Waste Incineration Directive (2000/76/EC) pose a risk to reproductive and infant health?





Location of 21 operating MSWI in England and Wales between 2003-2010

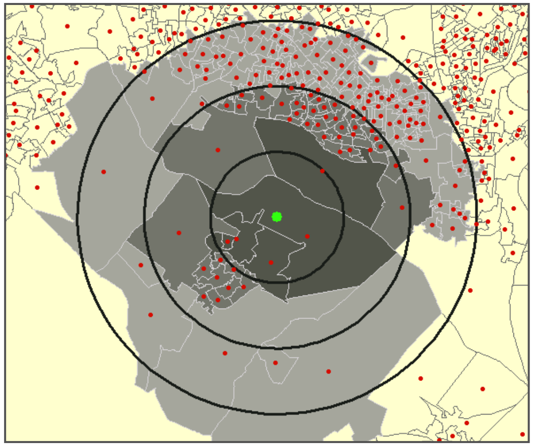
Flow chart exposure modelling process



Example proximity vs modelling

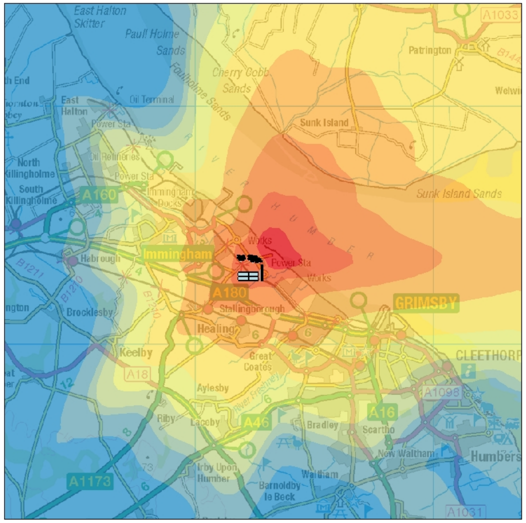
Location (x,y)

Distance bands



Details of source
Emission rate/stack characteristics
Meteorology

Dispersion modelling



Residential exposure

Concept that residential exposure is the main choice for exposure assessment in epidemiological studies and health impact assessment

Despite the ovbvious introduction of an error, it is the best chioice also for working people (>60% of time spent at home for people in working age)

Residence and workplace together could improve accuracy and precision of exposre assessment

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Fundamental aspect: accuracy of address geocoding

Example: use of buffer with a line source

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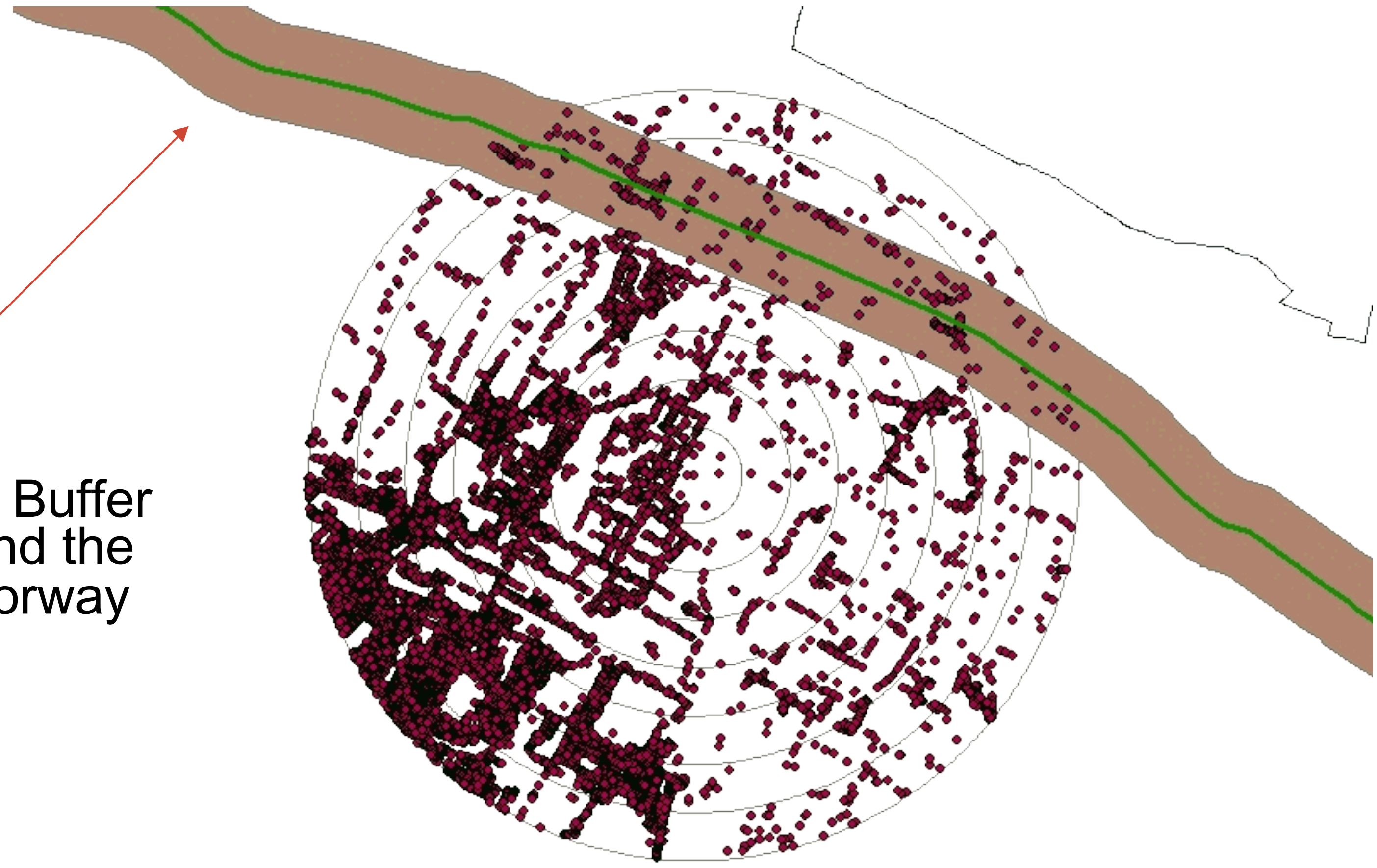
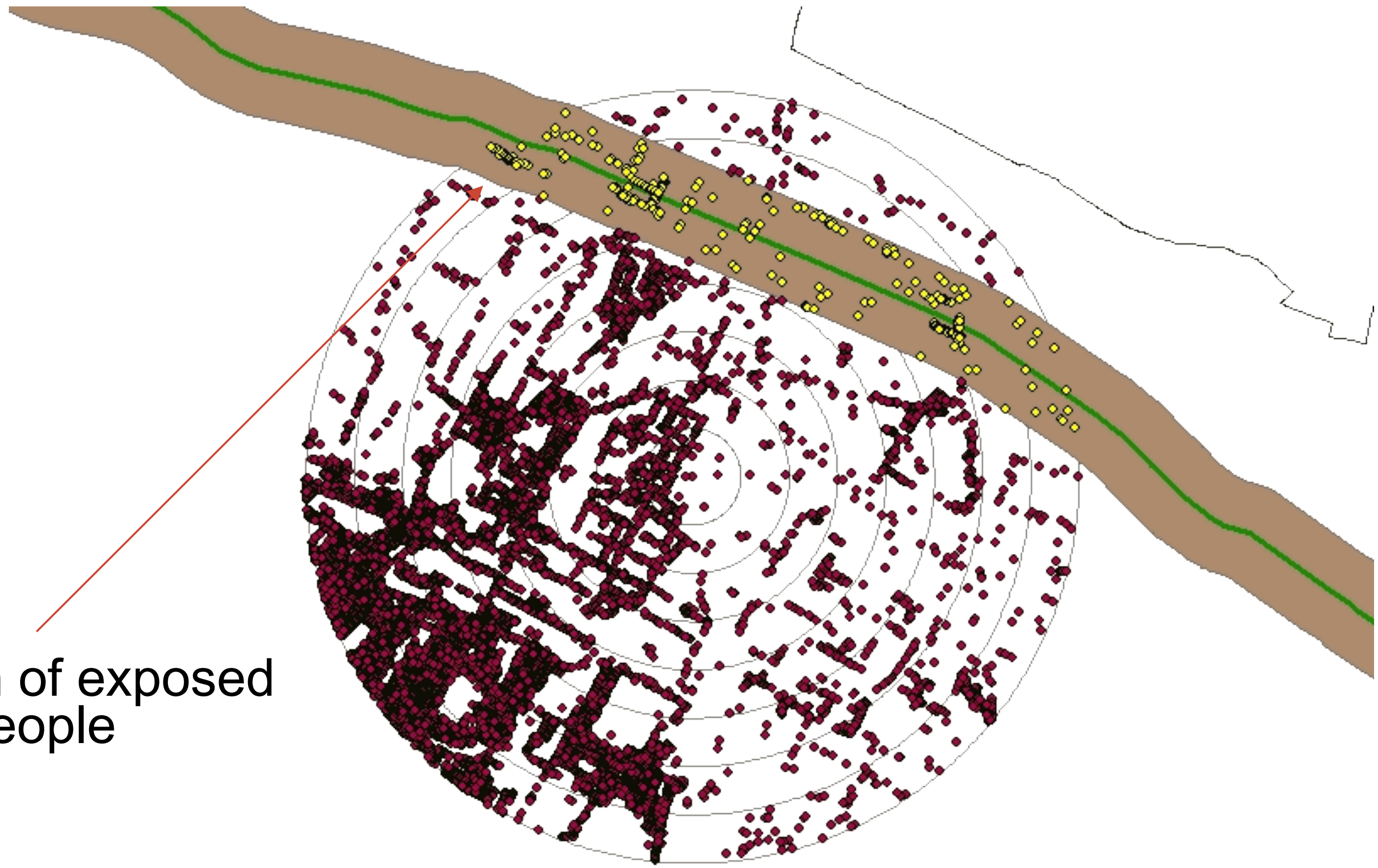


500m Buffer around the motorway

Example: use of buffer with a line source



Selection of exposed people

Residence and workplace

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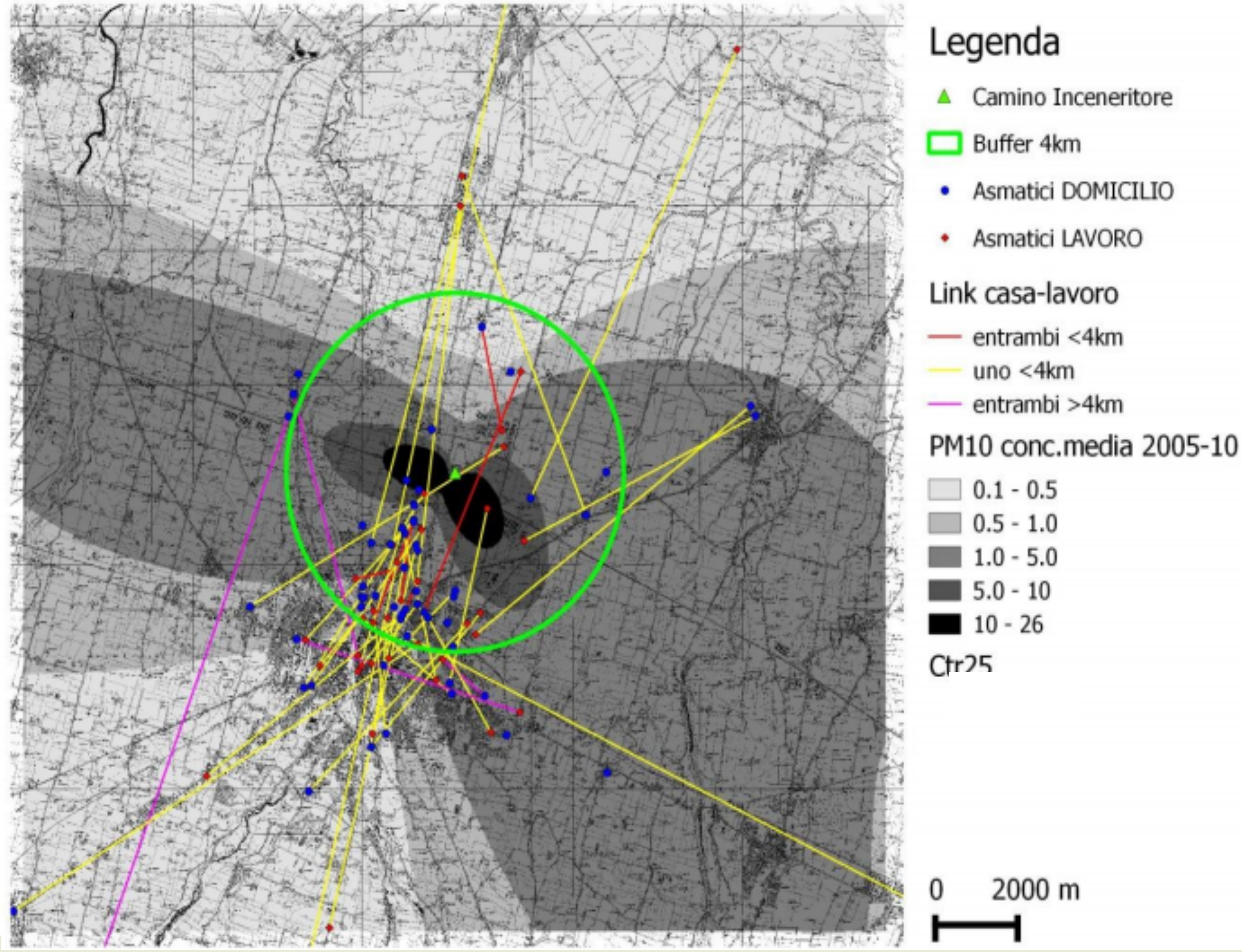
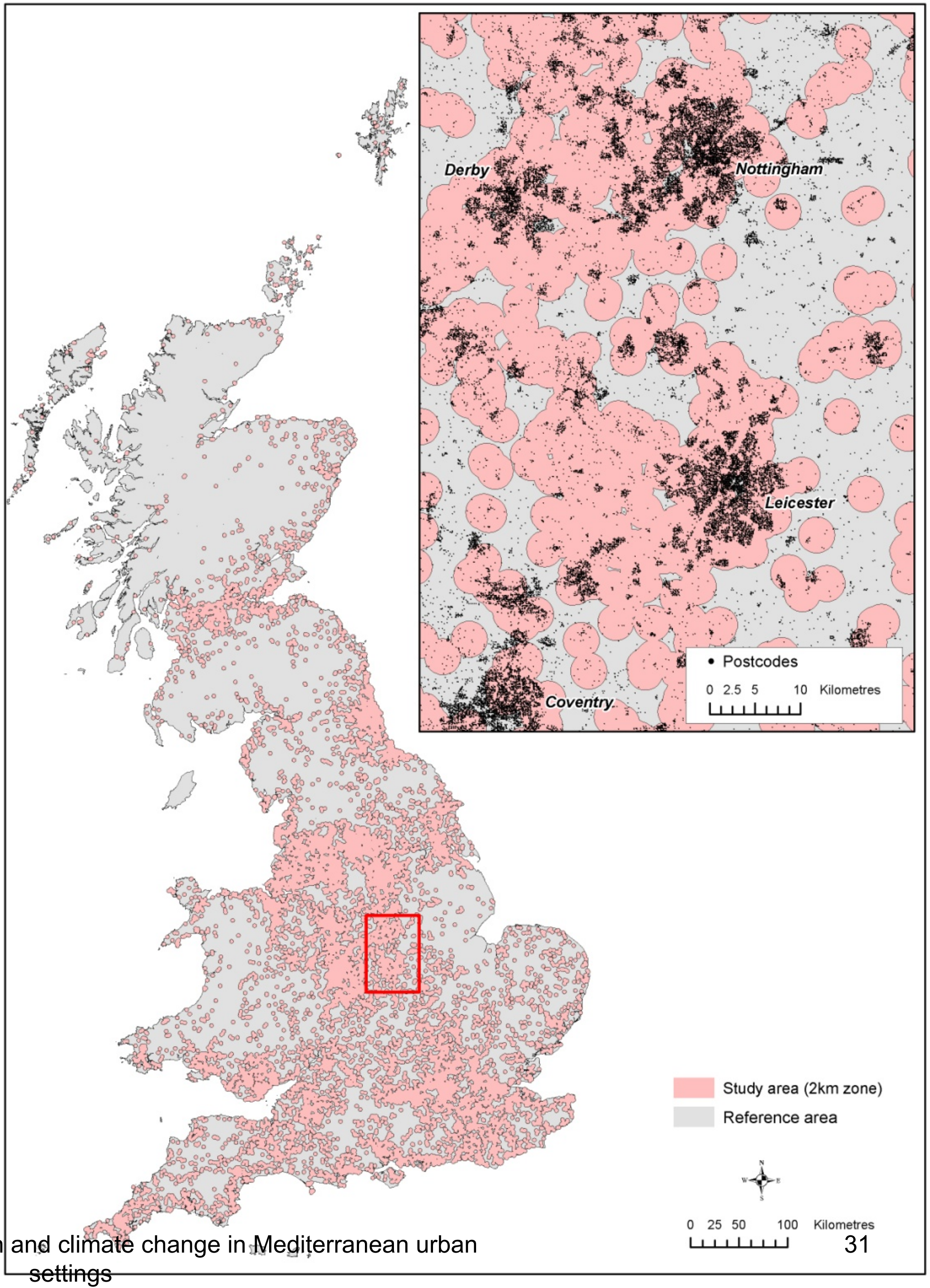


Examples

Risk of adverse birth outcomes in populations living near landfill sites

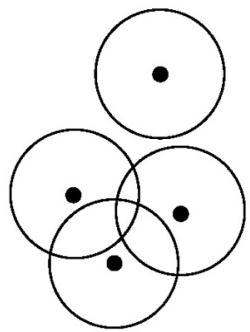
Elliott P, Briggs D, Morris S, de Hoogh C, Hurt C, Jensen T K, Maitland I, Richardson S, Wakefield J, and Jarup L. BMJ 2001;323:363-368

Areas within 2 km of a landfill site in Great Britain

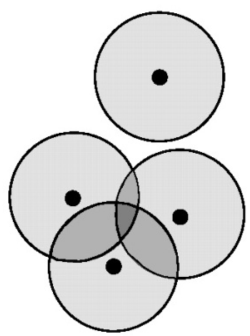


Exposure assessment

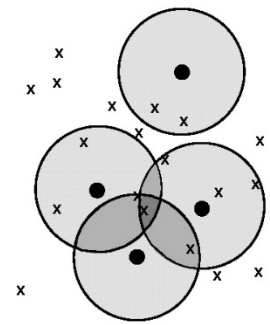
a) Construct separate 2km buffers around each landfill site



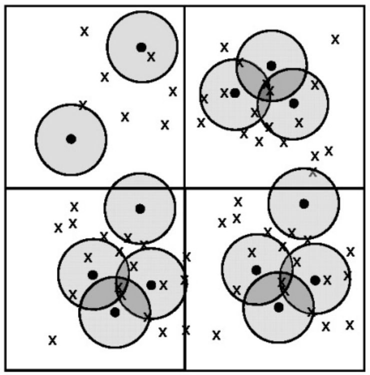
b) Intersect buffers and create density map with number of overlaps (landfill sites within 2km) attributed to each polygon



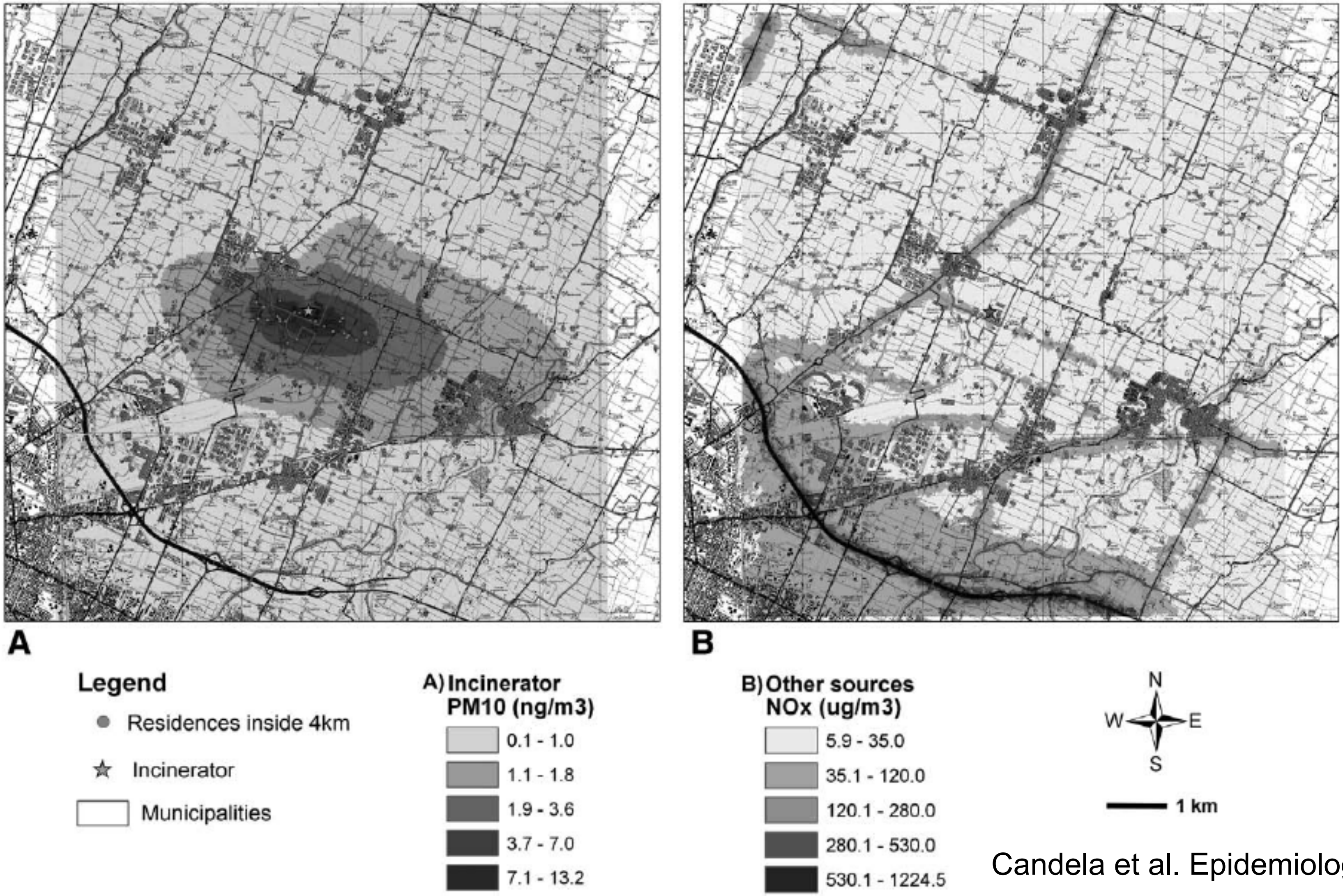
c) Intersect density map with postcodes and attribute number of landfill sites to each postcode



d) Intersect with 5km grid cells and compute birth- and time-weighted landfill index for each cell



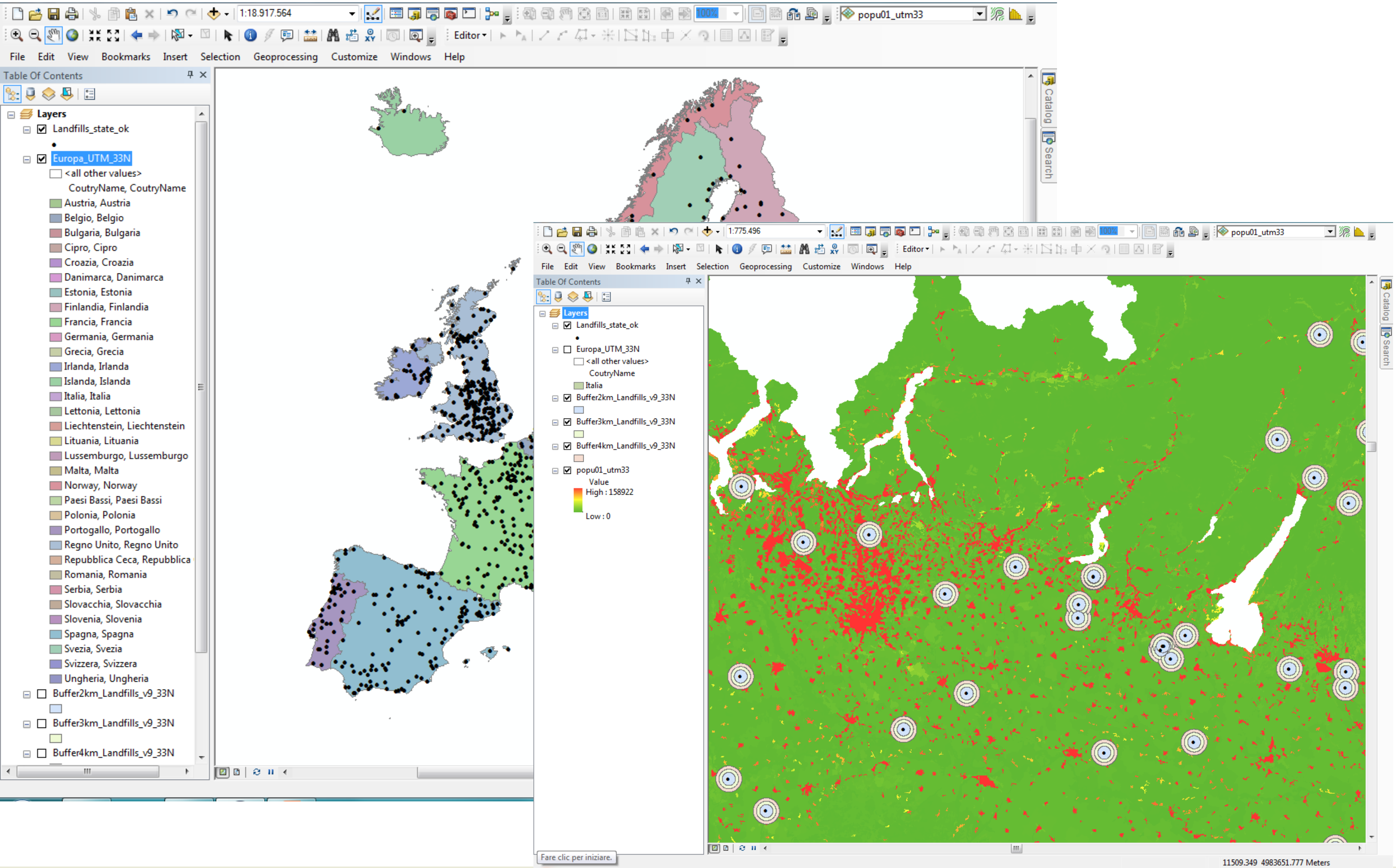
Air Pollution from Incinerators and Reproductive Outcomes



Candela et al. Epidemiology 2013

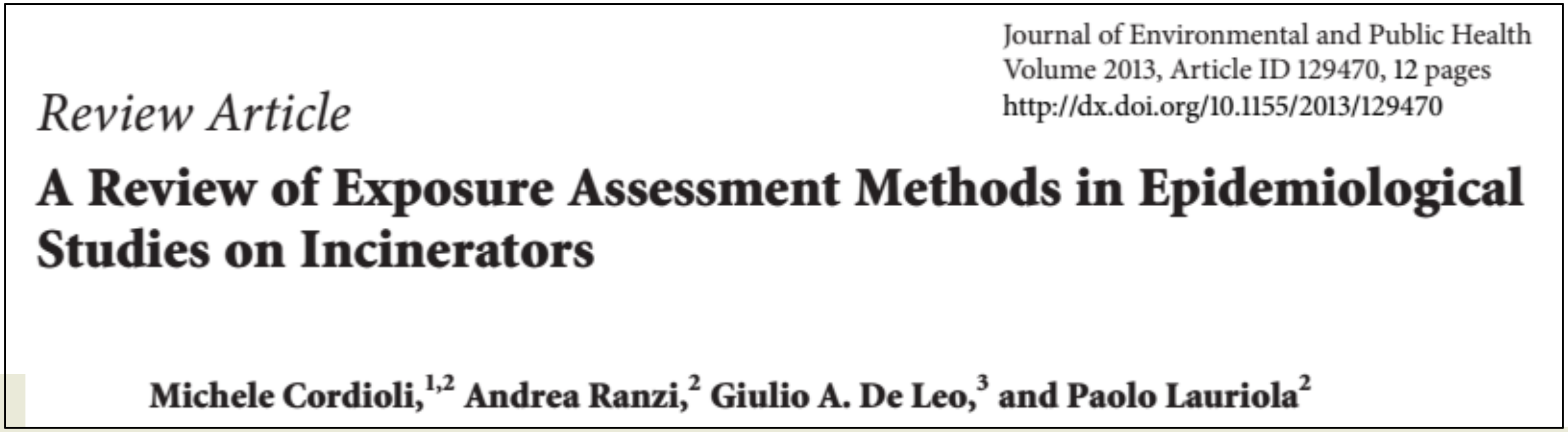
FIGURE 1. Pollutant dispersion map of Bologna site: A, PM_{10} (year 2006) for incinerator; B, NO_X for other sources.

HIA for residents near landfills sites in EU



Literature review on incinerators

- Incinerators as examples of industrial sources of atmospheric pollution
- Many reviews available on health effect
- No review on exposure assessment methods


Journal of Environmental and Public Health
Volume 2013, Article ID 129470, 12 pages
http://dx.doi.org/10.1155/2013/129470

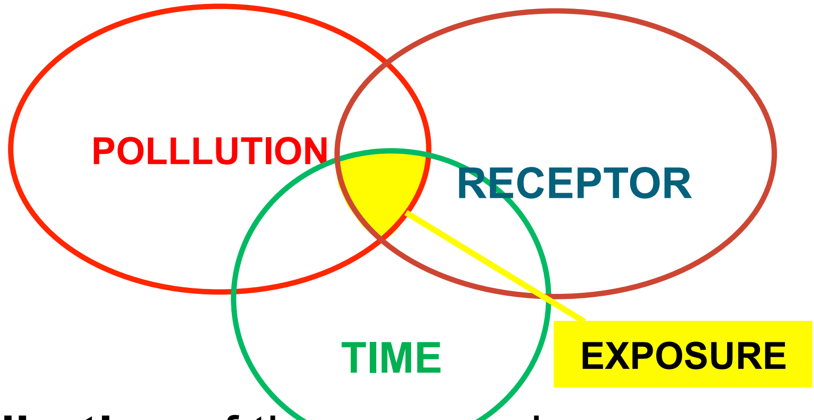
Review Article

A Review of Exposure Assessment Methods in Epidemiological Studies on Incinerators

Michele Cordioli,[1,2] Andrea Ranzi,[2] Giulio A. De Leo,[3] and Paolo Lauriola[2]

Framework for exposure assessment quality

Three criteria:



1. the approach used to define the **intensity** of exposure to the emission source;

2. the scale at which the **spatial distribution** of the exposed receptors is accounted for;

3. whether **temporal variability** in exposure is considered or not.

Table 1: Classification of exposure assessment methods.

Category	Description
	Criterion 1: definition of exposure intensity
1	Qualitative (e.g., presence/absence of the source/contamination in an area)
2	Distance from the source (e.g., linear distance)
3	Dispersion models (e.g., average annual atmospheric concentration)
	Criterion 2: definition of population distribution
1	Municipality/community/postcode sector
2	Census unit/full postcode
3	Exact residential address location
	Criterion 3: temporal variability
1	Time-invariable (i.e., fixed) exposure
2	Time-variable exposure (e.g., residential history and/or variability in emissions from the source)

WORST → BEST

Literature review

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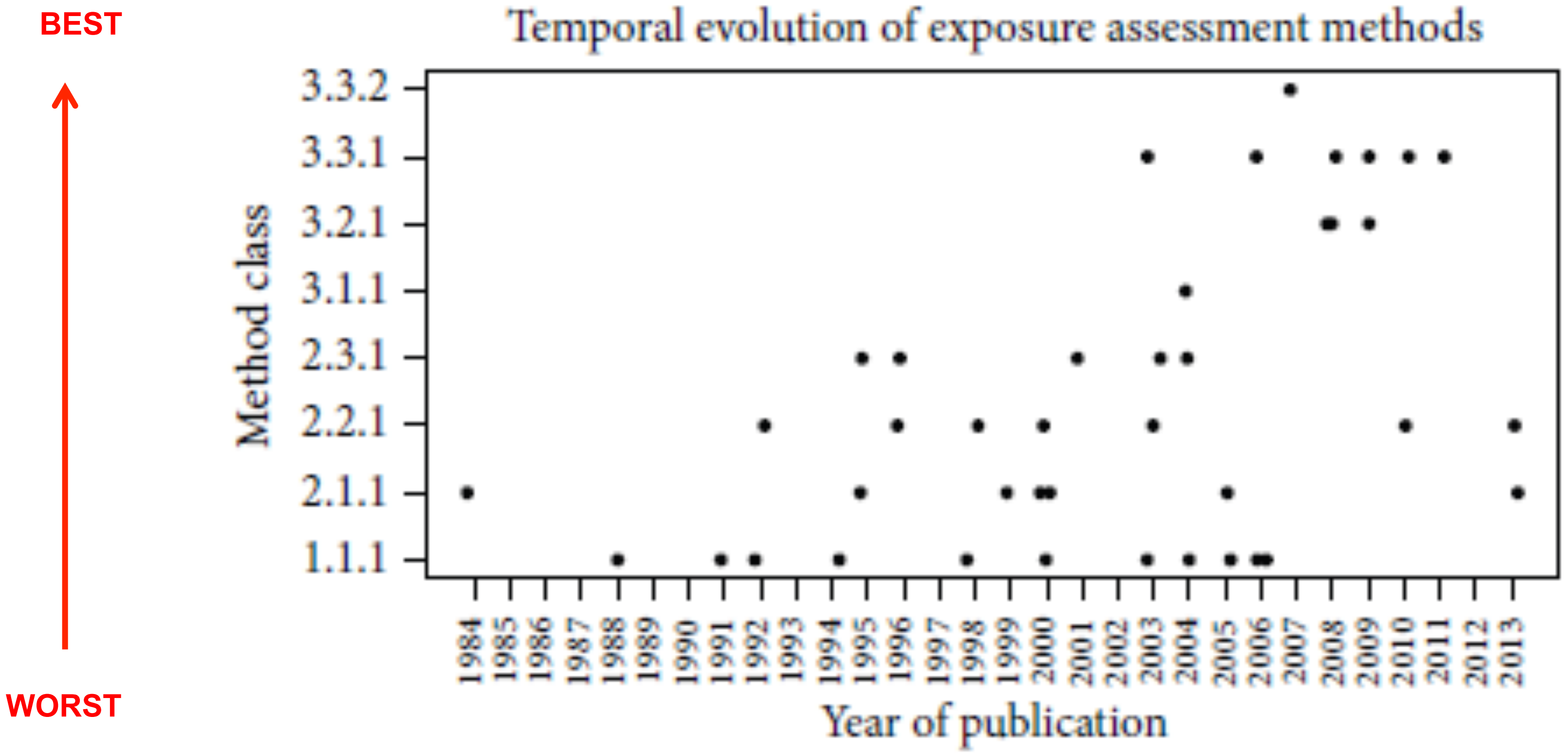
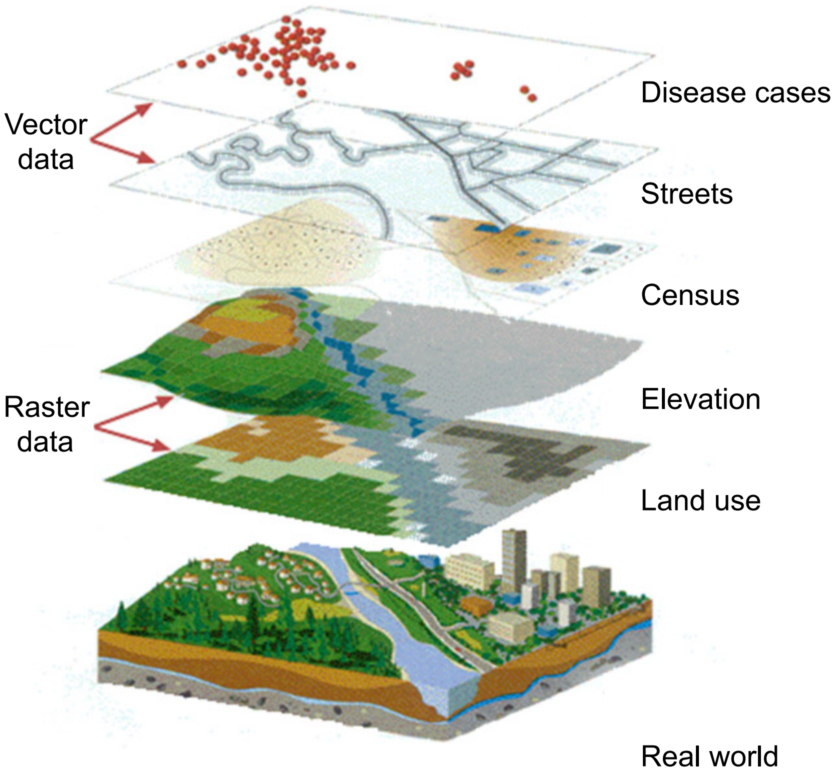


Improvements in Exposure Assessment are mainly due to the use of GIS

Summary: Role of GIS

- Capture geographic data
- Integrate data into a common geographic format
- For data validation & quality control
- Map disease, environmental hazards and SES factors
- Spatial modelling
- Link exposures
- Integration of models
- Provide a basis for:
  1. Exposure assessment
  2. Risk assessment
  3. Scenario analysis

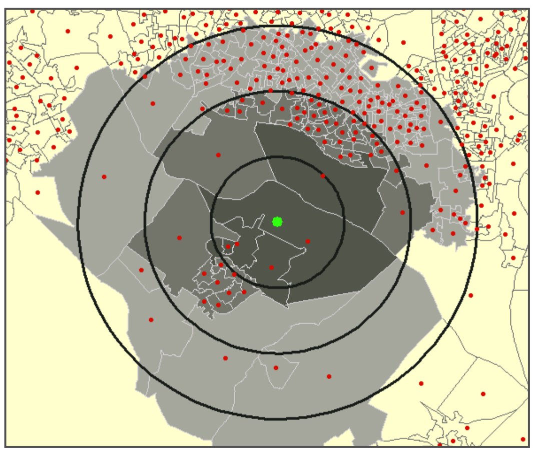


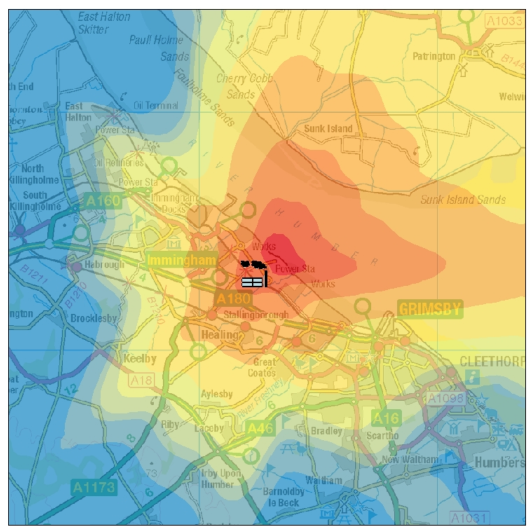
GIS Software

Commercial	Open source (free)
ArcGIS (ESRI)	GRASS GIS – The world's leading Free GIS software
MapInfo Professional	PostGIS – Spatial PostgreSQL
manifold.net	QGIS
	R

Incinerator	N	Deciles	Quintiles	Tertiles
Crymlyn Burrows	13069	0.307	0.519	0.553
Marchwood	19166	0.198	0.446	0.448

Kappa factor (where 0 = no agreement; 1 = perfect agreement)





Measure of agreement (Kappa factor, Weighted-Equal) between modelled long term PM_{10} concentrations and distance away from stack categorised in deciles, quintiles and tertiles at postcode level