

# Land use from remotely sensed data & networks of land cover objects

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# Structure

- **Mapping land use from remotely sensed data**
  - 1) Reliable land use maps
  - 2) Unified classification frameworks for mapping land use
  - 3) Modelling human behaviour with GPS data collection
- **Networks of land cover objects**
  - **Separating land use from land cover**

# Mapping land use from remotely

# Introduction

- Originally: examine transitions of land cover to land use
  - Contrasting case studies
  - Network Theory
- But yesterday: many of your classifications are 'relatively' **spectrally distinct**
  - Land use CAN be identified from land cover
  - Perhaps in part, this is because the number of land use classes is small

# Introduction

- So I have considered what was said yesterday
- But I will return to my original plan at the end
- I will go through the suggestions for the different objectives identified by Umezaki

# 1) Reliable land use maps

- Remote sensing issues in mapping
  - Green is green, subpixel variation, repeatability
  - Incorporation of **knowledge** suggested by many workers
- OO offers opportunity to incorporate knowledge
  - **RS knowledge**: Sequential hierarchy to reflect image characteristics
    - E.g. large spectrally homogenous classes **before** small heterogeneous ones
    - Use of **different types of image** to identify different features – heterogeneity at 5m pixel may be homogeneity at 30m
  - **Land Use knowledge**: topological, context, specific to the class
    - E.g. phonological sequence of crops
    - Paddy fields or glass houses may have a regular shape
    - Land use class A composed of land cover classes X,Y,Z

# 1) Reliable land use maps

- Aim: to separate different **signals** (of land use) from the **noise**
- eCognition
  - Construct **sequences** of segmentation / classification
  - Reflect these in **class hierarchies**
- The manual for field workers
  - should encourage workers to think about how to **incorporate their knowledge** of the land use
  - into the classification process, sequence and hierarchy

# 1) Reliable land use maps

- Lex's possible role:
  - (Background in incorporating knowledge into RS classification)
  - Direct support for mapping
    - Help formalise knowledge
    - Classification / segmentation work flows
    - Hierarchies and Sequences
    - Image selection
  - Input into field worker manual: “these are the things you need to think about”



## 2) Unified classification frameworks for

- problem is the heterogeneity of classifications
  - different land uses required for different studies
- Want to maintain classification diversity
  - NOT a single, all encompassing classification
  - NOT a standard!
- traditional approaches
  - **Aggregate** to few super classes
    - e.g. Forest, Grass, Urban, Water, etc
    - BUT over-simplification
  - Calculate **overlaps** between different classification
    - measures of correspondence and use to parameterise probabilistically
    - BUT aspatial, hard to pass information to non-specialists

## 2) Unified classification frameworks for

- Other approaches
  - Reference classifications
    - LCCS describes each class in terms of different characteristics
      - Veg Structure, height, etc
      - Generate unique hierarchical code for each land use
      - BUT some of these are non-continuous and may not fit the requirements (e.g. 3 height classes)
  - Data primitives: **Dimensions of land use**
    - E.g. Biomass, anthropogenic disturbance, height, canopy cover, financial value, etc ( $n$  dimensions)
    - Scored by local expert – act as class description
    - Each class has a position in  **$n$ -dimensional feature space**
    - **distances** between classes can be calculated (relatedness)
  - Measures of the **conceptual overlaps** between different classes
    - ontologies, meaning, semantics

## 2) Unified classification frameworks for

- Lex's possible role:
  - (background in data primitives)
  - Research
    - to develop and apply data primitive dimensions
    - evaluation and comparison with LCCS
  - Input into manual to support good land use and land cover maps for each areas: “these are the important land use dimensions internationally, nationally, locally”

# 3) Modelling human behaviour with

- Objectives:
  - Link human behaviour to land use
  - Manual for data collection
- Meta-Objective:
  - to identify (spatial) statistical relationships between human health and land use (activity and environment)
- Spatial and temporal modelling techniques
  - Point distributions
  - Paths (time / distance) to infer activity
  - Look to identify global and / or local relations
    - Spatial Statistical techniques to do this (e.g. GWR)
    - Depends on the human ecology objectives

### 3) Modelling human behaviour with

- Lex's possible role
  - Validation and advice on construction of land use data (especially the international dataset)
  - Some possible input into spatial statistics
  - BUT other local people will be better placed (Tomoki Nakaya)

# Mapping land use from remotely

- Summary of Lex's possible input

## 1) Reliable land use maps

- Direct support for mapping
  - Help **formalise knowledge** into classification / segmentation flows
- Input into field worker manual: *“these are the things you need to think about”*

## 2) Unified classification frameworks for mapping land use

- Research
  - to develop and apply **data primitive** dimensions
  - evaluation and comparison with LCCS
- Input into manual to support good land use and land cover maps for each areas: *“these are the important land use*

# Mapping land use from remotely

## 3) Modelling human behaviour with GPS data collection

- Some possible input into spatial statistics
- BUT other local people will be better placed (Tomoki Nakaya)

## 4) Also: methods based on network and graph theory

- New methods in RS
- Particularly relevant to OO classifications
  - Objects and their relations
- Another one of my current research interests
- Possibly: land use mappings in YOUR projects that require MY input
- Compare different case studies

# Part 2: **Networks of land cover objects**

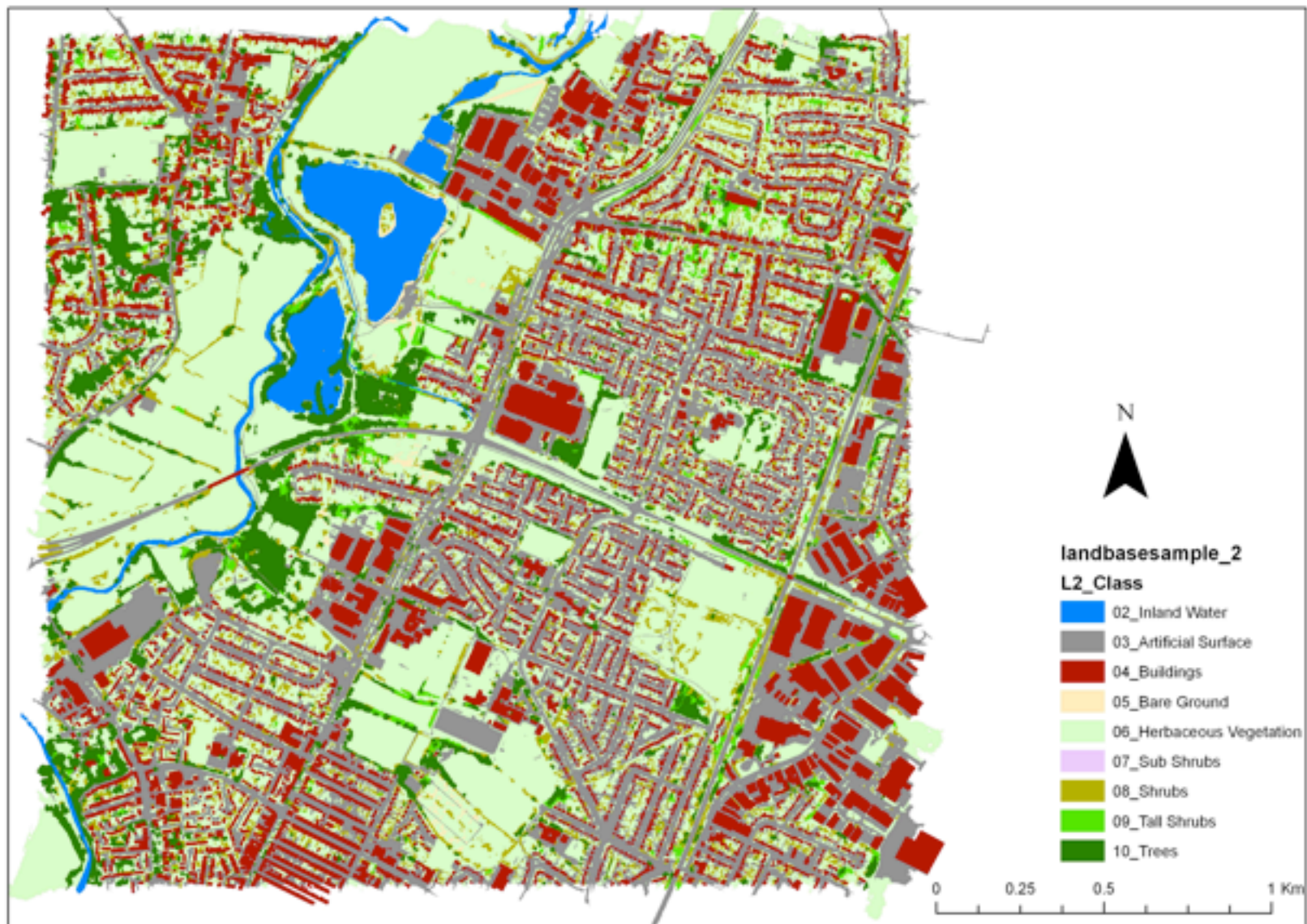
- Separating land cover from land use



# Aim

- Identify Land Use from Land Cover objects
- Land use
  - Difficult to identify directly from remotely sensed data
    - Especially when many classes:
    - Grass: sheep, park, garden, sport
  - Composed of different land covers
    - Same land covers → different land uses
  - Relevant to many policy applications
- Lack of infrastructure in developing countries
  - (cf Wyatt (2004) mapped land use from existing digital infrastructure)

# Example: Landbase (Infoterra)



# National Land Use Classification

- NLUDS

NLUD Classification Version 4.4

LAND USE

## 4.0 RECREATION AND LEISURE

### 4.1 Outdoor amenity and open spaces

- + Outdoor amenity and open spaces e.g. gardens, parks, zoos, picnic areas and play areas.
- + Civic spaces e.g. civic squares, plazas, sea fronts (including promenade).
- + Heritage sites and monuments.
- Excludes sports facilities (4.5)

### 4.2 Amusement and show places

- + Places for amusement and entertainment e.g. cinemas, theatres, concert halls and arenas, broadcast studios, dance halls, bingo halls, gaming and gambling clubs and premises.
- + Amusement arcades, fun fairs and circuses.
- + Visitor centres and interpretation centres.

### 4.3 Libraries, museums and galleries

- + Buildings, places, or institutions devoted to the acquisition, conservation, study, exhibition, and educational interpretation of objects having scientific, historical, or artistic value e.g. museums, libraries, art galleries, public and exhibition halls.

### 4.4 Sports facilities

- + Facilities for land sports e.g. pitches and stadiums for ball games, greens and courts for ball games, golf courses, athletics grounds, skating rinks, shooting ranges, race tracks, ski fields.
- + Facilities for water sports e.g. swimming, boating, sailing.

### 4.5 Holiday camps

- + Holiday camps and sites, including camping and touring caravan sites.
- Excludes caravan sites and mobile homes used as permanent dwellings (7.1).

### 4.6 Allotments and urban farms

- + Allotments and urban farms.

# National Land Use Classification

- NLUDS

NLUD Classification Version 4.4

LAND USE

## 7.0 RESIDENTIAL

### 7.1 Dwellings

- + Houses and flats for individuals and families living as a single household, including adjoining garages, gardens, estate roads and pathways.
- + Caravan sites and mobile homes used as permanent dwellings.
- + Sheltered residential accommodation with separate front entrances.

### 7.2 Hotels, boarding and guest houses

- + Hotels, B&B's, boarding houses, and residential clubs (where no significant element of care is provided).

### 7.3 Residential institutions

- + Residential accommodation for provision of care e.g. old peoples' homes, children's homes and other non-medical homes.
- + Residential schools and colleges and training centre, including university and hospital residences.
- + Communal residences e.g. barracks, monasteries and convents.

# National Land Use Classification

- NLUDS

NLUD Classification Version 4.4

LAND USE

## 10.0 INDUSTRY AND BUSINESS

### 10.1 Manufacturing

- + *Factories and refineries for processing of coal, petroleum, metals and other raw materials.*
- + *Manufacturing of food, drink, tobacco.*
- + *Manufacturing of chemical and allied products.*
- + *Mechanical, instrument and electrical engineering.*
- + *Marine engineering and shipbuilding yards.*
- + *Manufacturing of vehicles and other metal goods.*
- + *Textile and clothing manufacturing.*
- + *Brick, pottery, glass and cement manufacture.*
- + *Timber, furniture, paper and printing works.*
- + *Factory construction and demolition sites.*
- *Excludes utilities and infrastructure (6.1 – 6.6).*
- *Excludes primary extractive industries e.g. coal mines, stone quarry, and gravel pits (3.1).*

### 10.2 Offices

- + *Offices of central and local government, company offices, and other general offices.*
- + *Offices for research and development of products or processes.*
- + *Business meeting places and centres.*
- *Excludes offices providing financial, professional and other services for visiting members of the public (9.2).*

### 10.3 Storage

- + *Storage places and facilities for onward distribution (not sale) of equipment, bulk materials and goods e.g. warehouses, repositories, open storage land.*

### 10.4 Wholesale distribution

- + *Places for bulk dealing of raw materials, industrial supplies and machinery and livestock.*
- + *Wholesale distribution places for food and drink, petroleum and other non-food products.*



# National Land Use Classification

- NLUDS

NLUD Classification Version 4.4

LAND USE

## 11.0 PREVIOUSLY DEVELOPED LAND

*Previously developed land is that which is or was occupied by a permanent structure (excluding agricultural or forestry buildings), and associated fixed surface infrastructure. The definition covers the curtilage of the development. Previously developed land may occur in both built-up and rural settings. Includes defence buildings and land used for mineral extraction and waste disposal where provision for restoration has not been made through development control procedures*

*Excludes land and buildings that are currently in use for agricultural or forestry purposes, and land in built-up areas which has not been developed previously (e.g. parks, recreation grounds, and allotments - even though these areas may contain certain urban features such as paths, pavilions and other buildings).*

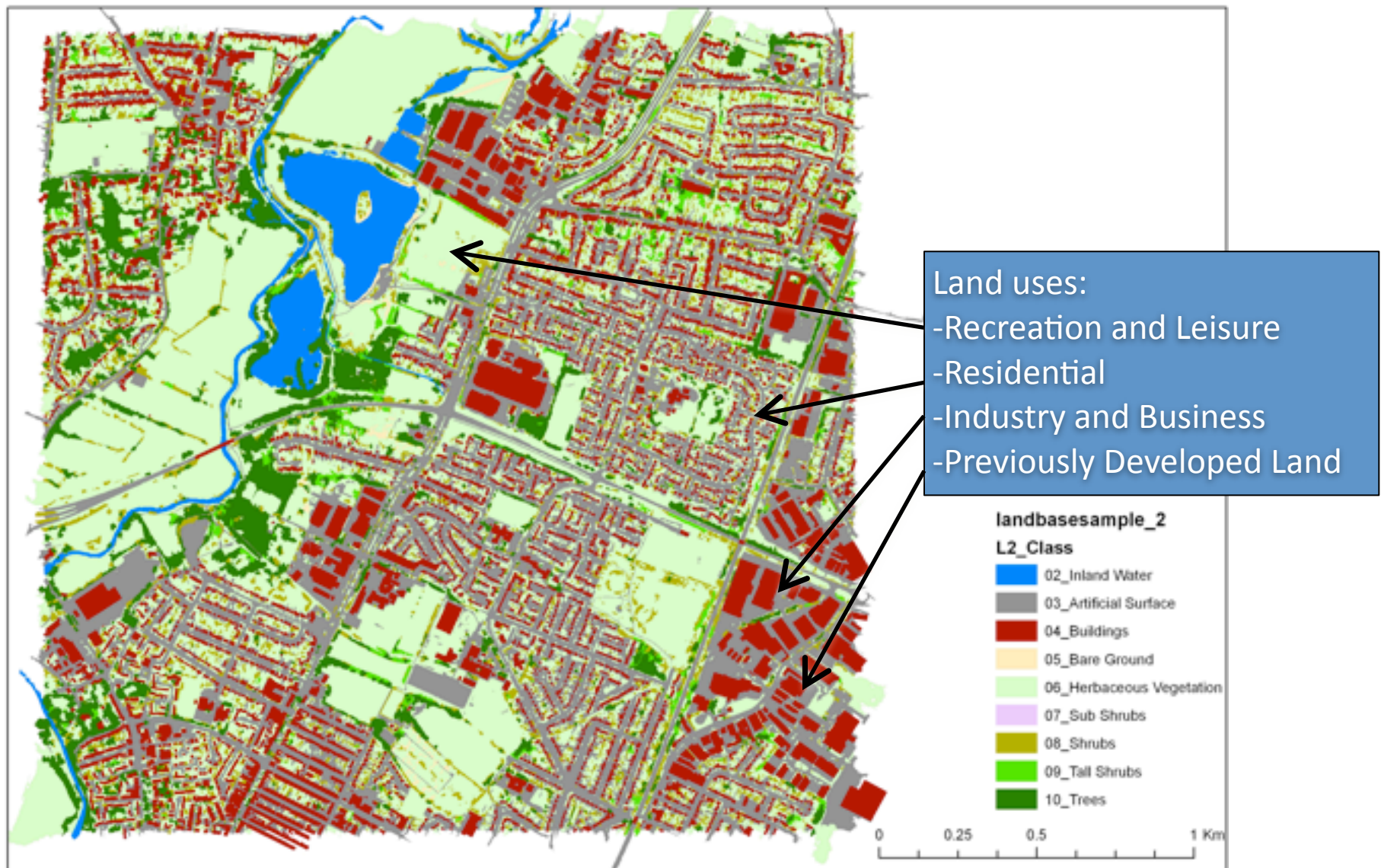
### 11.1 Vacant

- + *Previously developed land which is now vacant and could be redeveloped without treatment, where treatment includes any of the following: demolition, clearing of fixed structures or foundations and levelling.*
- + *Vacant buildings that are structurally sound and in a reasonable state of repair (i.e. capable of being occupied in their present state) where re-letting for their former use is not expected or that have been declared redundant.*
- *Excludes land previously used for mineral extraction or waste disposal which has been or is being restored for agriculture, forestry, woodland or other use.*

### 11.2 Derelict

- + *Land so damaged by previous industrial or other development that it is incapable of beneficial use without treatment, where treatment includes any of the following: demolition, clearing of fixed structures or foundations and levelling.*
- + *Abandoned and unoccupied buildings in an advanced state of disrepair i.e. with unsound roof(s).*
- *Excludes land damaged by development which has been or is being restored for agriculture, forestry, woodland or other open countryside use.*
- *Excludes land damaged by a previous development where the remains of any structure or activity have blended into the landscape in the process of time (to the extent that it can reasonably be considered as part of the natural surroundings), and where there is a clear reason that could outweigh the re-use of the site - such as its contribution to nature conservation - or it has subsequently been put to an amenity use and cannot be regarded as requiring redevelopment.*

# Example



# Problem

- How to translate land cover to land use whilst taking account of:
  - The **many land cover components** associated with any given land use
  - The **different aggregations** of land cover
    - Buildings and Artificial surfaces → residential or commercial?
  - Spatial aspects of translation
    - Different kernels or windows → different land uses



# Other work

- Moving window or kernel based methods (e.g. Barr and Barnsley, 1996)
- Graph / network theory (Barr and Barnsley, 1997a, 1997b)
- Landscape spatial metrics (e.g. Herold *et al.*, 2002)
- Hybrid approaches using knowledge in object oriented classifications (e.g. Wastfelt, 2009)
- Good review of LC to LU in Lu and Weng (2007).

# Methods

- Combination of different approaches for different land uses

## 1) GIS Querying Landbase attributes

- Proportions of classes within 50m of the object (adjacencies)
- GIS operations
  - Aggregation of features
  - Queries based on object adjacency and spatial attributes

## 2) Network based approaches

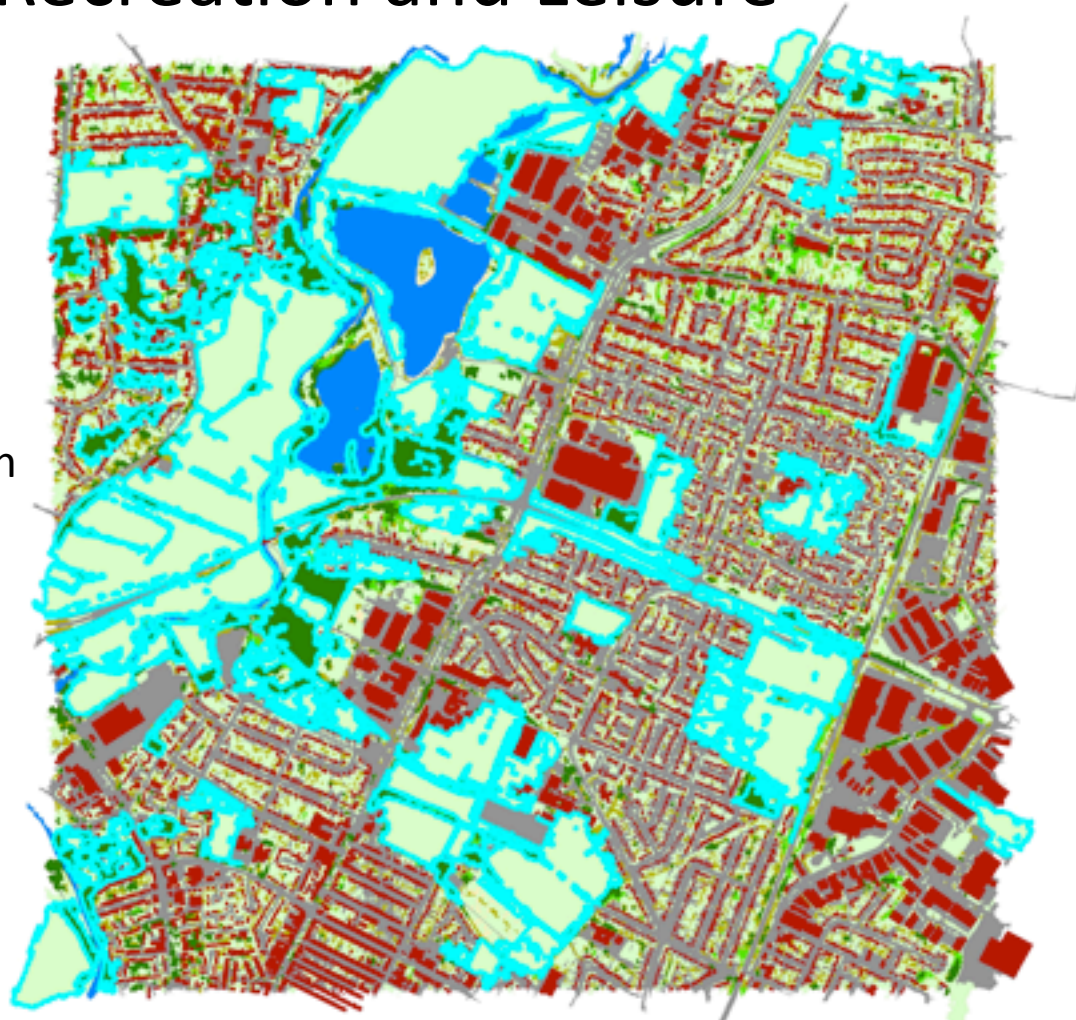
- Relations between objects (spatial e.g. adjacency, attribute similarities)

# Queries

- Recreation and Leisure
  - Associated with large areas and greenery
- GIS operations
  - Dissolve objects
  - Query to identify *Recreation and Leisure* land use
    - “Herbaceous Vegetation with large area
    - OR
    - Trees with large area 10000)
    - OR
    - Trees next to Herbaceous Vegetation ( $>0.3$ ) and moderate area”

# Queries

- Fine for Recreation and Leisure



Large areas of  
Herbaceous Vegetation  
and/or Trees

# Queries

- Not so good for 'Residential' & 'Industry and Business'





# Queries

- Not so good for 'Residential' & 'Industry and Business'

Small buildings & roads



# Queries

- Not so good for 'Residential' & 'Industry and Business'



Small buildings & roads

# Queries

- Not so good for 'Residential' & 'Industry and Business'



Large buildings & roads



# Queries

- Not so good for 'Residential' & 'Industry and Business'



Large buildings & roads

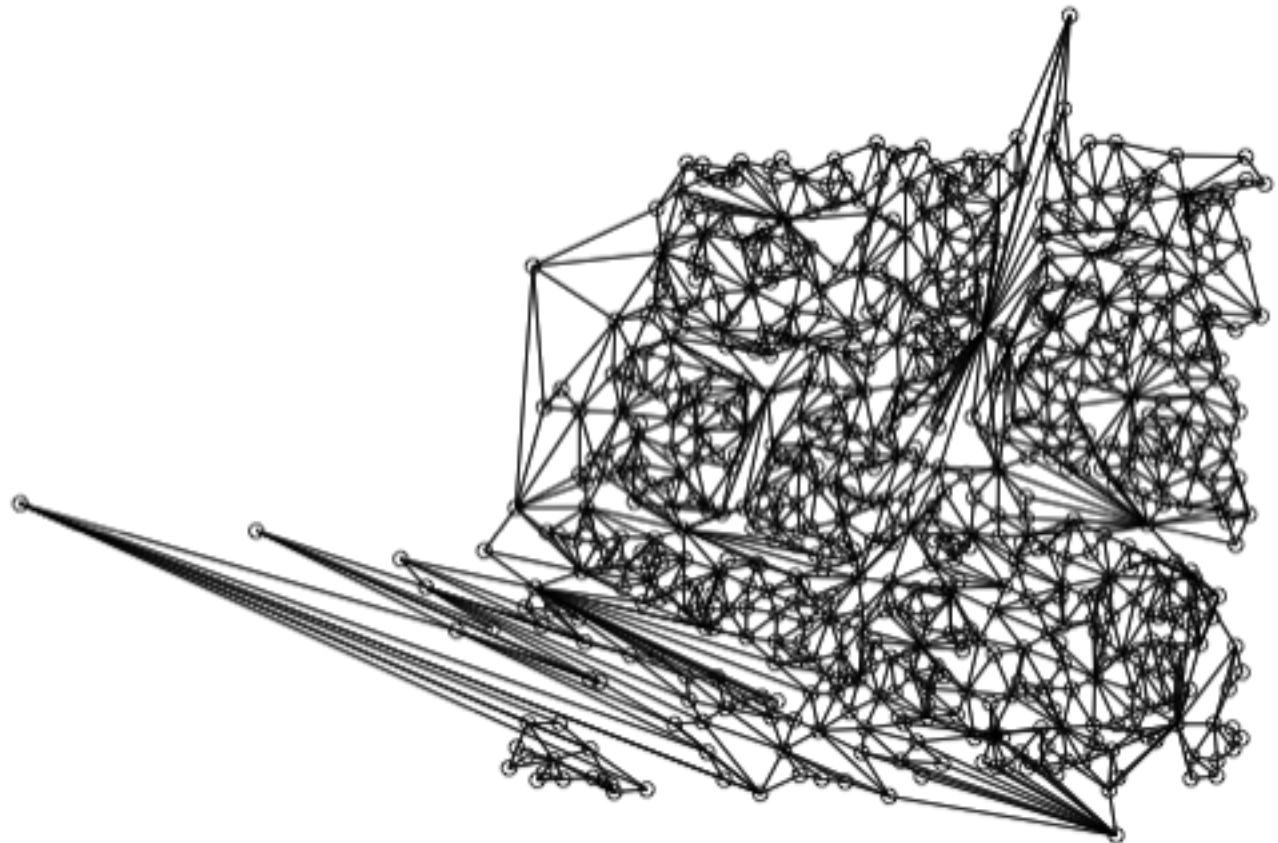
# Network based approaches

- R software & libraries (igraph spdep maptools)
- Using neighbour functions
- Small portion of test data



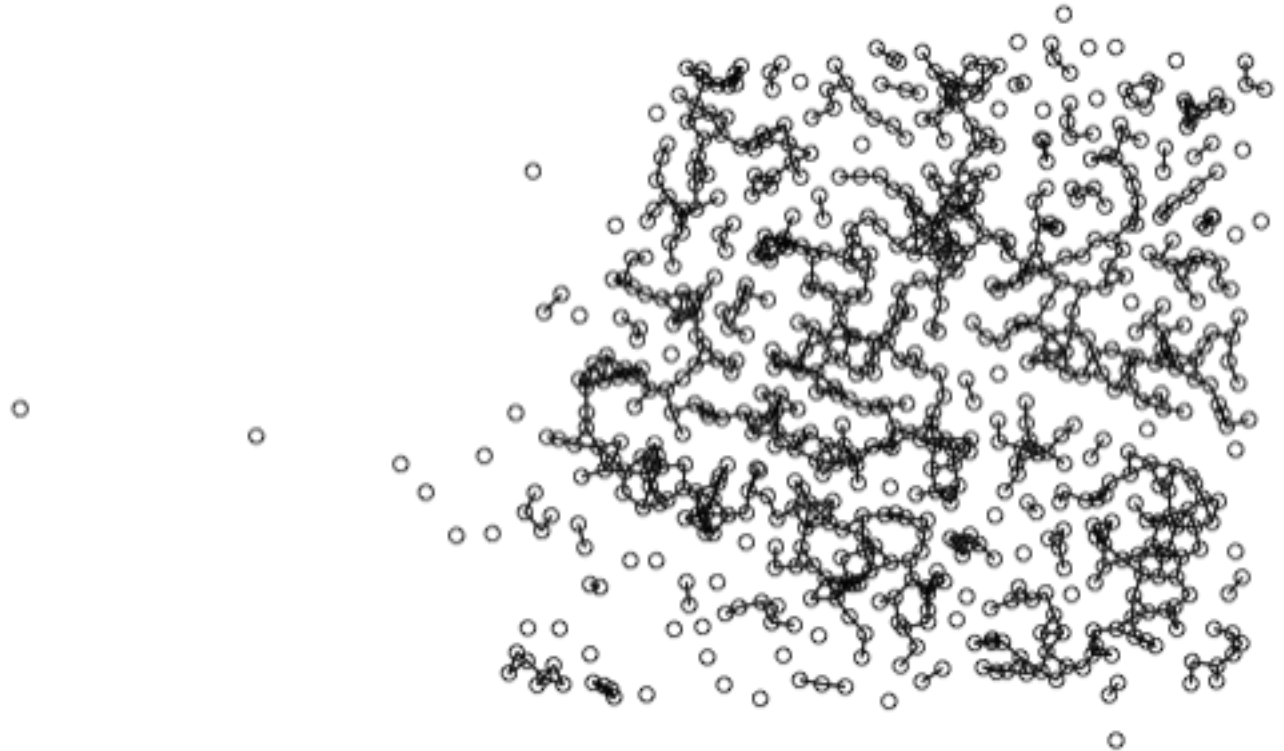
# Network based approaches

- Network of adjacencies



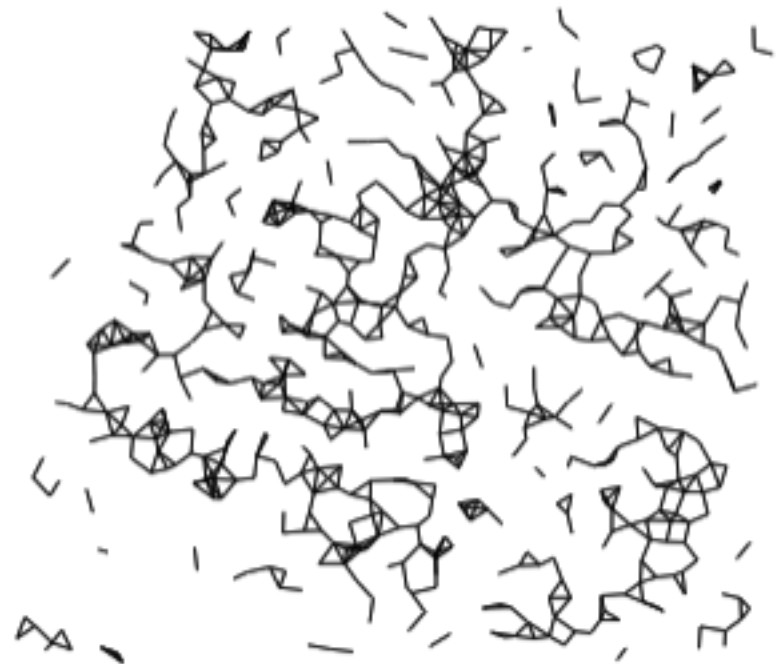
# Network based approaches

- But actually interested in more ‘local networks’
  - Impose a neighbourhood search space



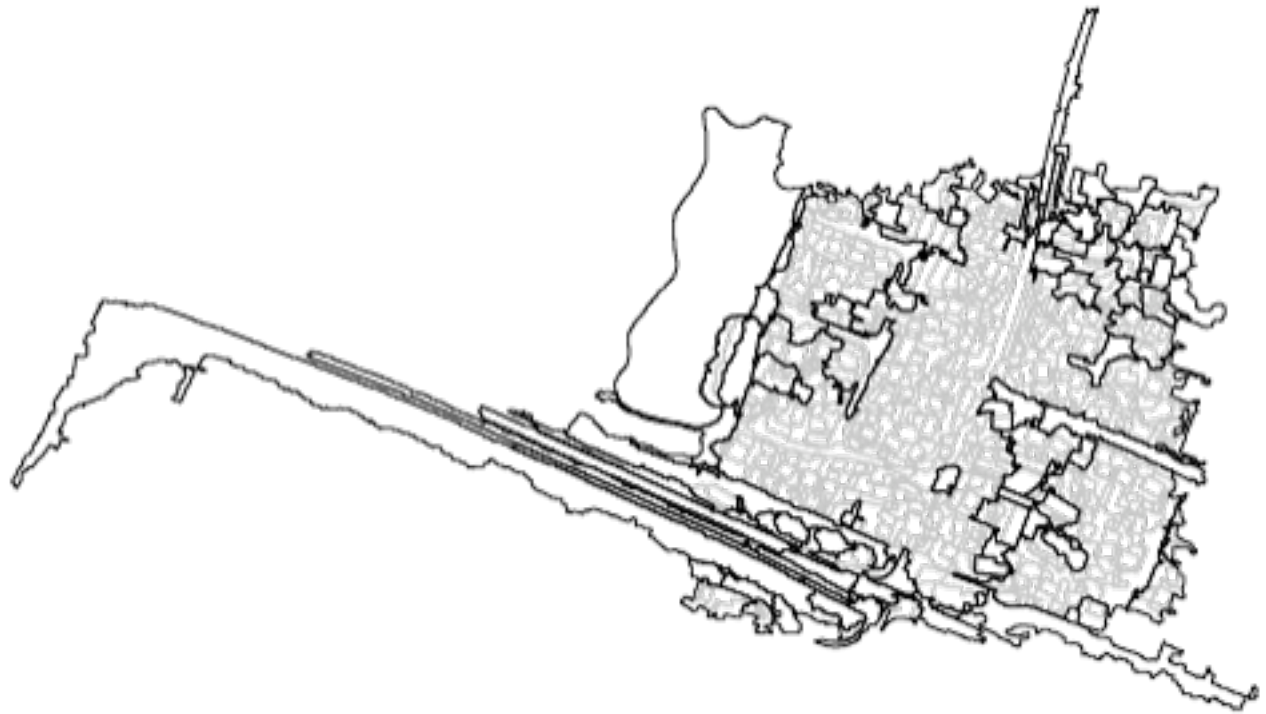
# Network based approaches

- But interested in more ‘local’ networks
  - Impose a neighbourhood search space
  - Adjacency 0 to 10m
  - Identifies clusters



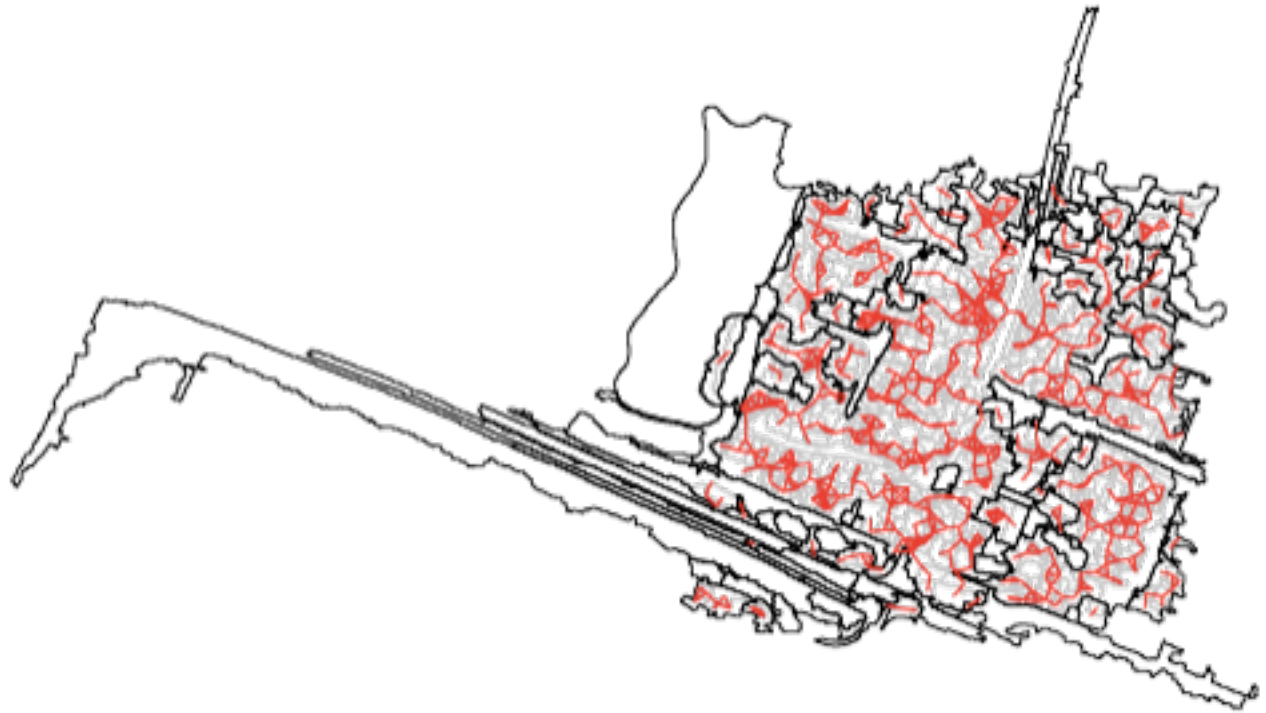
# Network based approaches

- Create new regions from network clusters



# Network based approaches

- Create new regions from network clusters



# Network based approaches

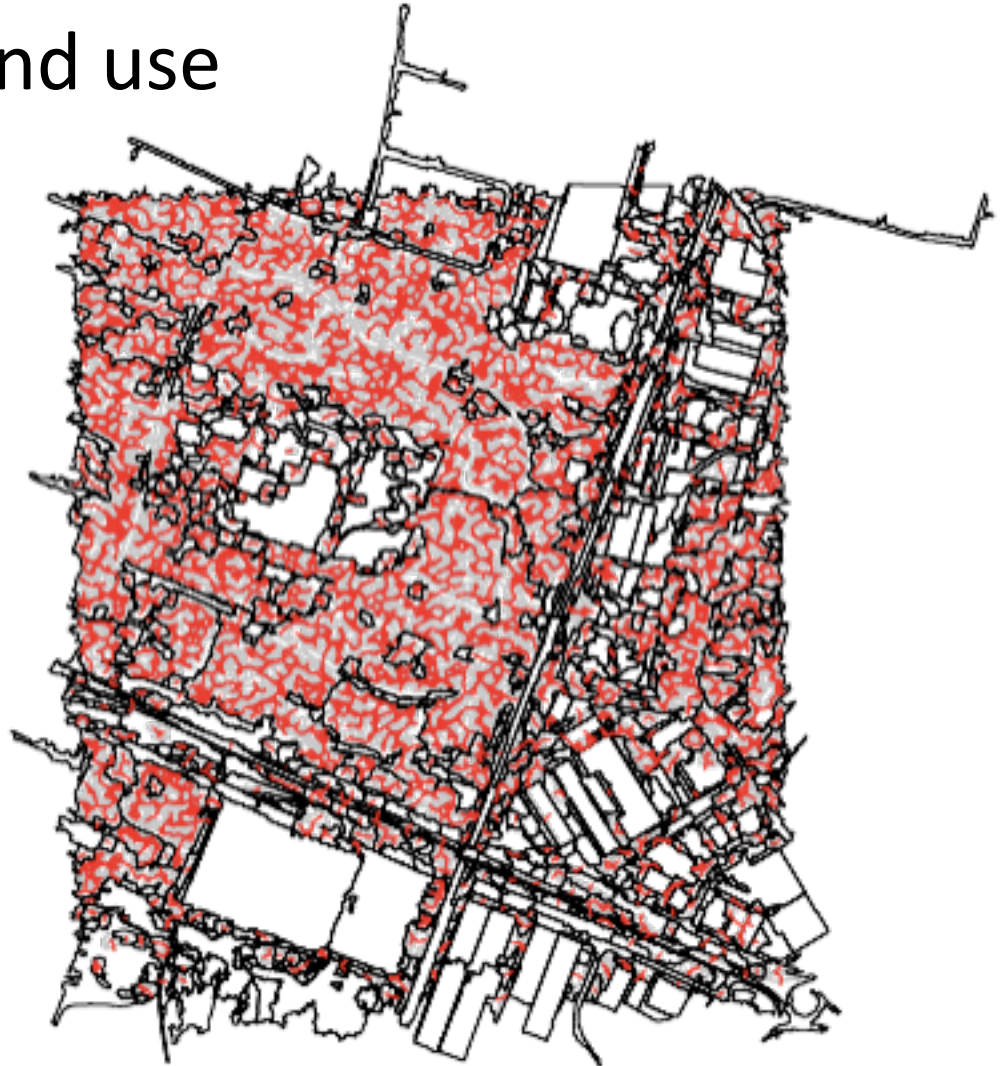
- Compare with original land cover data





# Network based approaches

- Areas with mixed land use



# Network based approaches

- Other mixed land use areas
- Separates residential and commercial

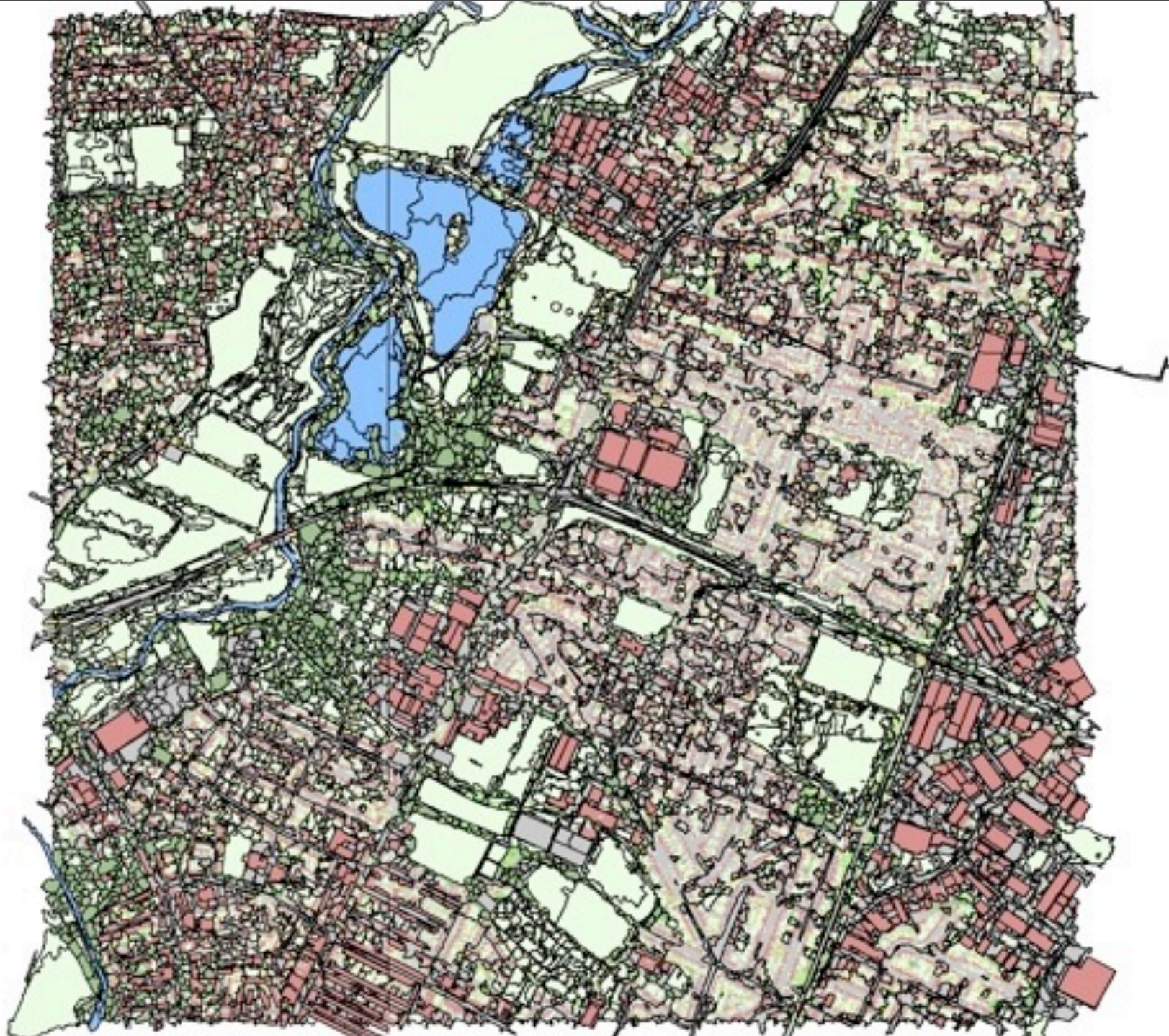


# Land cover composition

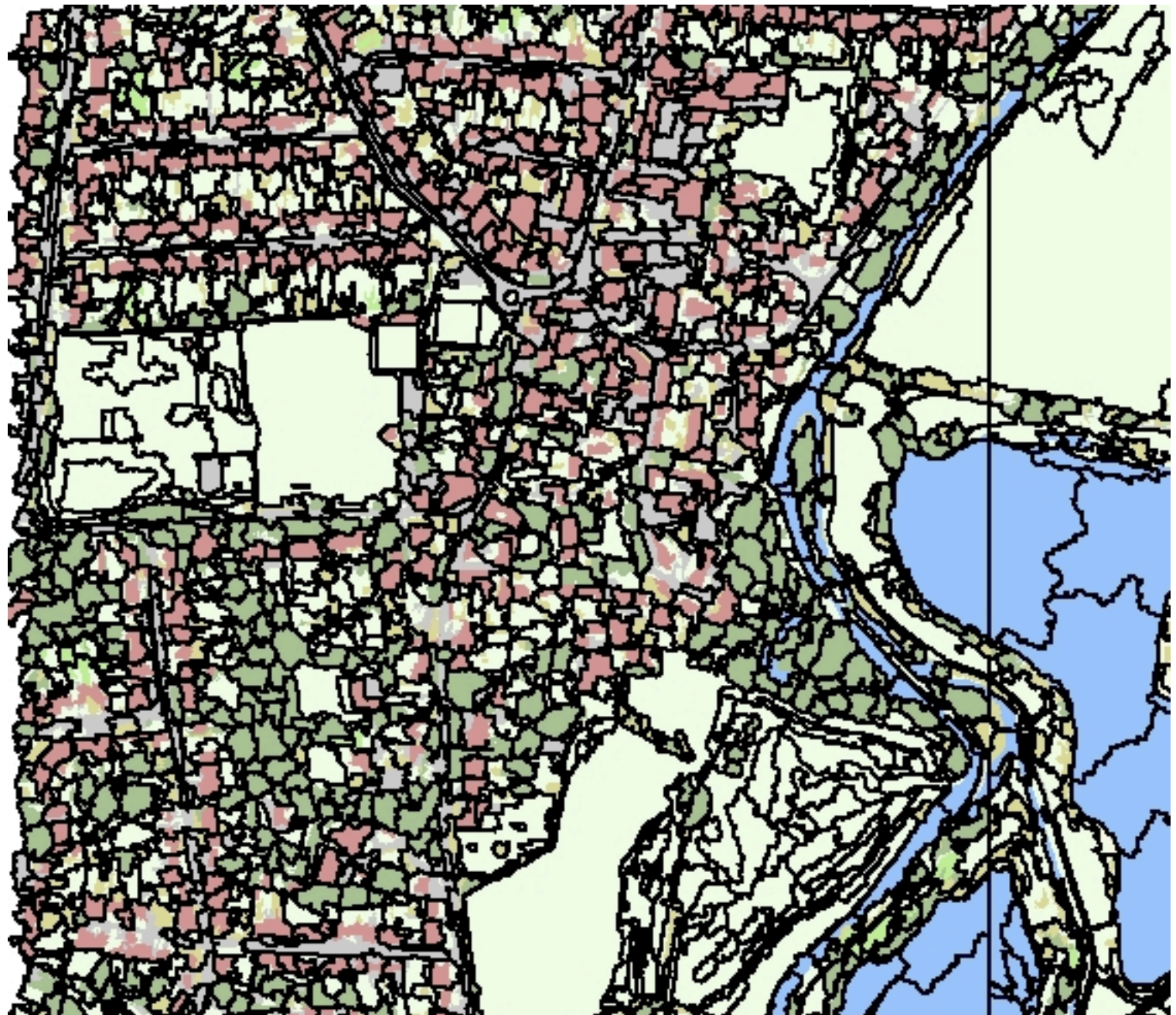
- Proportions of different land cover classes in output

ID	Sea	Water	ArtSurf	Build	Bare	Herb	SubShrub	Shrub	TallShrub	Tree
0	0	0	1	0	0	0	0	0	0	0
1	0	0	1	0	0	0	0	0	0	0
2	0	0	0	0	0	1	0	0	0	0
3	0	0	0.25	0.375	0	0.375	0	0	0	0
4	0	0	0	0.125	0	0.5	0	0.25	0	0.125
5	0	0	0	0	0	1	0	0	0	0
6	0	0	0	0	0	0	0	0	0	1
7	0	0	0	0	0	0.6667	0	0.3333	0	0
8	0	0	0	0	0	0	0	0	0	1
9	0	0	0	0	0	0.5	0	0.5	0	0
10	0	0	0	0	0	1	0	0	0	0
11	0	0	0.1111	0.2222	0	0.4444	0	0.2222	0	0
12	0	0	0.2	0.1333	0	0.4667	0	0.2	0	0
13	0	0	1	0	0	0	0	0	0	0
14	0	0	0.1667	0.25	0	0.25	0	0.1667	0.1667	0
15	0	0	0	0	0	0	0	0	0	1
16	0	0	0	0.2	0	0.4	0	0.4	0	0
17	0	0	0	0	0	0.6667	0	0.3333	0	0
18	0	0	0	0	0	0	0	0	0	1
19	0	0	0	0	0	1	0	0	0	0
20	0	0	0	0	0	0.5	0	0.25	0	0.25
21	0	0	0.25	0.25	0	0.25	0	0.25	0	0
22	0	0	0	0	0	0.5	0	0	0	0.5
23	0	0	0.4118	0.1765	0	0.2941	0	0.0588	0.0588	0
24	0	0	0.125	0.0938	0	0.4063	0	0.2188	0.0625	0.0938









# Summary

- Land use is difficult to measure directly from RS data
  - Same cover: many uses, Single use: many covers
- Some LUs can be identified using spatial & attribute query
- Network and Graph Theory are promising for others
  - Neighbourhood analyses (e.g. Adjacency)
  - Ideas from Barr and Barnsley BUT they did not follow through – stopped!
- My research: aims to find natural clusters in the data
  - Different methods for identifying clusters
  - More intuitive for object based analyses
  - Different types of use have different spatial patterns
    - e.g. different types of urban residential
- Future work will continue to develop and refine these ideas
  - Network relations based thematic with spatial attributes
  - Eigenvectors to determine subsets 'minimum cut sets'
  - Match to land use characteristics to land use composition of clusters
  - Possible 2<sup>nd</sup> case study: Papua New Guinea or other SE Asia



# Thanks!

## References

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## Acknowledgements

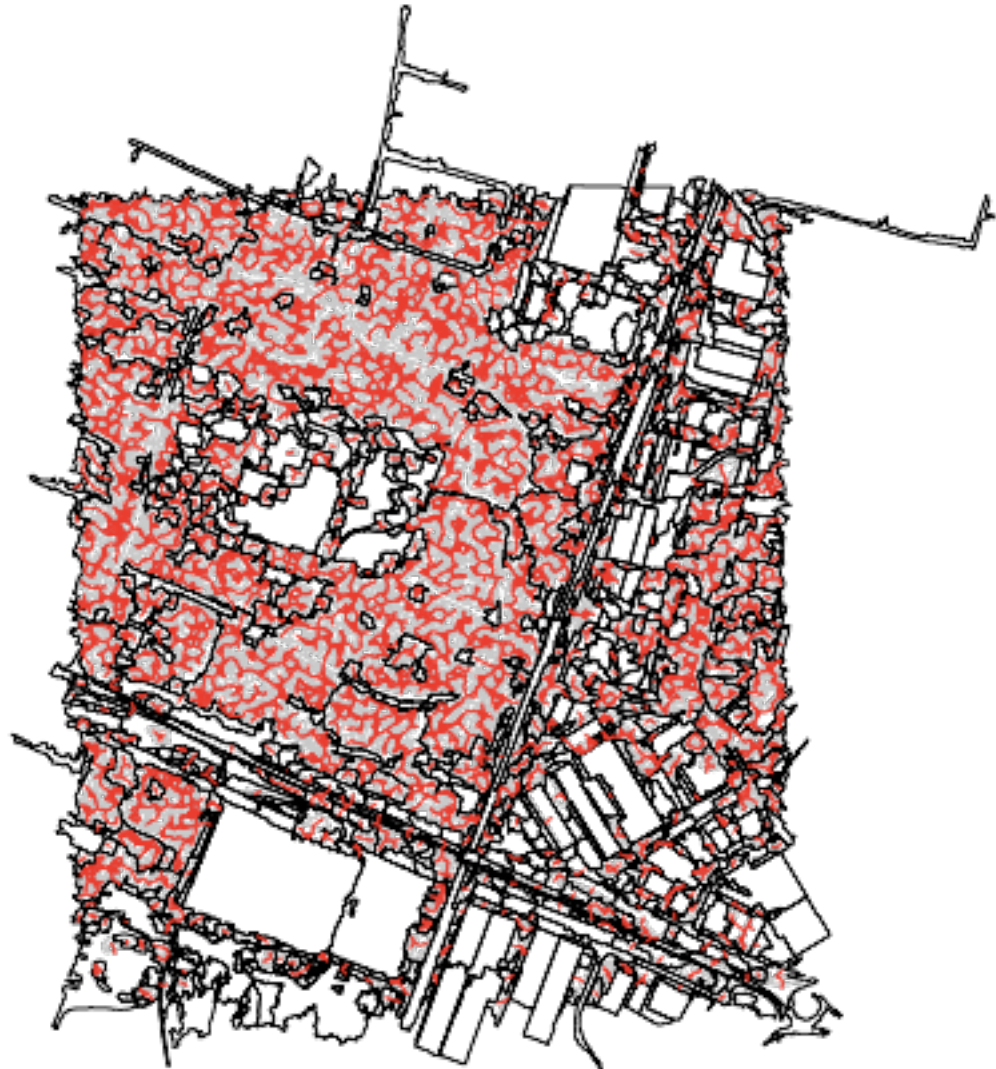
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University of Leicester for a sabbatical and the thinking time



# 0 to 10





# 10 to 15



# 15 to 20

