Session 4: Lecture 5:

Development of a CA Urban Growth Model

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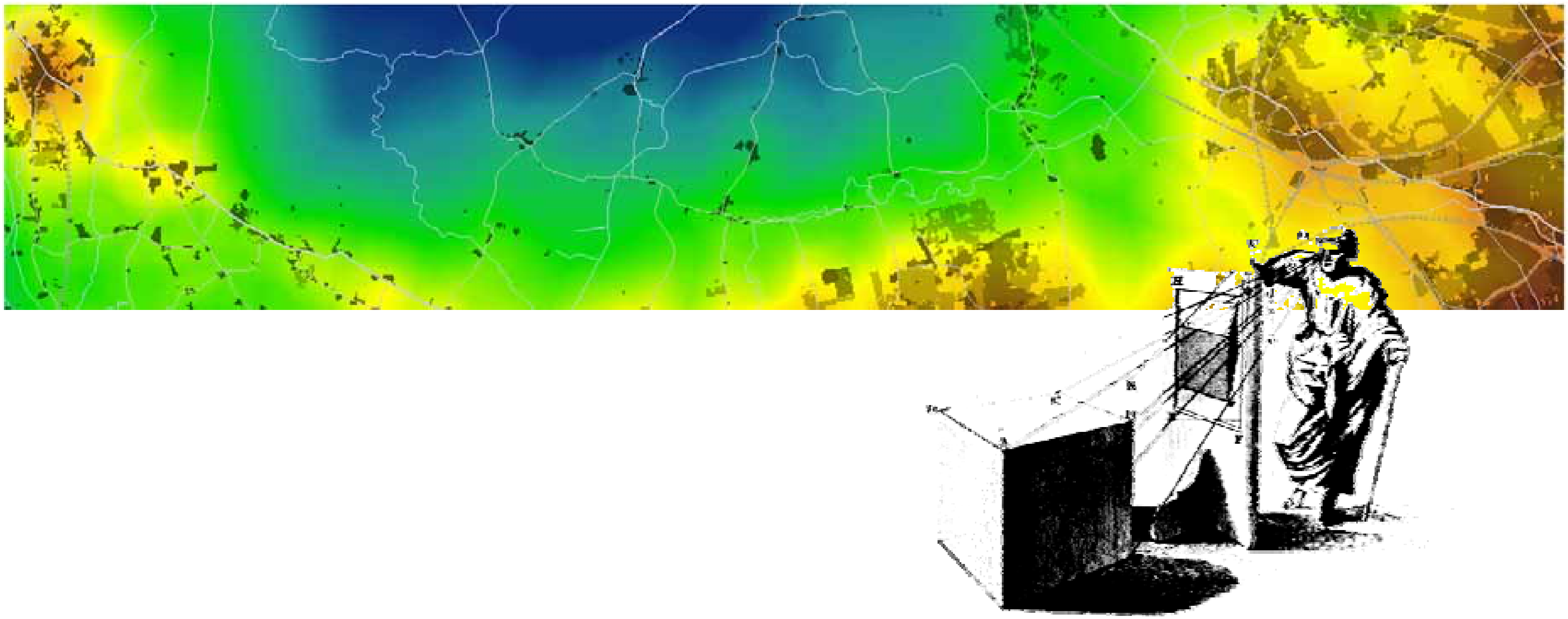
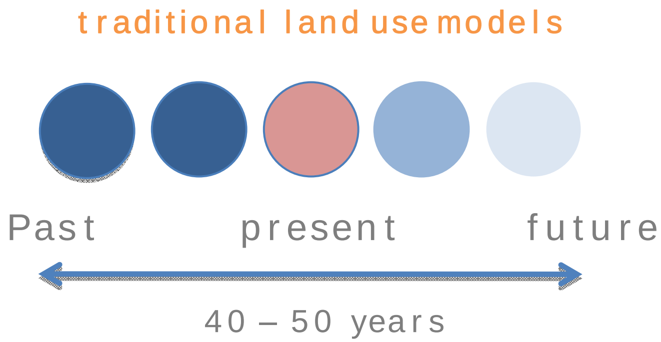
development of a CA urban growth model




traditional land use models
Past
present
future
40 – 50 years

The Idea

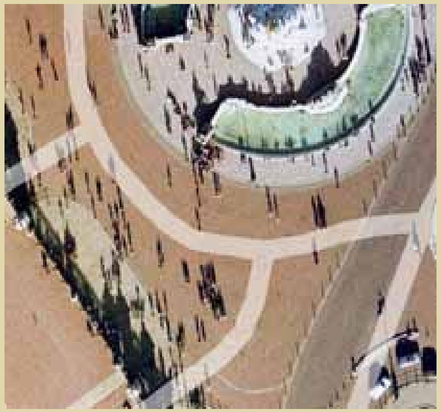
traditional land use models

Past present future

40 – 50 years

Past present

130 years



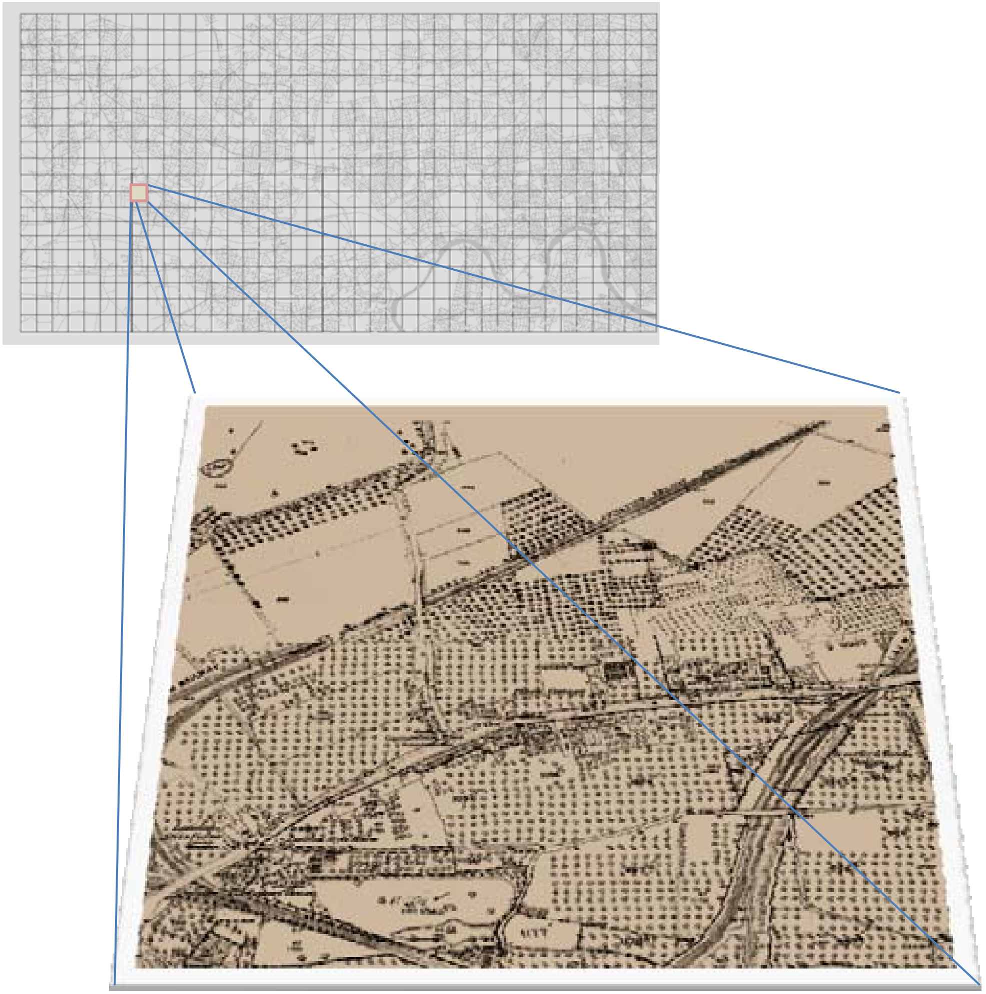
West London model

study *area*

Mersea Is
Foulness Islan
Canvey Island
Greater London
Isles of Sheppey

data

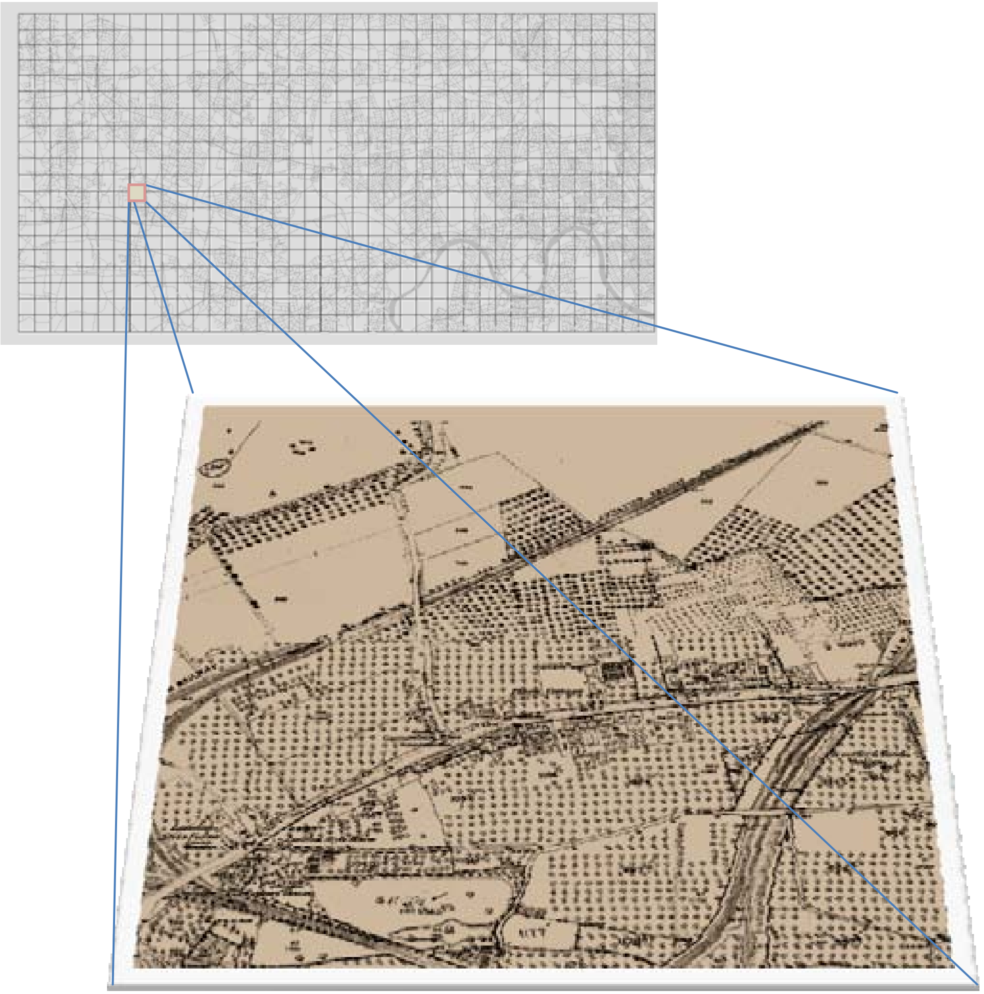
Ordnance Survey
County Series 1:2,500



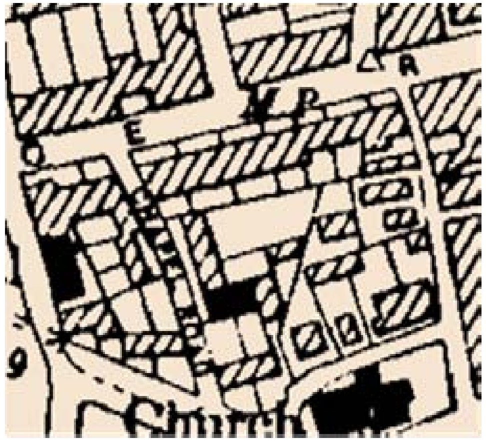
1875

data

Ordnance Survey
County Series 1:2,500



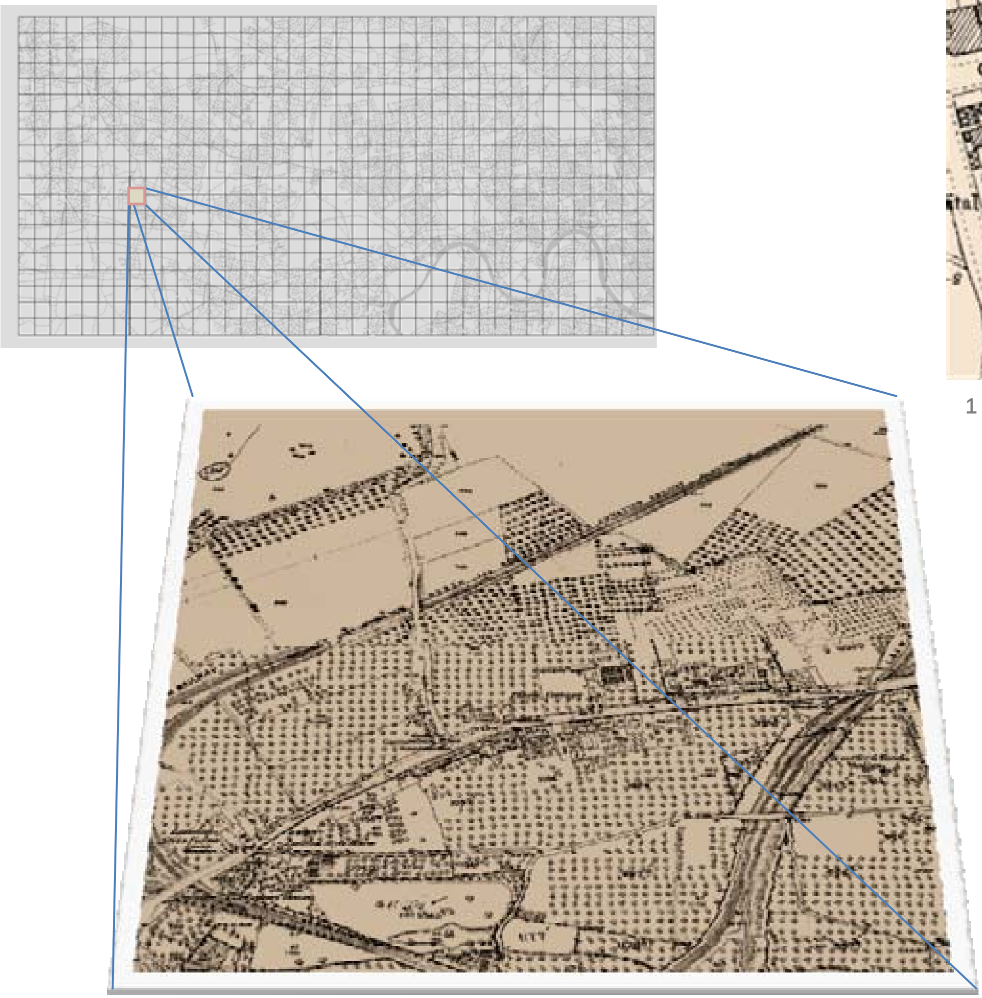
1875



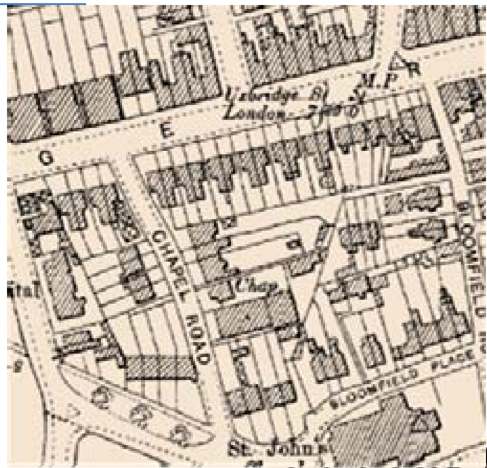
1 : 10,000

data

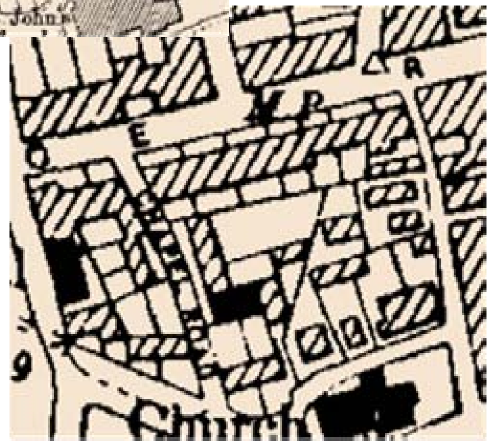
Ordnance Survey
County Series 1:2,500



1875



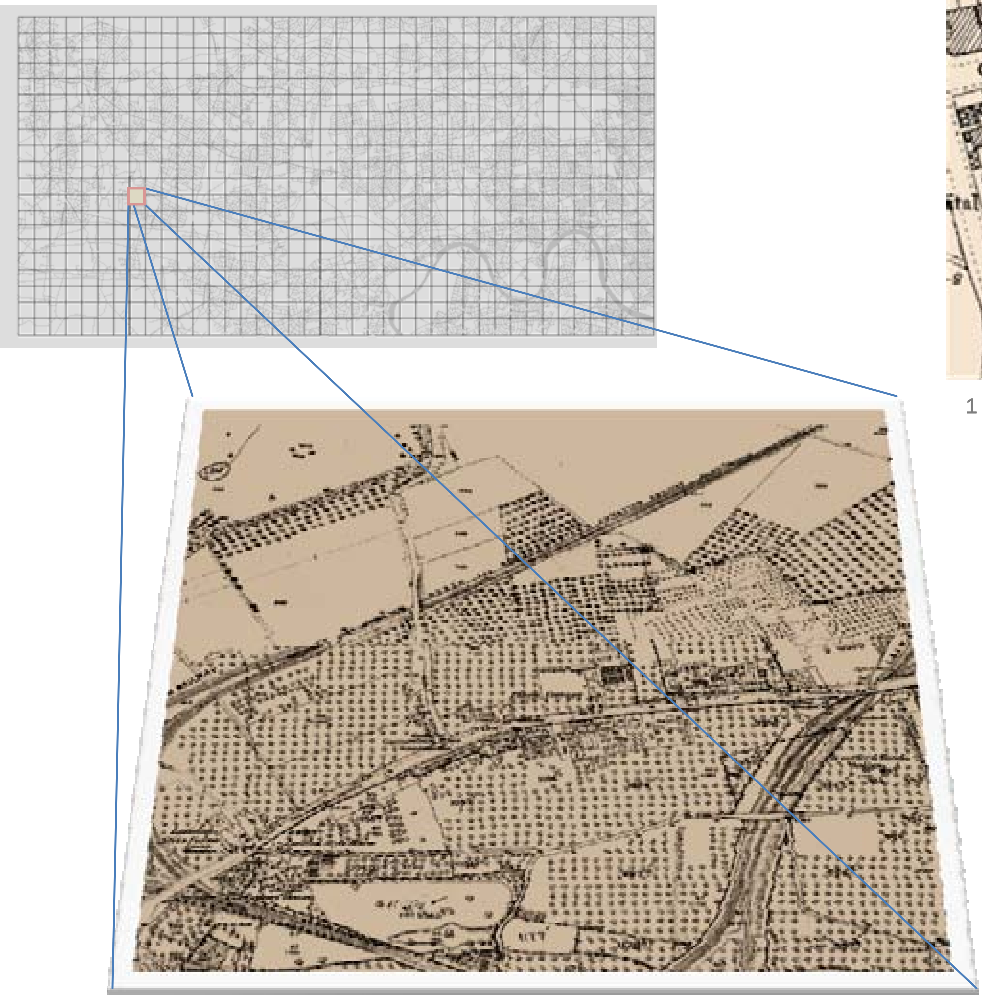
1 : 2,500



1 : 10,000

data

Ordnance Survey
County Series 1:2,500



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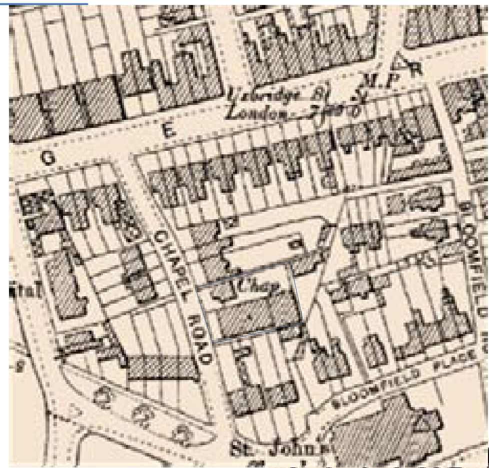
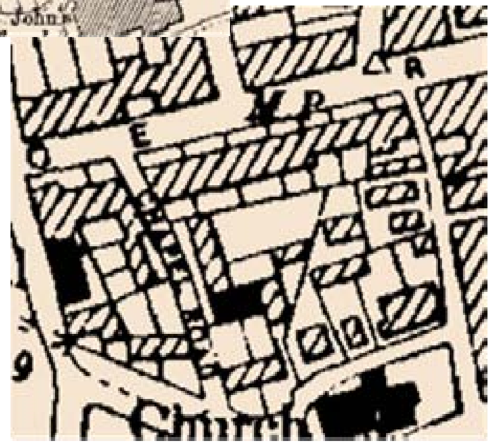


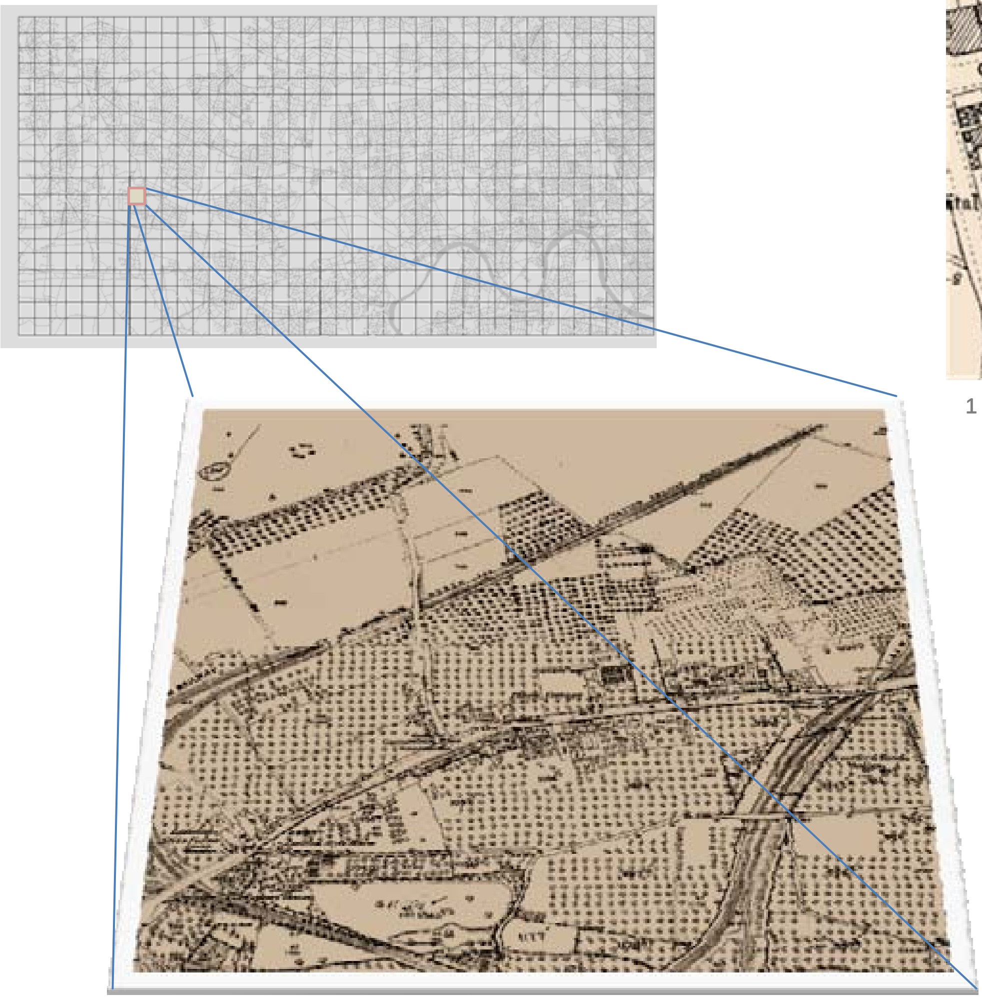
1 : 2,500



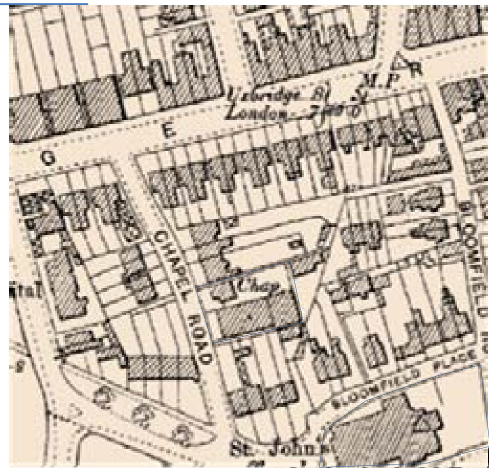
1 : 10,000

data

Ordnance Survey
County Series 1:2,500



1875

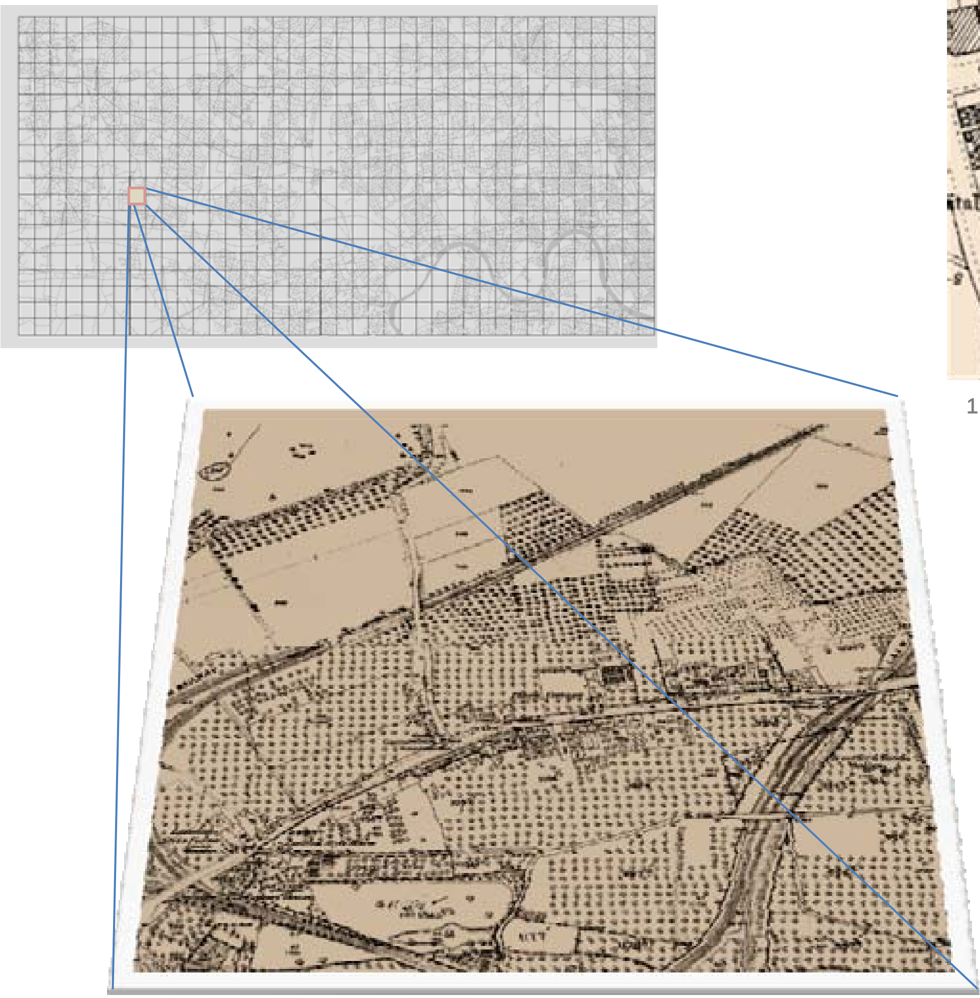


1 : 2,500

1 : 10,000

data

Ordnance Survey
County Series 1:2,500



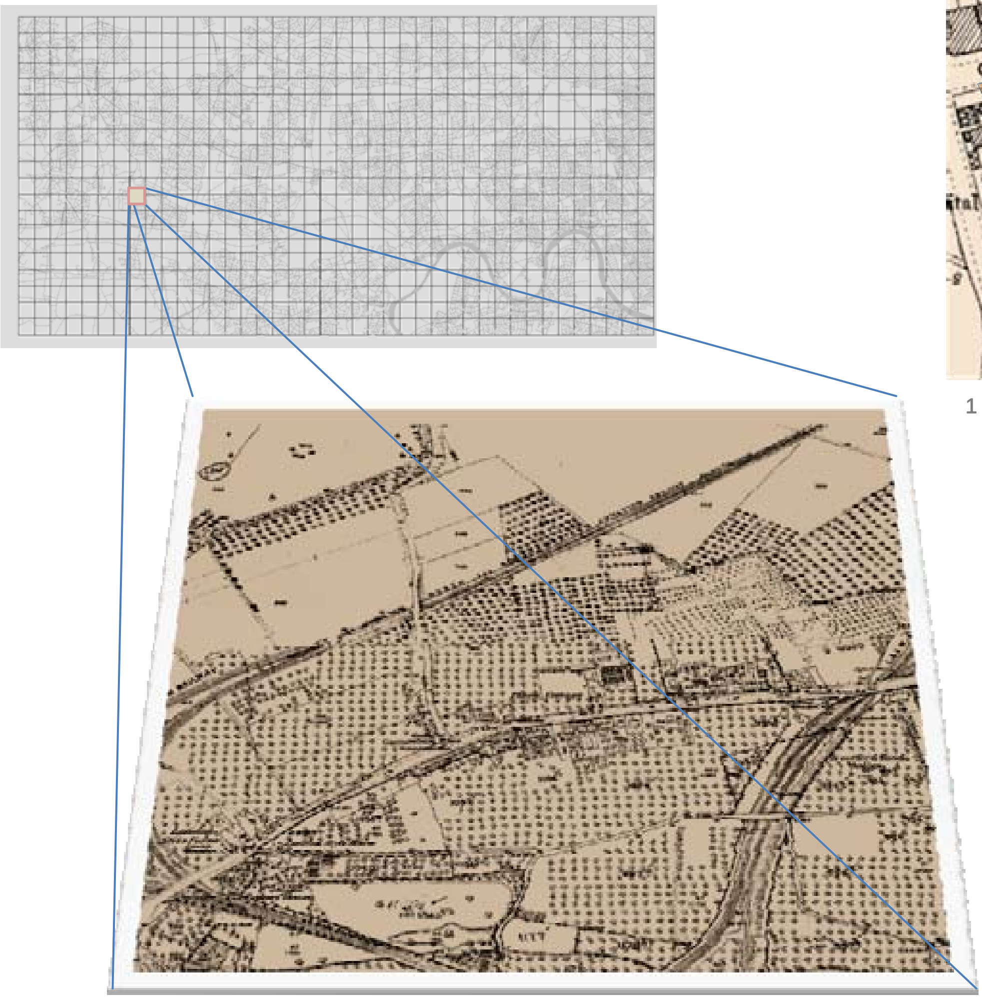
1875

1 : 2,500

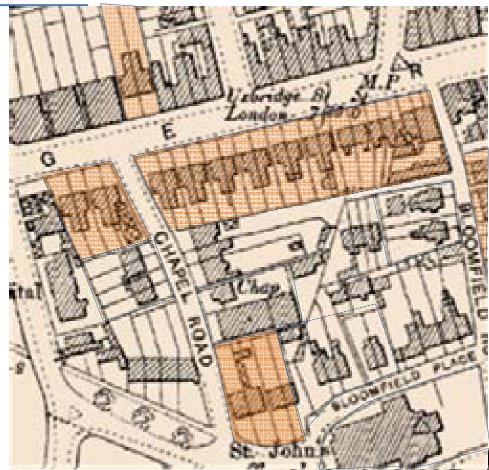
1 : 10,000

data

Ordnance Survey
County Series 1:2,500



1875

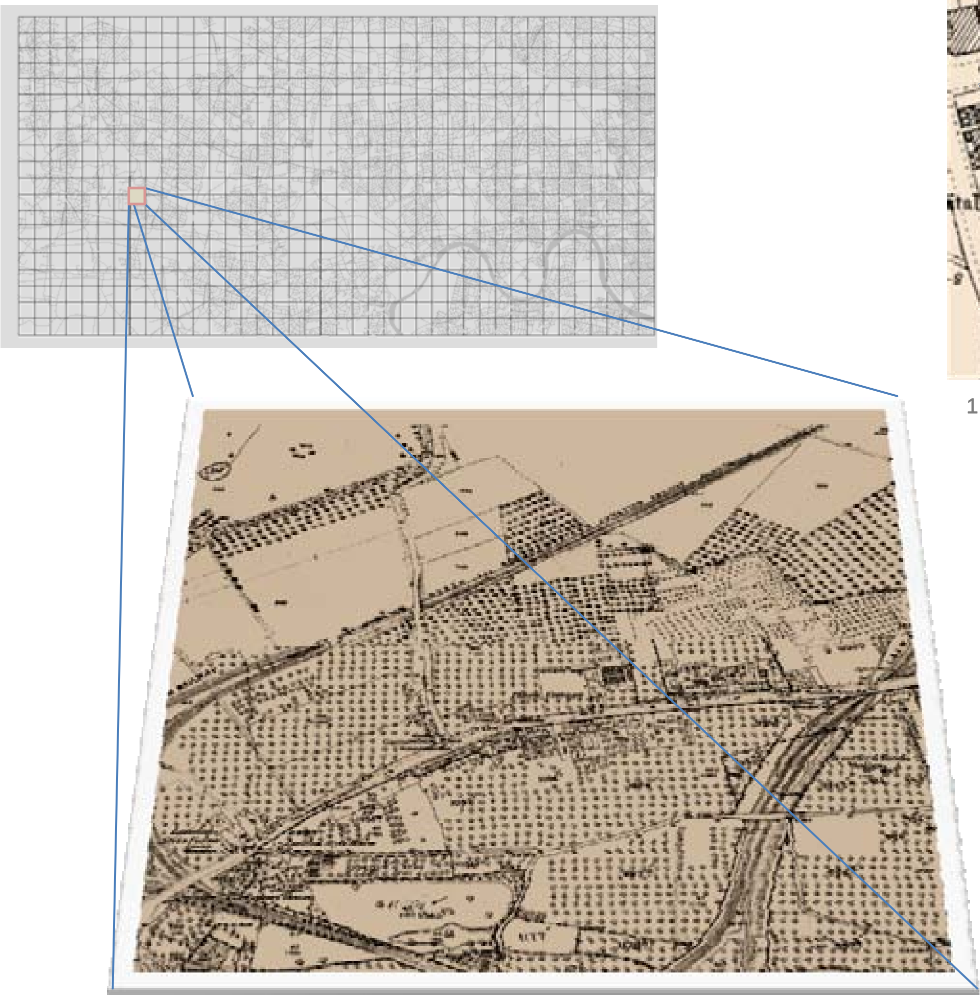


1 : 2,500

1 : 10,000

data

Ordnance Survey
County Series 1:2,500



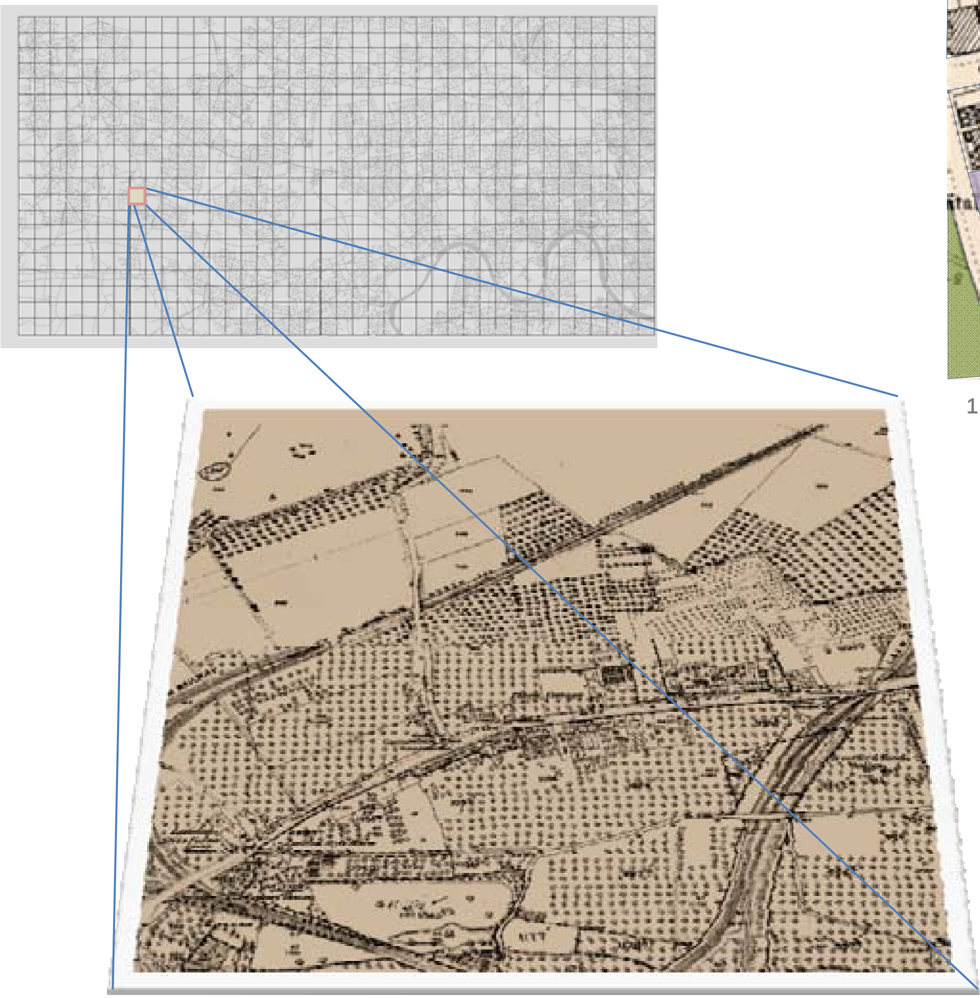
1875

1 : 2,500

1 : 10,000

data

Ordnance Survey
County Series 1:2,500

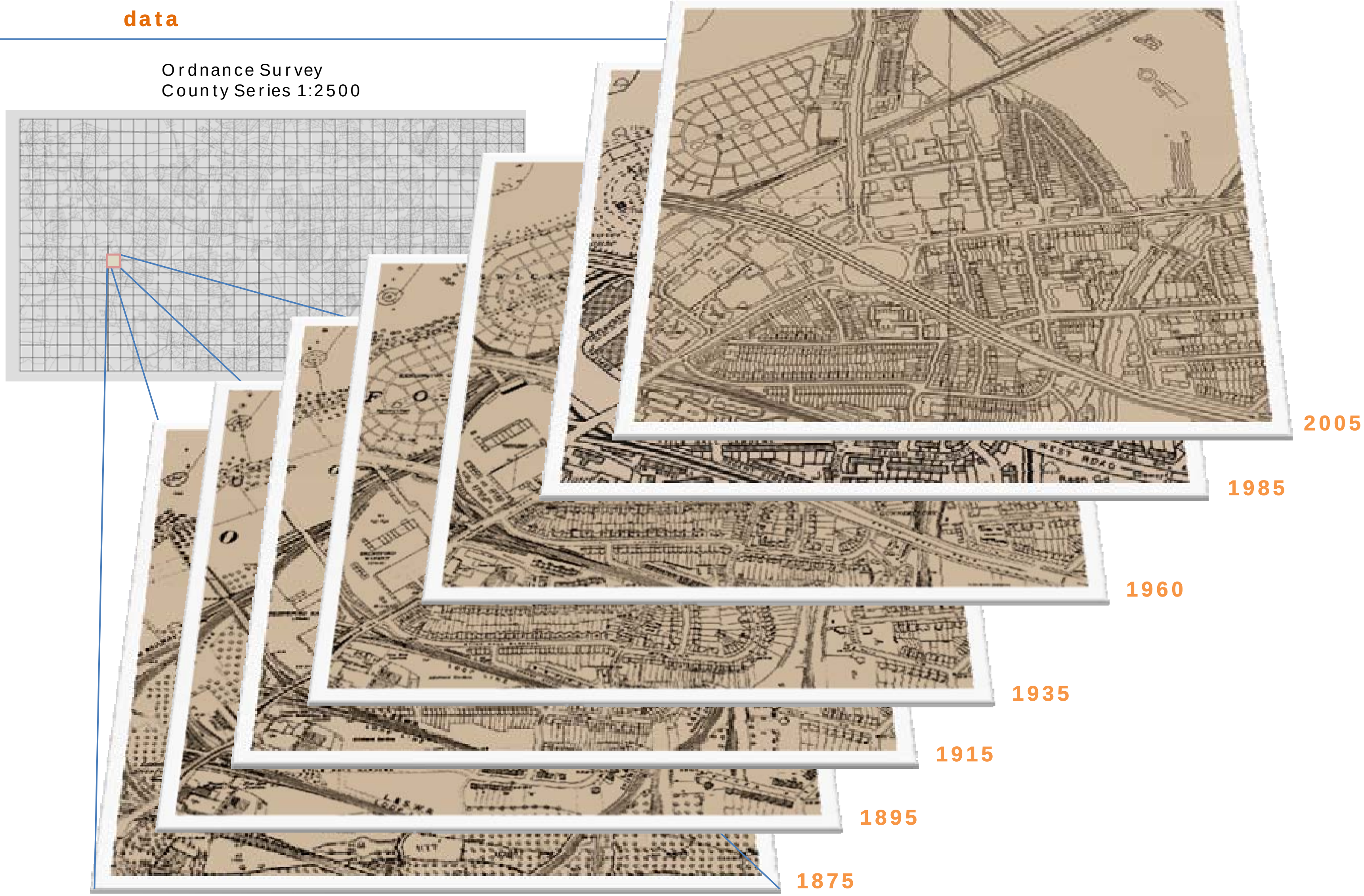


1875

1 : 2,500

1 : 10,000

data



Ordnance Survey
County Series 1:2500
2005
1985
1960
1935
1915
1895
1875

Land use *classification*

used in model	digitized in GIS	interpreted from OS maps
residential	apartments	low and mid-rise apartments (2 - 6 stories)
	high-rise apartments	high-rise apartments (over 6 stories)
	cottage houses	cottage houses
	terrace houses	terrace houses
	mews	mews
	semi-detached houses	semi-detached houses
	small lot detached houses	small lot detached houses
	detached houses	detached houses
	lodges	lodge
		inn
		hotel
	institutional public	city hall
		library
		police station
		fire station
		post office
		hospital
		asylum
		almshouse
		penitentiary
		prison
		museum
		convalescent home
		military barracks
	educational	daycare
		school
		college
		university
	religious	church
		convent
		rectory
		priory
		friar
		synagogue
		temple
		hermitage

used in model	digitized in GIS	interpreted from OS maps
commercial	old fabric	old fabric
	general	general
	retail	retail
	entertainment	public houses
		movie houses
		dance halls
	garages	garages
	office	office
industrial	industrial	works
		mills
		wharf
		docks
		depot
		brewery
		malthouse
	utilities	water works
		gas works
		sewer works
recreation	parks	parks
		commons
		greens
	cemeteries	cemeteries
		burial grounds
	recreation	golf course
		athletic club
		recreation ground
		playground
	stadia	stadia
airports	airports	airports
transportation	roads	roads
	railway lines	railway lines
water	rivers	rivers
	canals	canals
soft	estates	estates
	farms	farms
vacant	undeveloped	undeveloped
	allotment gardens	allotment gardens
	nurseries	nurseries
	cleared	cleared

terraced housing

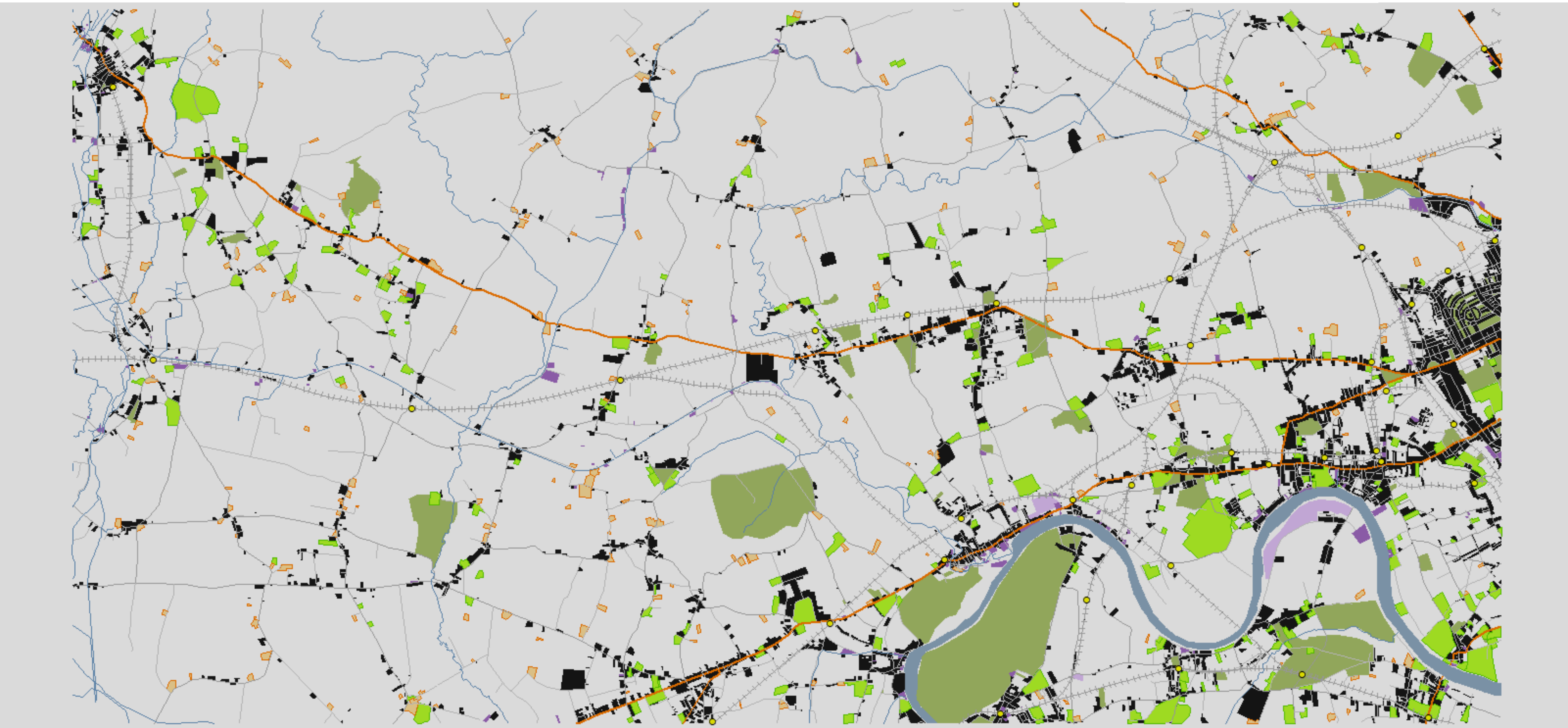
semi-detached housing

detached housing

multi-family housing

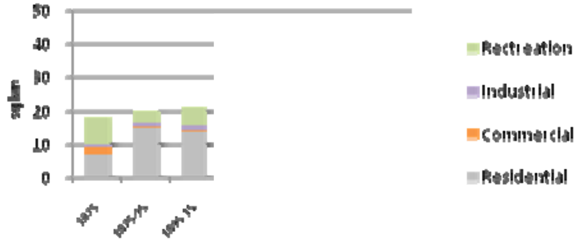
1875 development

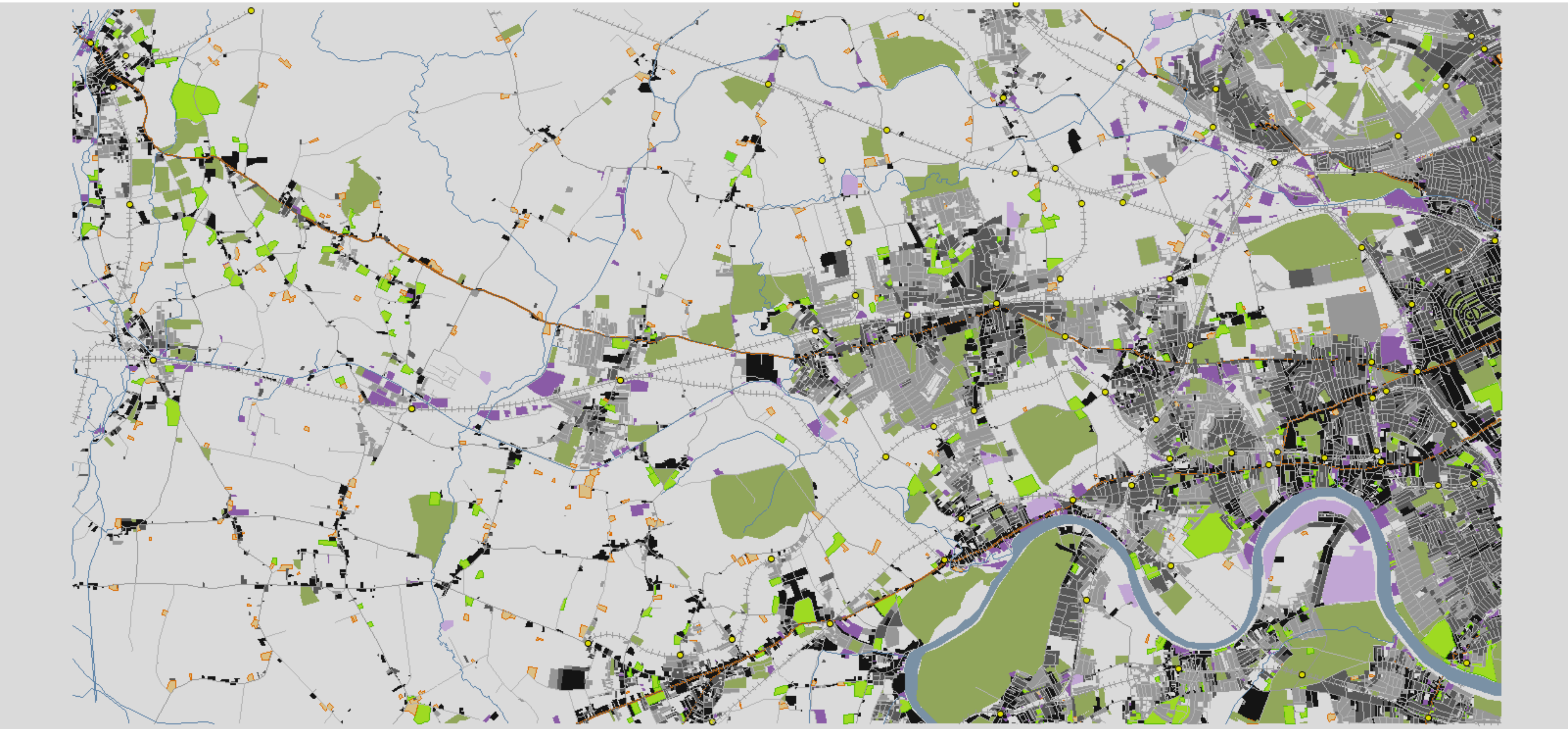
industrial uses



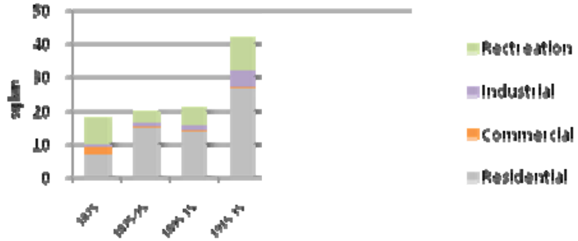
1875 development
1875-95 development
industrial uses

- 1875 development
- 1875-95 development
- 1895-15 development
- industrial uses

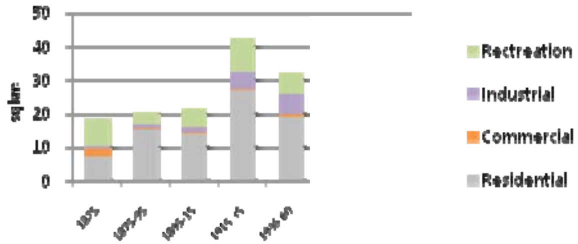




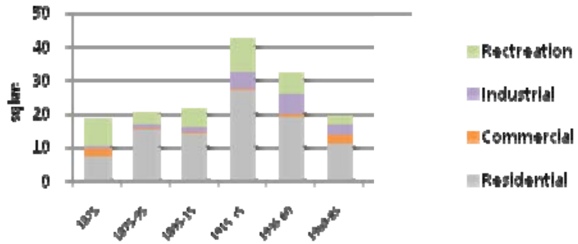
- 1875 development
- 1875-95 development
- 1895-15 development
- 1915-35 development
- industrial uses

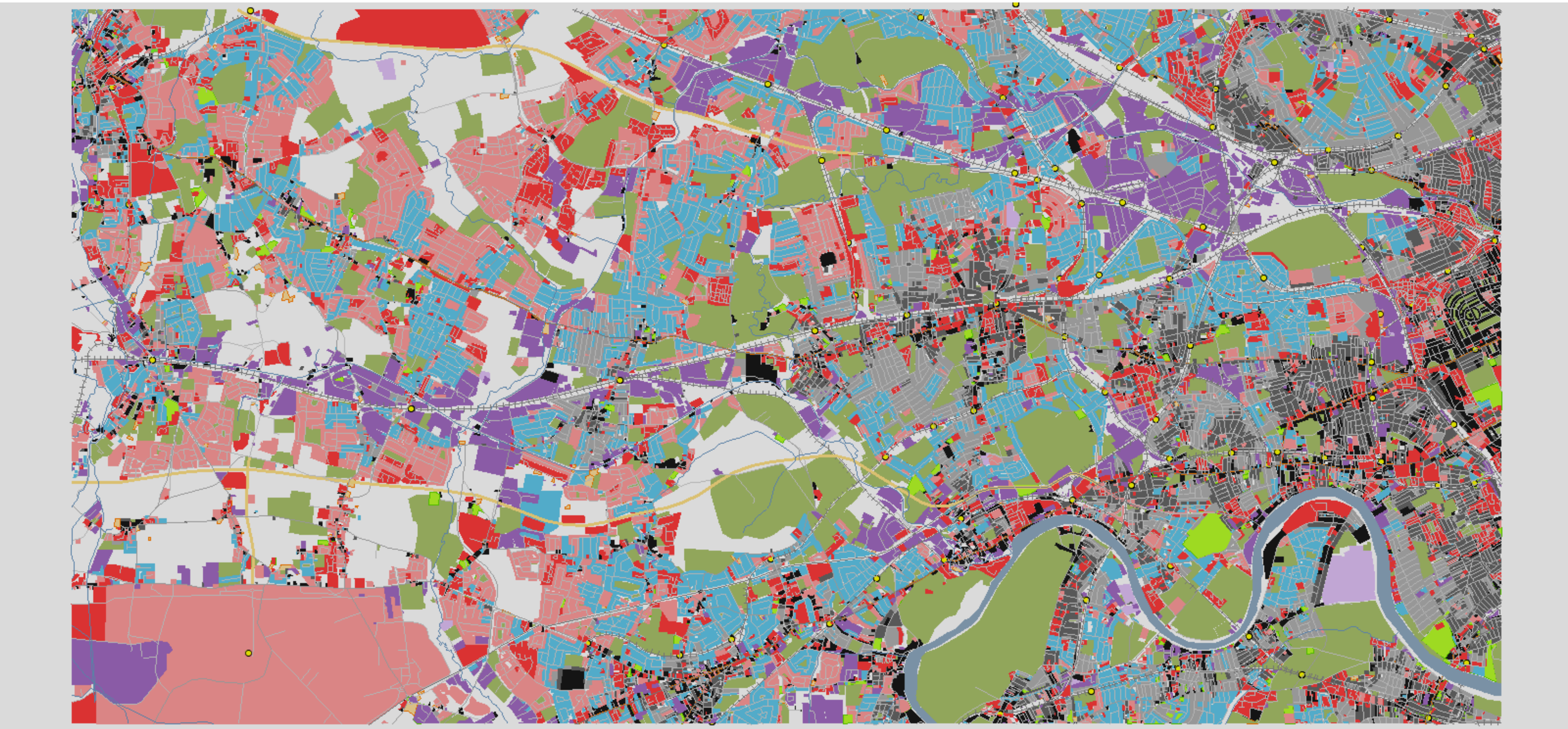


1875 development
1875-95 development
1895-15 development
1915-35 development
1935-60 development
industrial uses

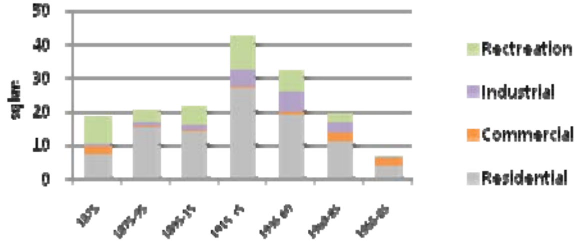


1875 development
1875-95 development
1895-15 development
1915-35 development
1935-60 development
1960-85 development
industrial uses

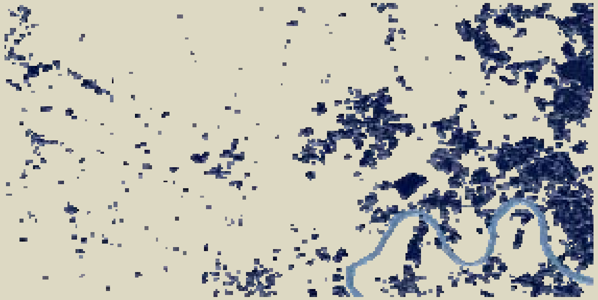




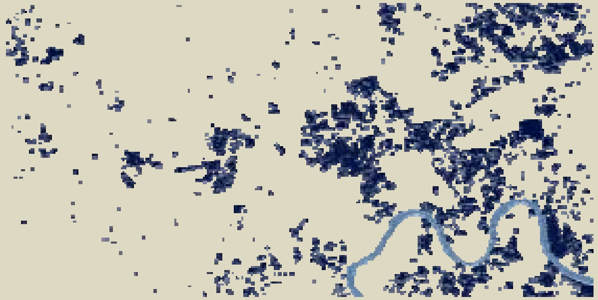
	1875 development		1960-85 development
	1875-95 development		1985-05 development
	1895-15 development		industrial uses
	1915-35 development		
	1935-60 development		



nucleation

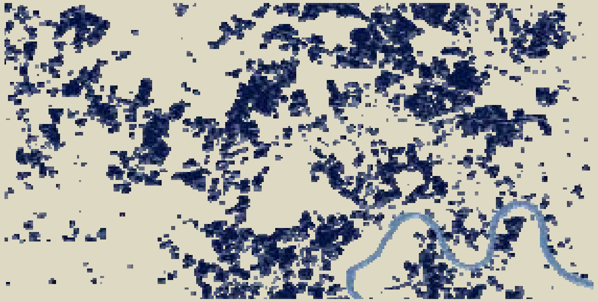


1875 - 95

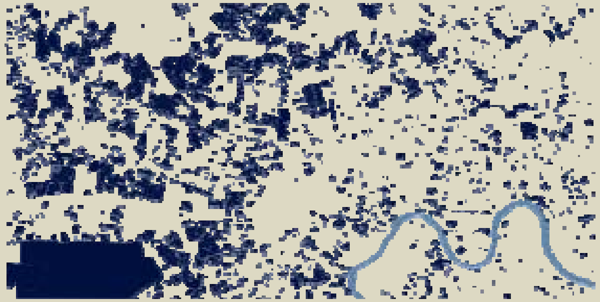


1895 - 15

diffusion



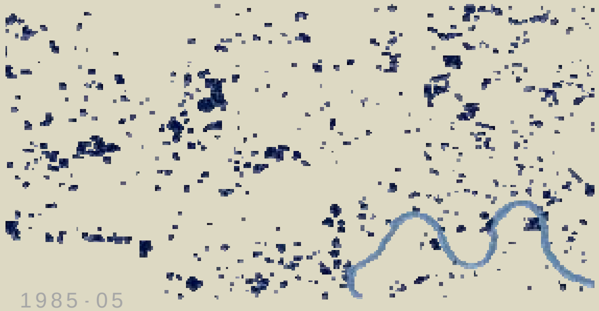
1915 - 35



1935 - 60

infill

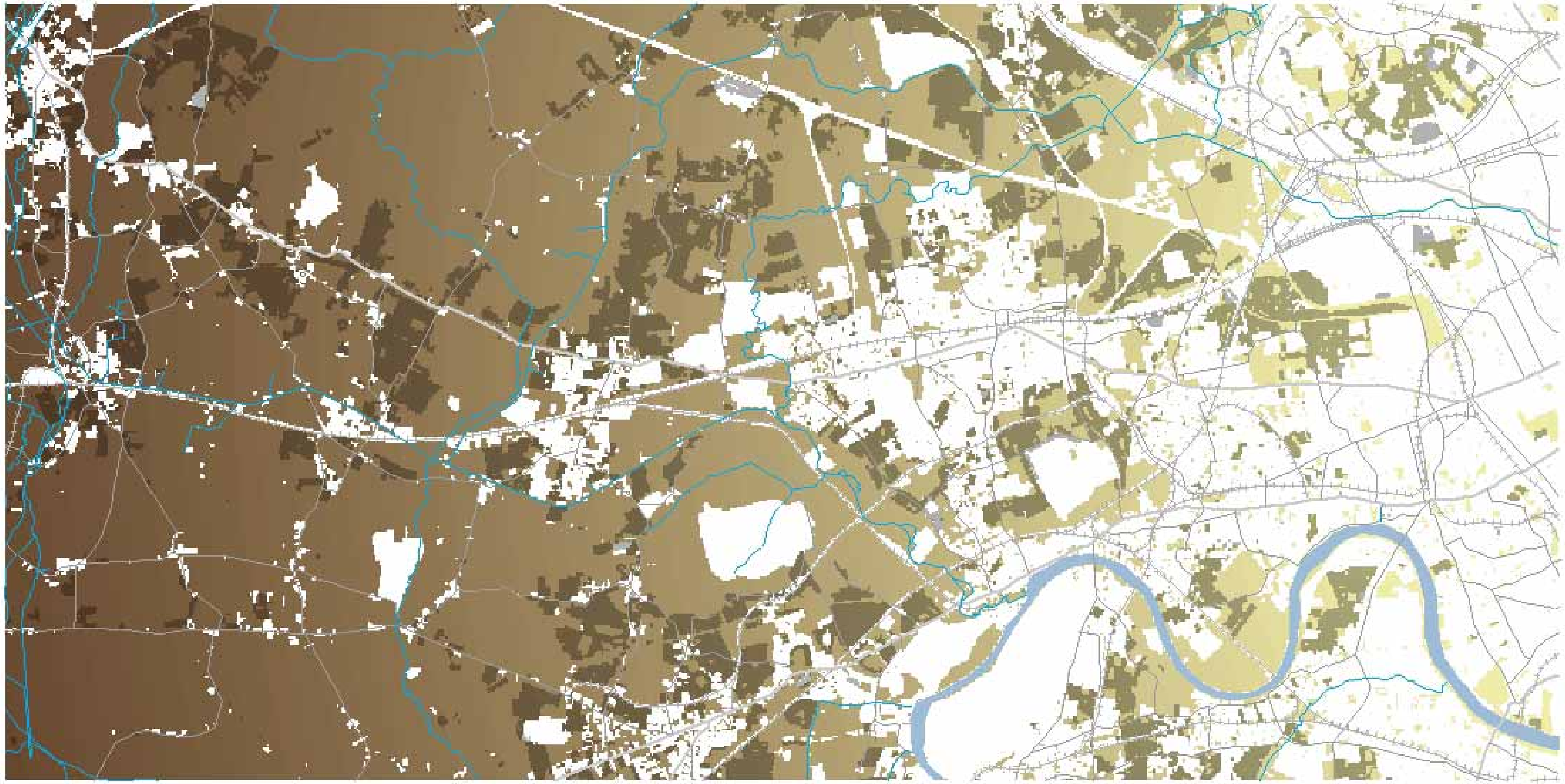
1960 - 85

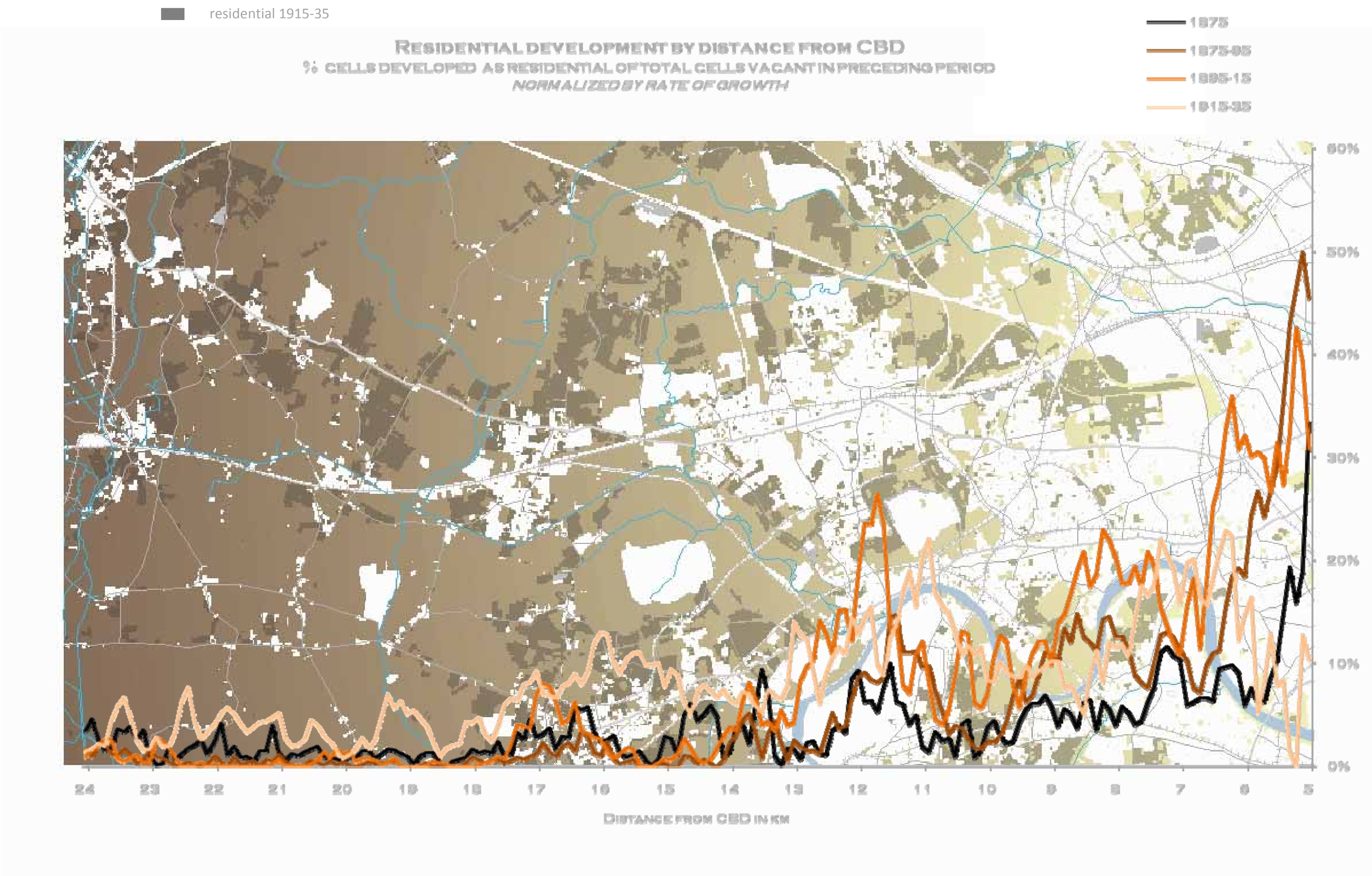


1985 - 05

residential 1915-35

residential 1915-35

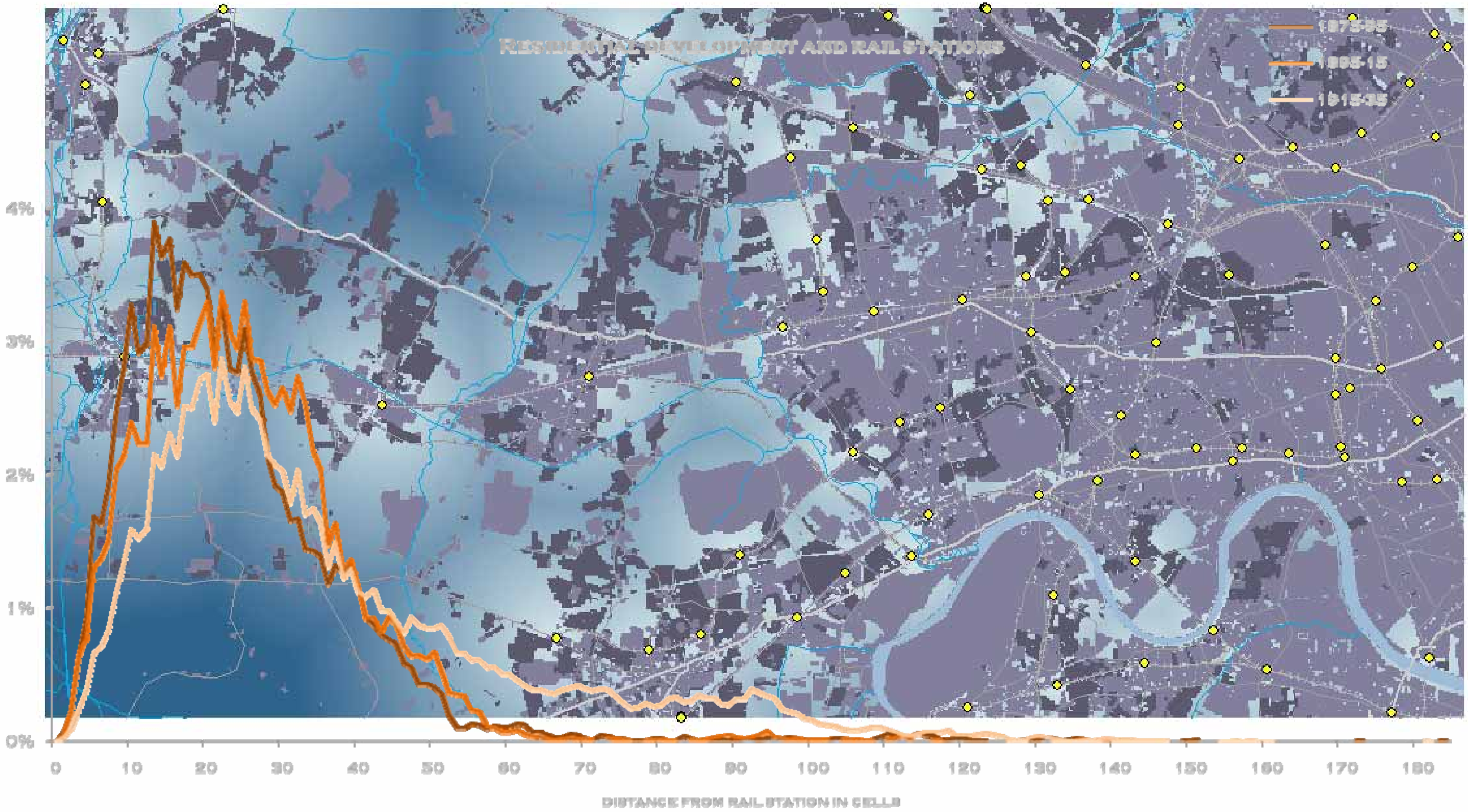


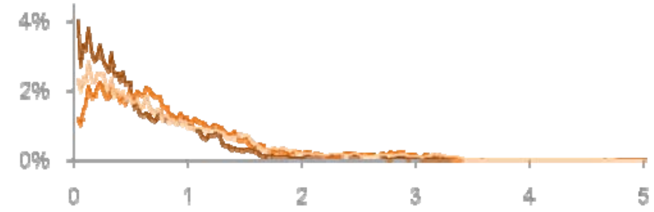

residential 1915-35
RESIDENTIAL DEVELOPMENT BY DISTANCE FROM CBD
% CELLS DEVELOPED AS RESIDENTIAL OF TOTAL CELLS VACANT IN PRECEDING PERIOD
NORMALIZED BY RATE OF GROWTH
1875
1875-95
1895-15
1915-35
60%
50%
40%
30%
20%
10%
0%
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
DISTANCE FROM CBD IN KM

1935 Distance to rail stations

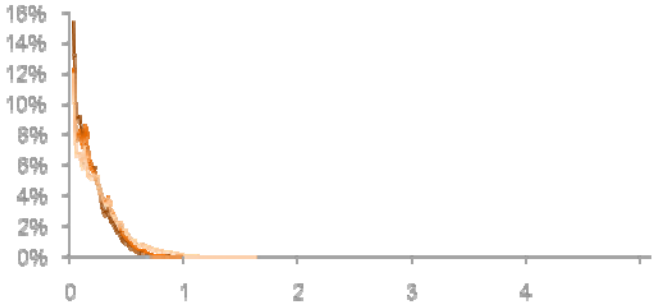
residential development 1915-35
rail station

residential 1915-35
developed land 1915
rail station

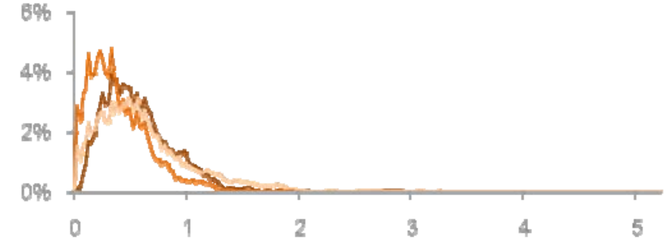




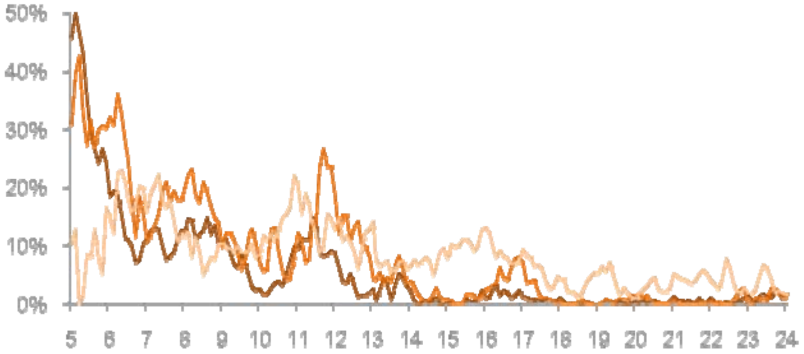
distance to arterial roads



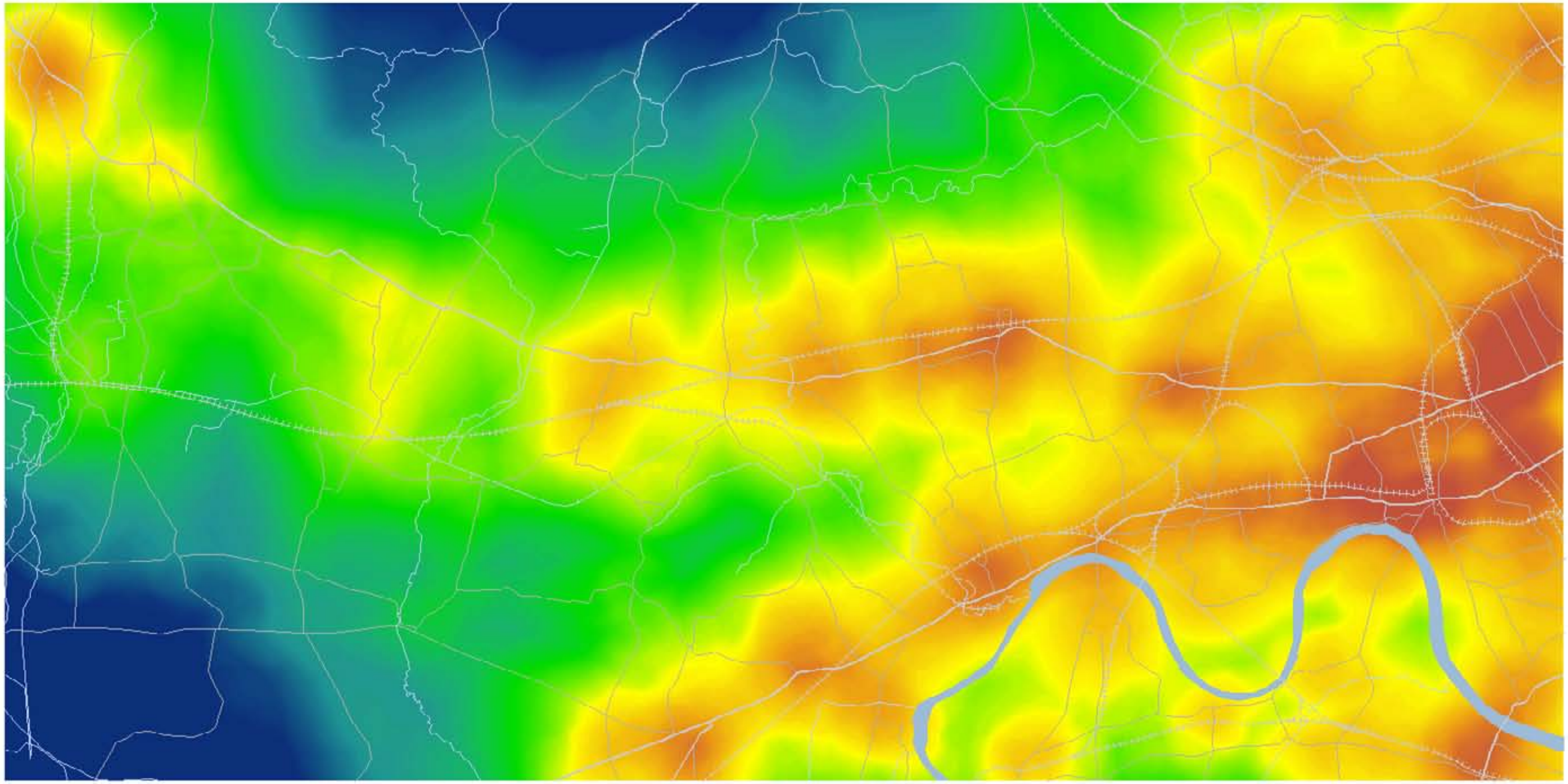
distance to connector roads

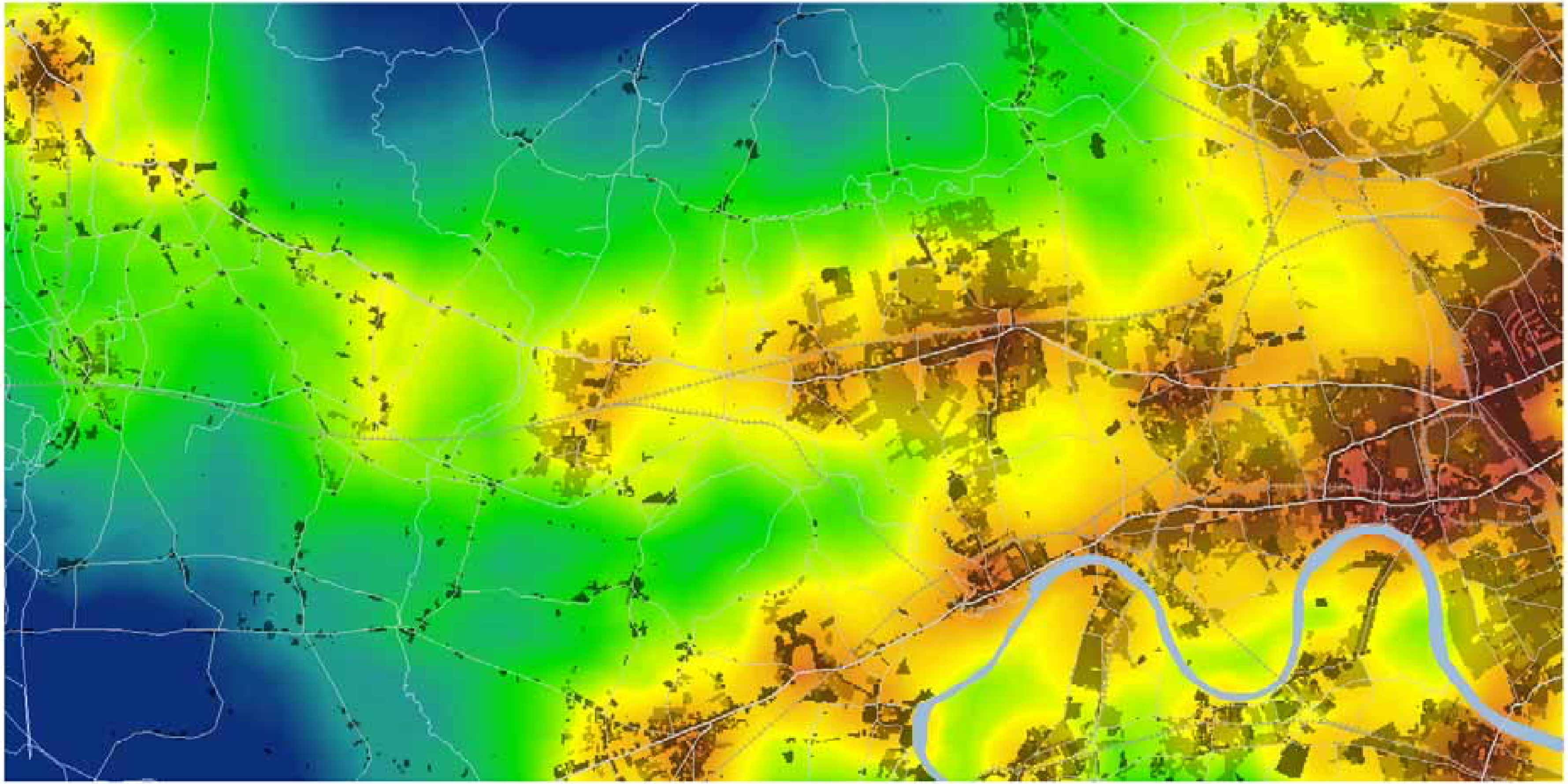


distance to rail stations

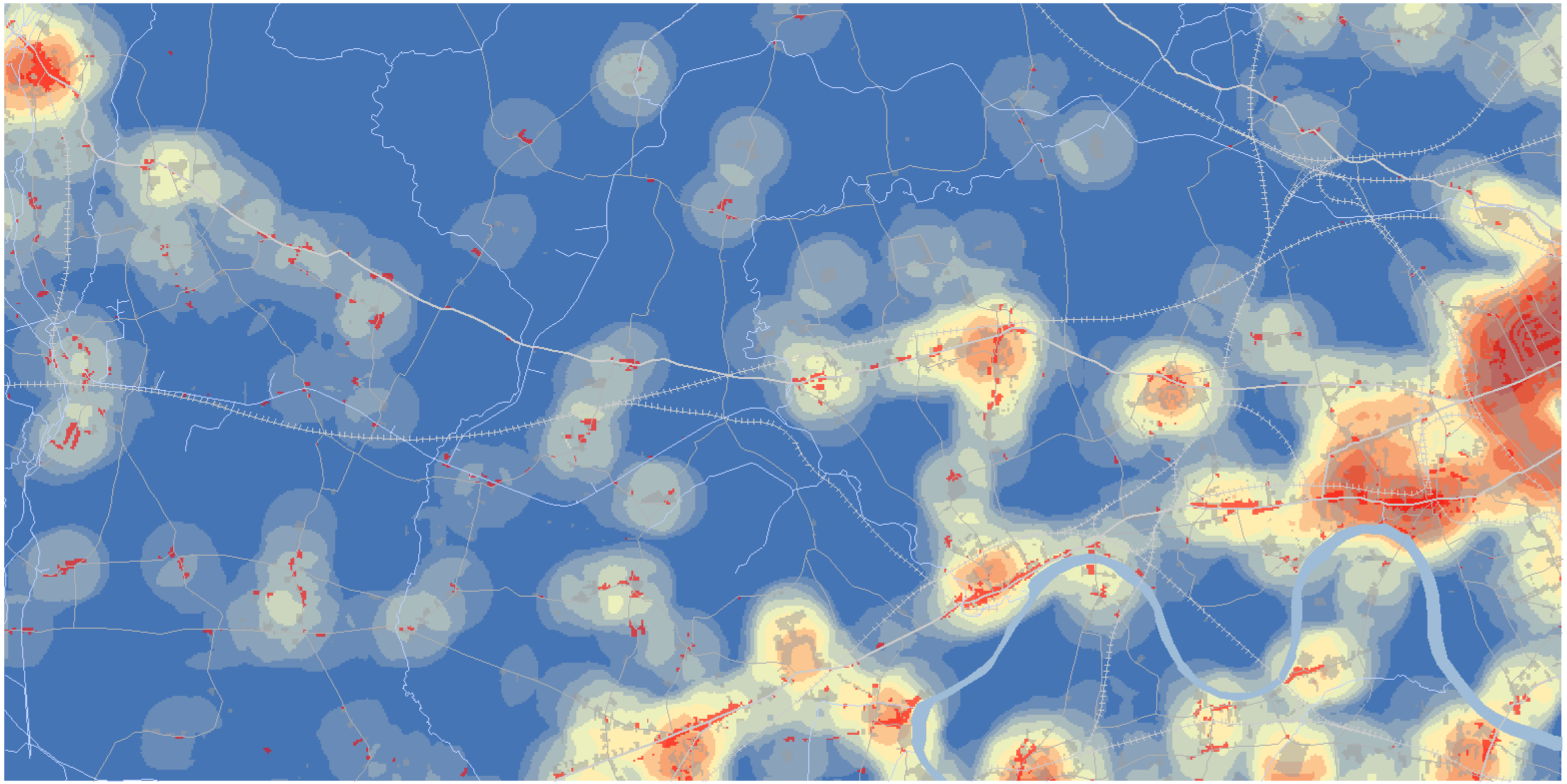


distance to rail stations



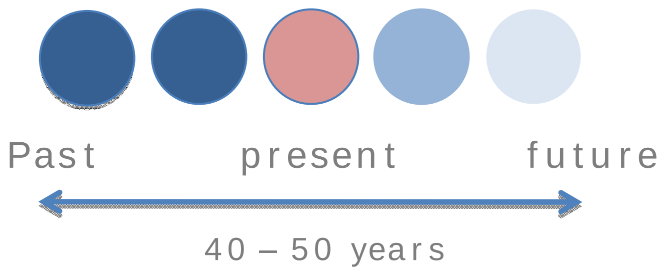


residential
commercial

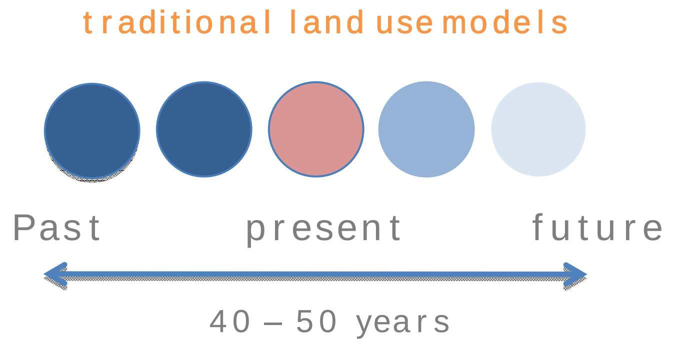


The Idea

traditional land use models



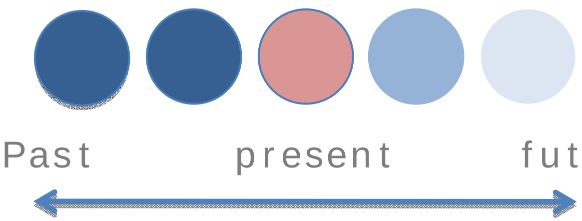
The Idea

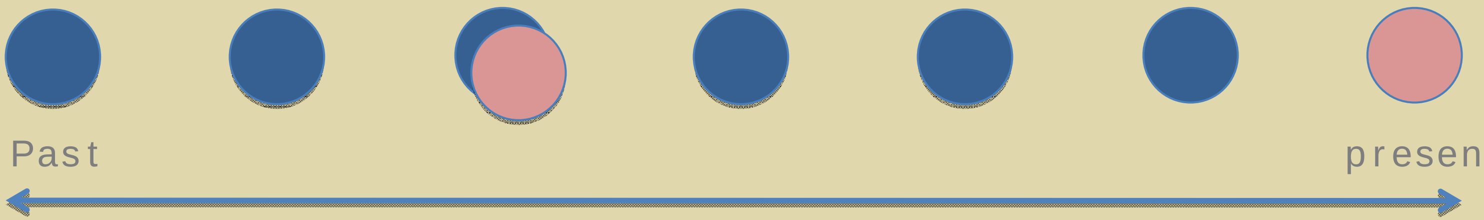

traditional land use models
Past
present
future
40 – 50 years


Past
present
130 years
West London model

The Idea

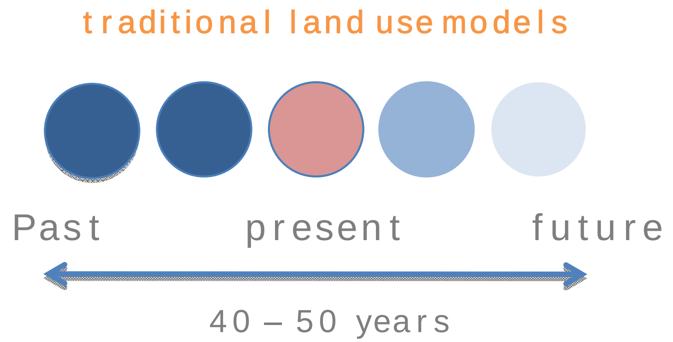
traditional land use models





West London model

The Idea


traditional land use models
Past
present
future
40 – 50 years

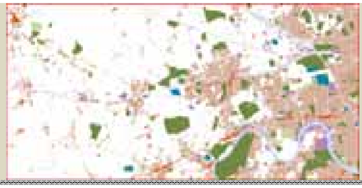
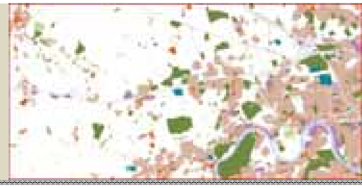

Past
present
130 years
West London model

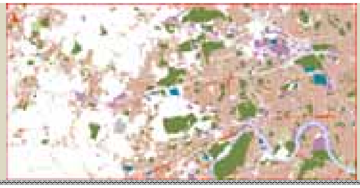
The Result

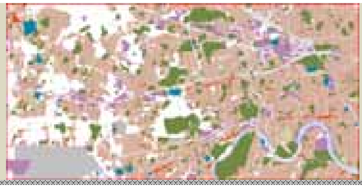
actual | modeled

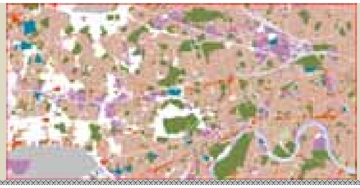


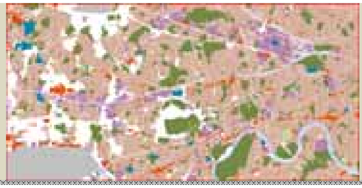
1895



1915


?
1935

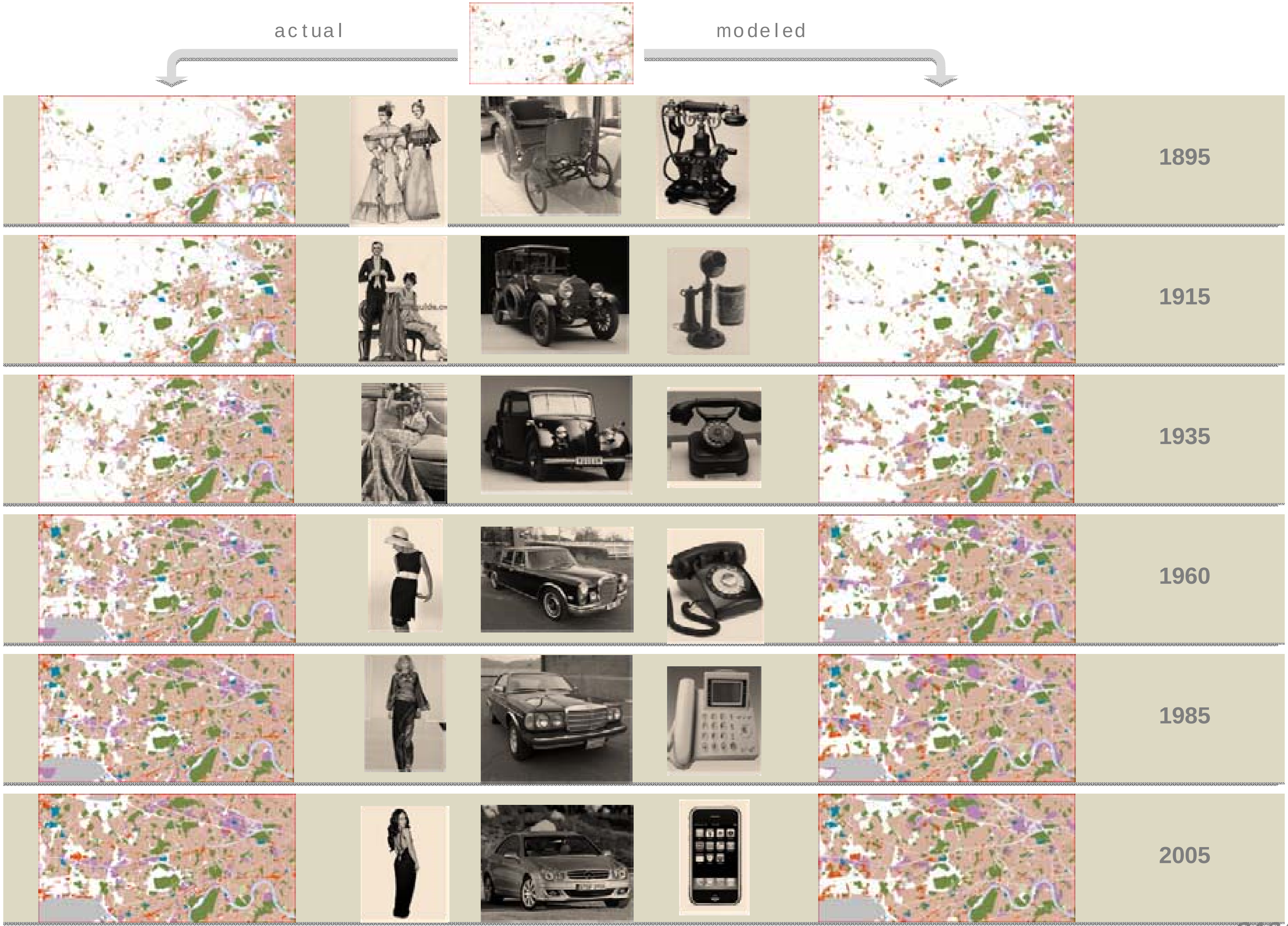

?
1960


?
1985


?
2005

The Result

The Result



The Result

2005 actual

2005 modeled

The Result

2005 actual

2005 modeled

Why Metronamica?

- Ability to model urban land uses (not available in SLEUTH)
- Intuitive interface – no need for programming
- Speed – “real time” interaction

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- Ability to model urban land uses (not available in SLEUTH)
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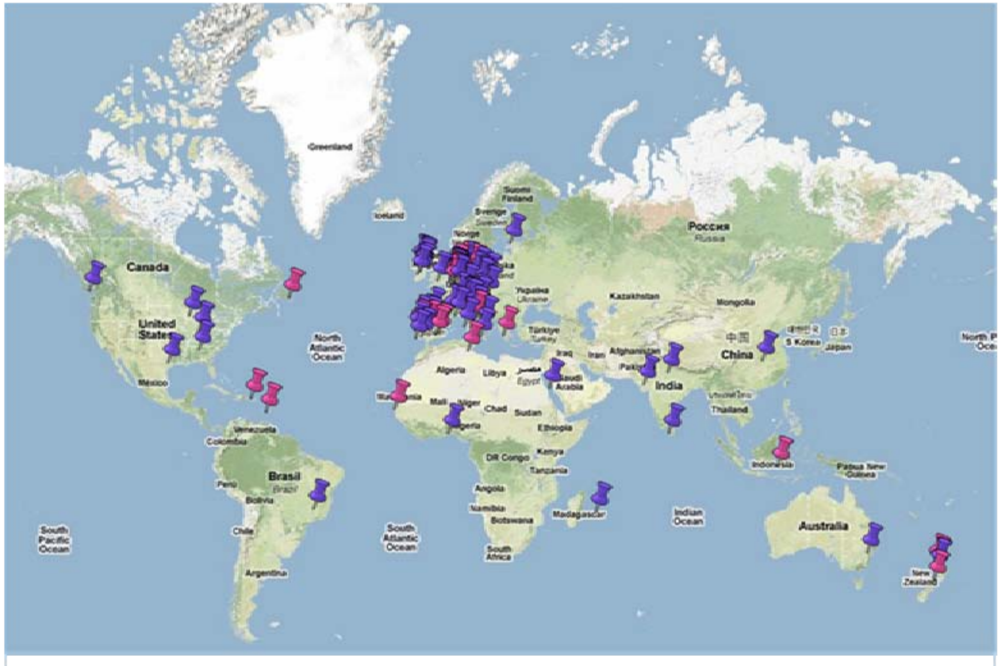
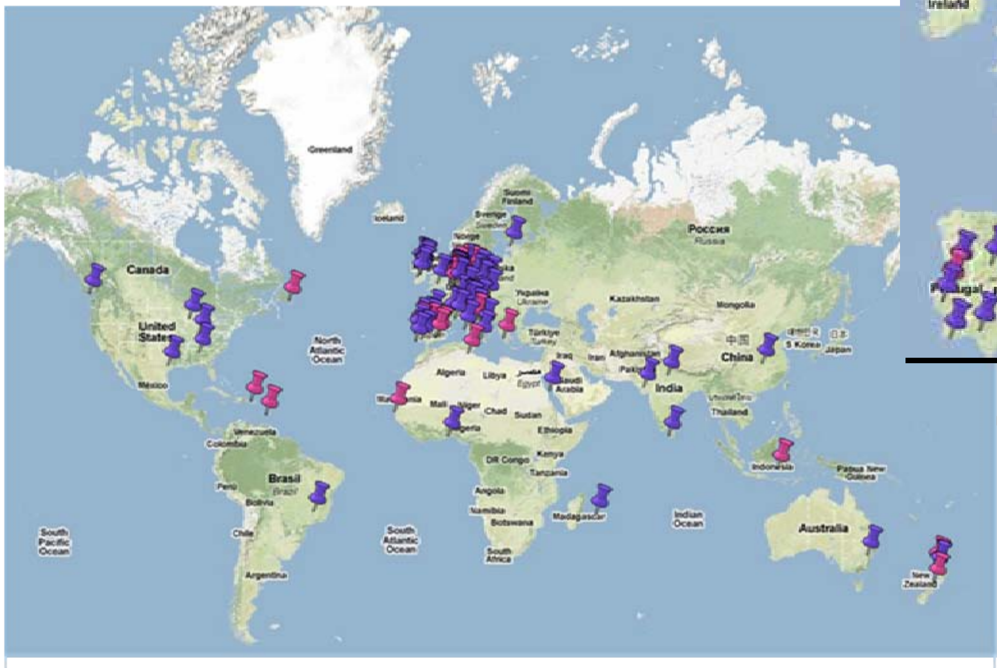
Background

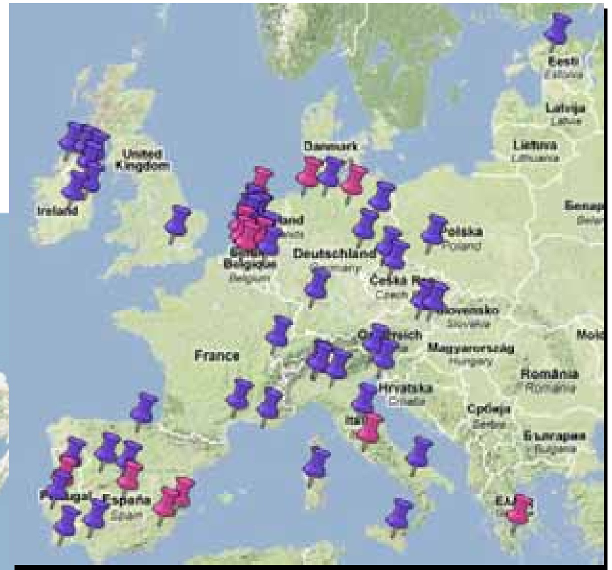
- White and Engelen (1997) Environment and Planning B
-

Applications



Applications

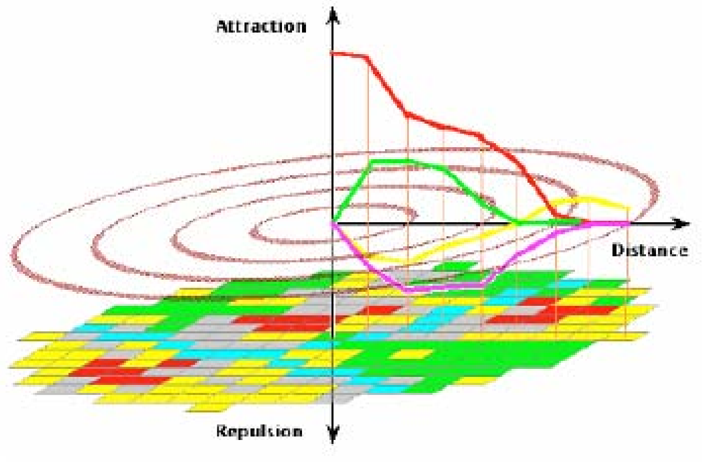




MOLAND – EC Joint Research Centre

4 determinants

- *Neighborhood effect* - cellular automata
- *Accessibility* - calculated for each land use relative to the distance of the cell to each of the infrastructure elements
- *Suitability* - elevation, soil type, air quality, noise pollution, etc.
- *Zoning* - specifying which cells can and cannot be taken by particular land use



4 determinants

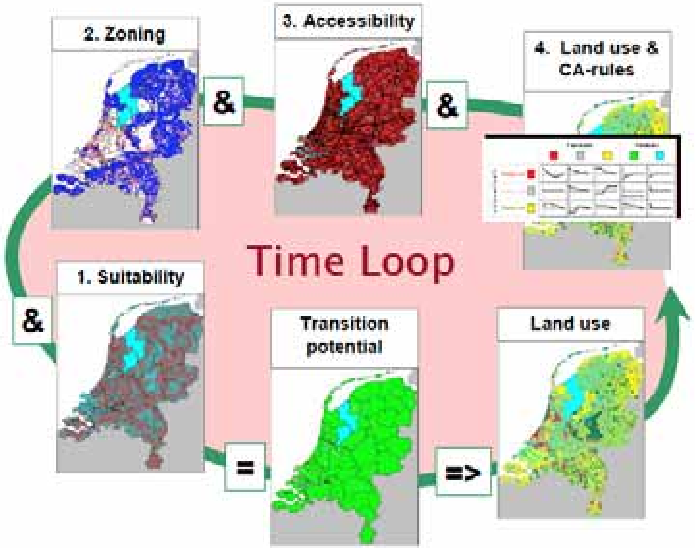
- *Neighborhood effect* - cellular automata
- *Accessibility* - calculated for each land use relative to the distance of the cell to each of the infrastructure elements
- *Suitability* - elevation, soil type, air quality, noise pollution, etc.
- *Zoning* - specifying which cells can and cannot be taken by particular land use

$P_k = r\, N_k\, A_k\, S_k\, Z_k$

P_k – transition potential
r - stochastic perturbation factor

The model calculates for every simulation step the *transition potential* for each cell and each land use.

Cells change to the land use for which they have the highest transition potential until regional demands are satisfied.



The Concept

27 54	22 65	43 13	68 0	97 10
15 44	8 68	90 99	32 87	34 16
96 36	24 65	81 75	58 8	19 22
32 24	68 97	69 4	87 26	43 17
56 21	59 66	12 30	6 34	0 88

t

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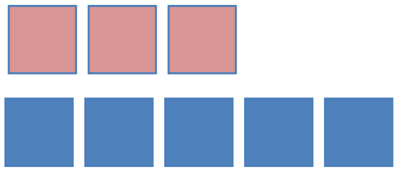
t + 1



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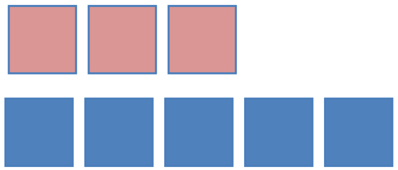

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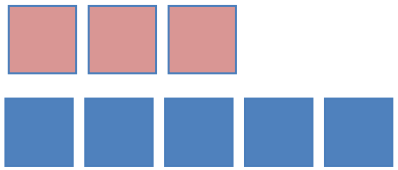

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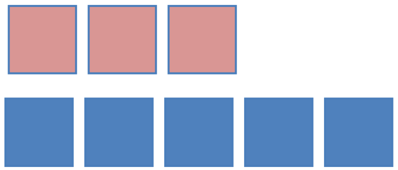

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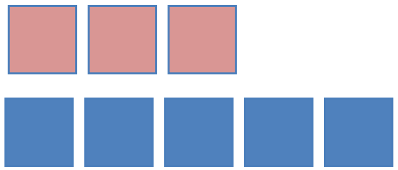

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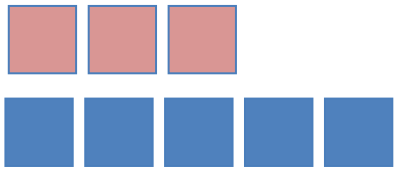

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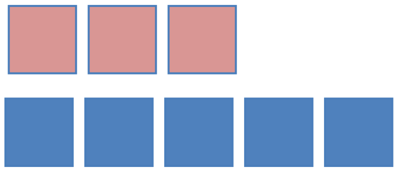


Model input



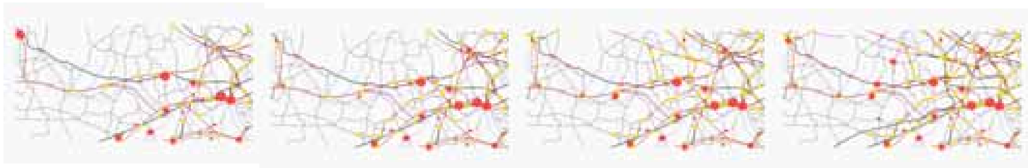

- Land use maps
  - ASCII files
  - spatial reference and demand

The Concept

Model input

- Land use maps
  - ASCII files
  - minimum of 2

- Accessibility
  - vector shape files



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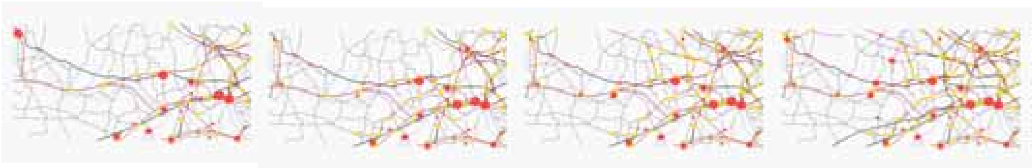
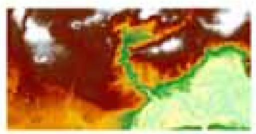


- Suitability maps - one for each land use
  - weighted linear sum of several factors
  - values normalized in the range of 0–1



The Concept

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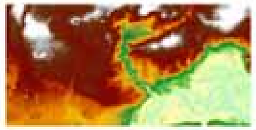

- Zoning maps - one for each land use

o each cell is associated with a set of codes (permitted, not permitted, permitted from certain year)

Land use classes

Land uses are broken in three categories treated differently by the model

1. *Active functions* – respond to exogenous demand
   - Residential
   - Industrial
   - Commercial

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    - Soft – Allotment gardens, nurseries

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    - Vacant
    - Soft – Allotment gardens, nurseries

3. *Fixed features* – do not change but affect other land uses through their attraction or repulsion effect
    - Recreational
    - Large institutional
    - Airport
    - Railways
    - Water

Calibration

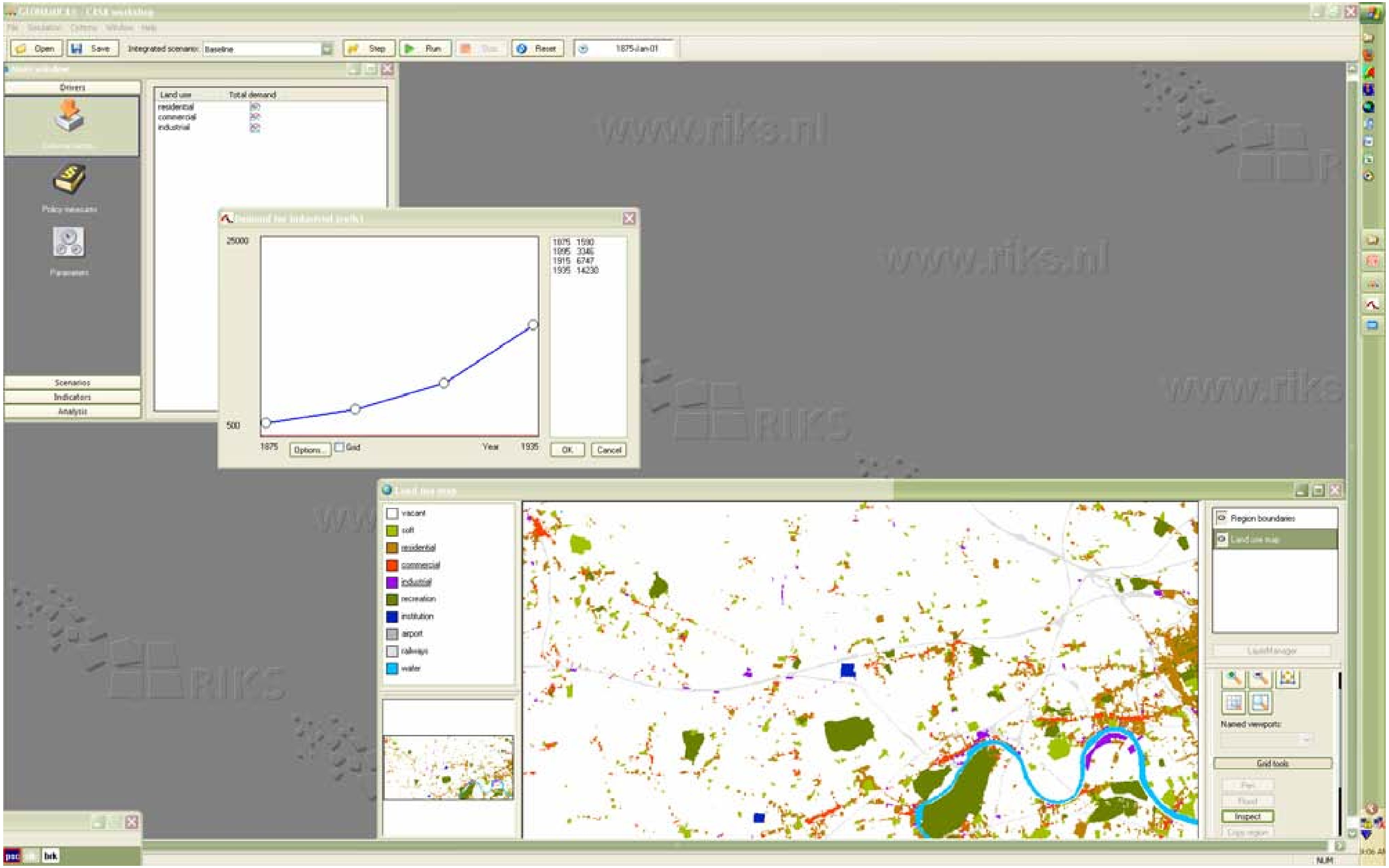
Hot topic
No adequate automated methods (ANN good but black box)
Metronamica relies on common sense, geographical knowledge and intuition

The steps

I.Qualitative calibration

1. Qualitative calibration of parameters defining neighborhood influence
2. Calibration of random perturbation coefficient
3. Introduction of Suitability, Accessibility, and Zoning
4. Fine tuning neighborhood interactions

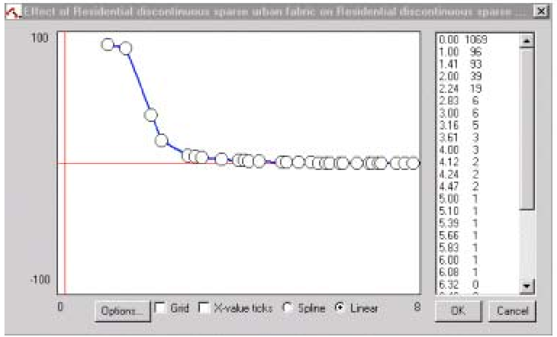
II. Quantitative calibration


Open
Save
Integrated scenario:
Baseline
Step
Run
Reset
1875-Jan-01
Drivers
Policy measures
Parameters
Scenarios
Indicators
Analysis
Land use
Total demand
residential
commercial
industrial
25000
500
1875
Options...
Grid
Year
1935
1875 1590
1895 3346
1915 6747
1935 14230
OK
Cancel
www.riks.nl
RIKS
vacant
soft
residential
commercial
industrial
recreation
institution
airport
railways
water
Region boundaries
Land use map
Named viewports:
Grid tools
Inspect
NUM

Step 1: neighborhood influence

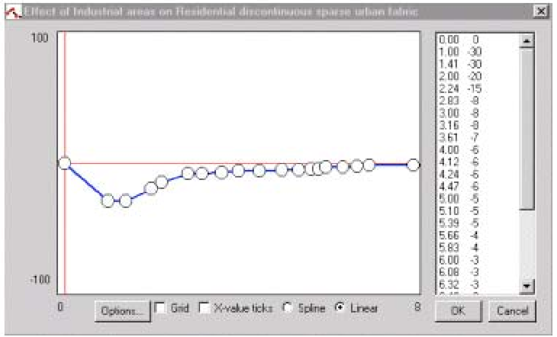
- keep the number of influence functions to a minimum
- influence functions are remarkably stable across context

(a)



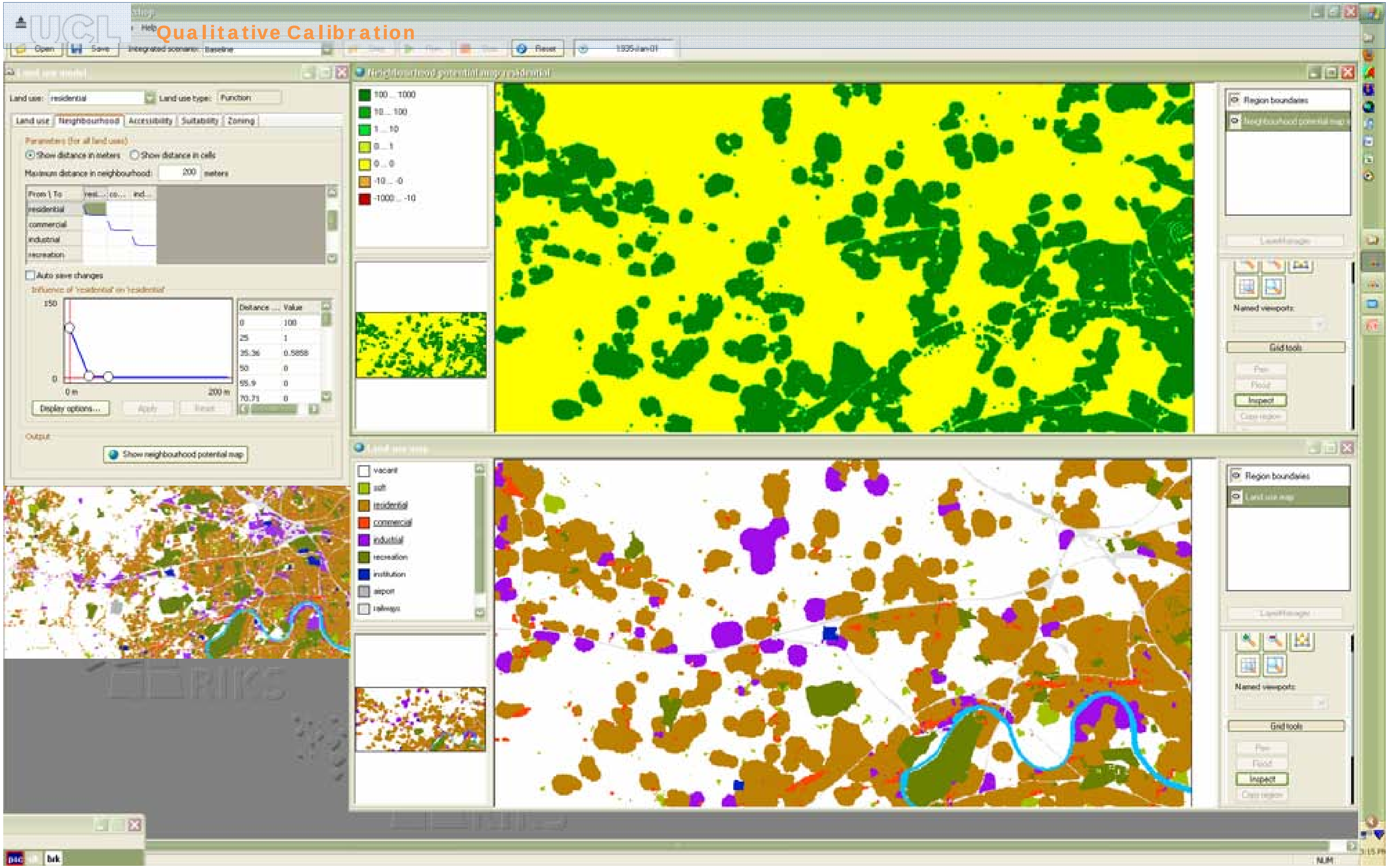
res-res

(b)

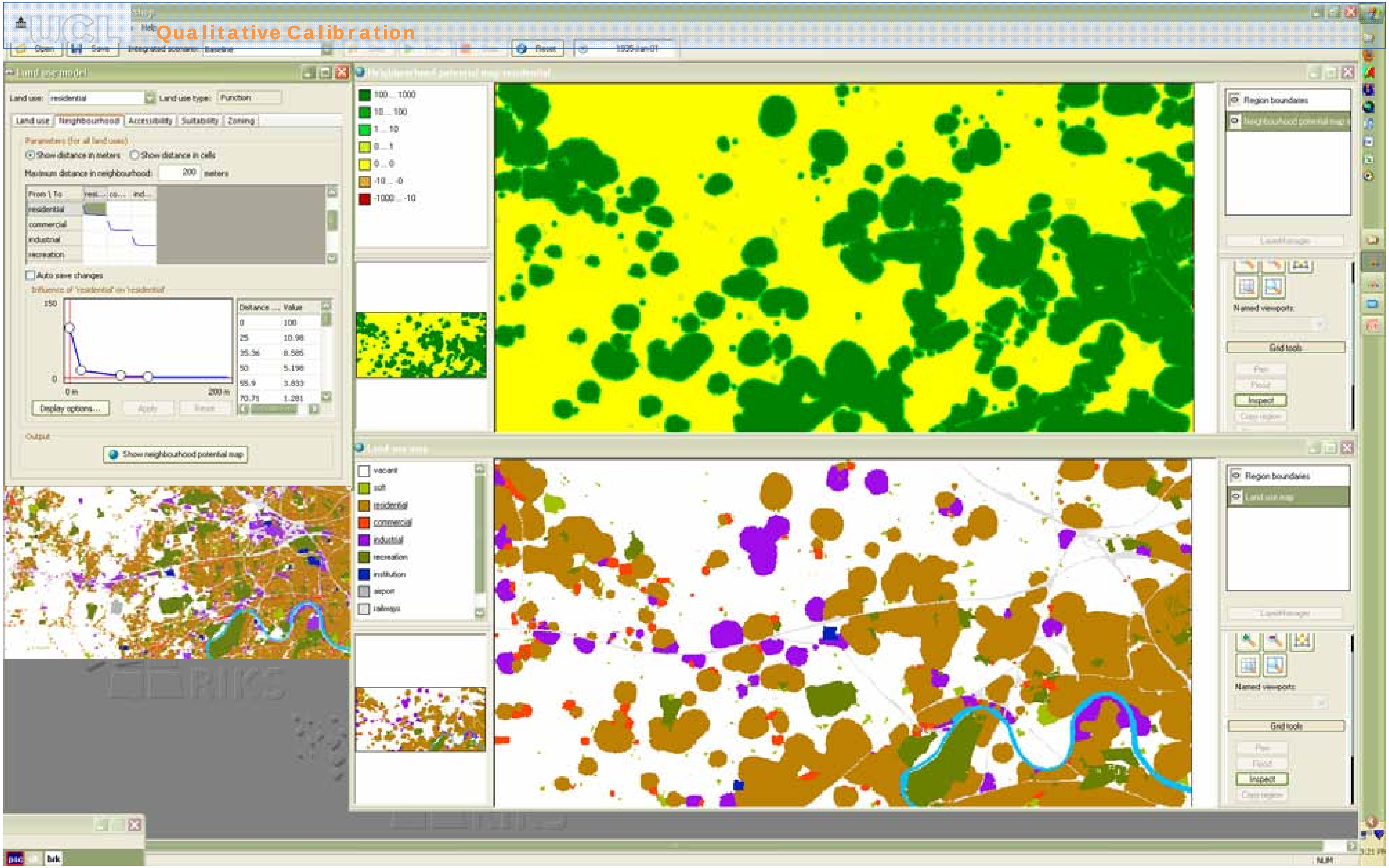


res - ind

Qualitative Calibration



Qualitative Calibration



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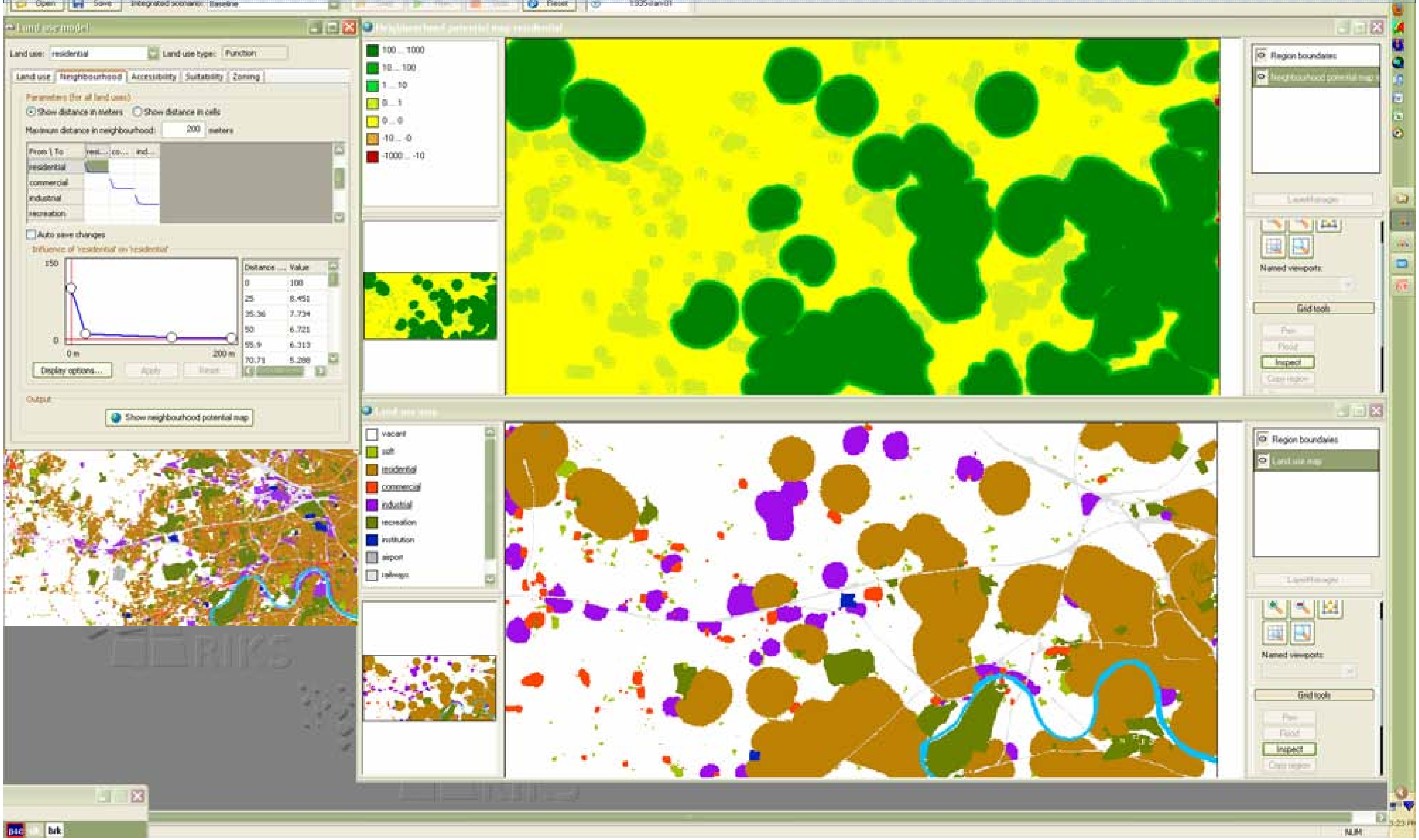


Step 2: stochastic parameter

controls the degree of scatter in land use patterns

impacts

- density gradient of land uses
- seeding of new clusters
- degree of irregularity of cluster boundaries

Step 2: stochastic parameter

controls the degree of scatter in land use patterns

impacts → fractal dimensions

impacts

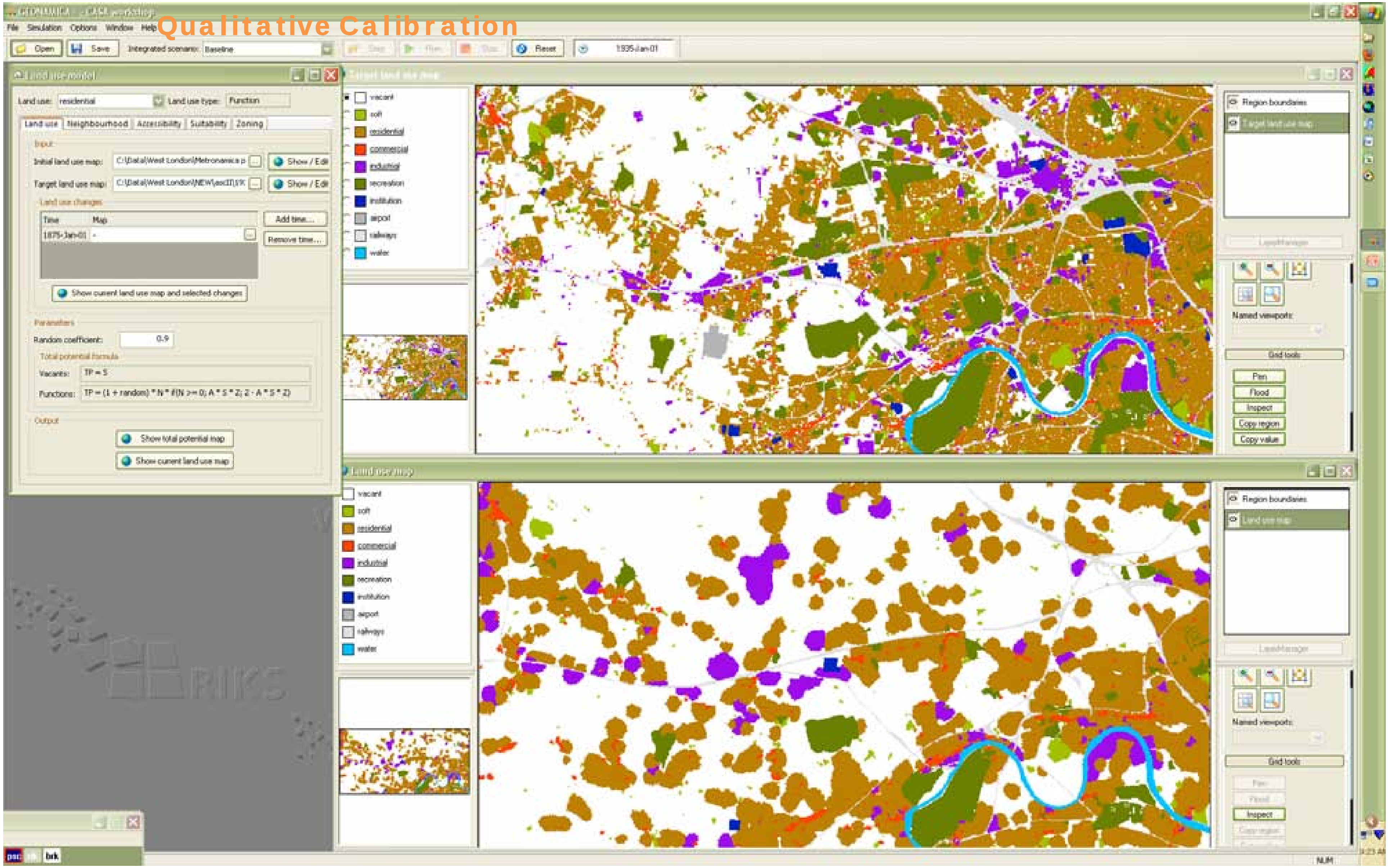
- density gradient of land uses
- seeding of new clusters
- degree of irregularity of cluster boundaries

fractal dimensions

- the radial dimension
- the cluster size – frequency dimension
- the perimeter scaling dimension

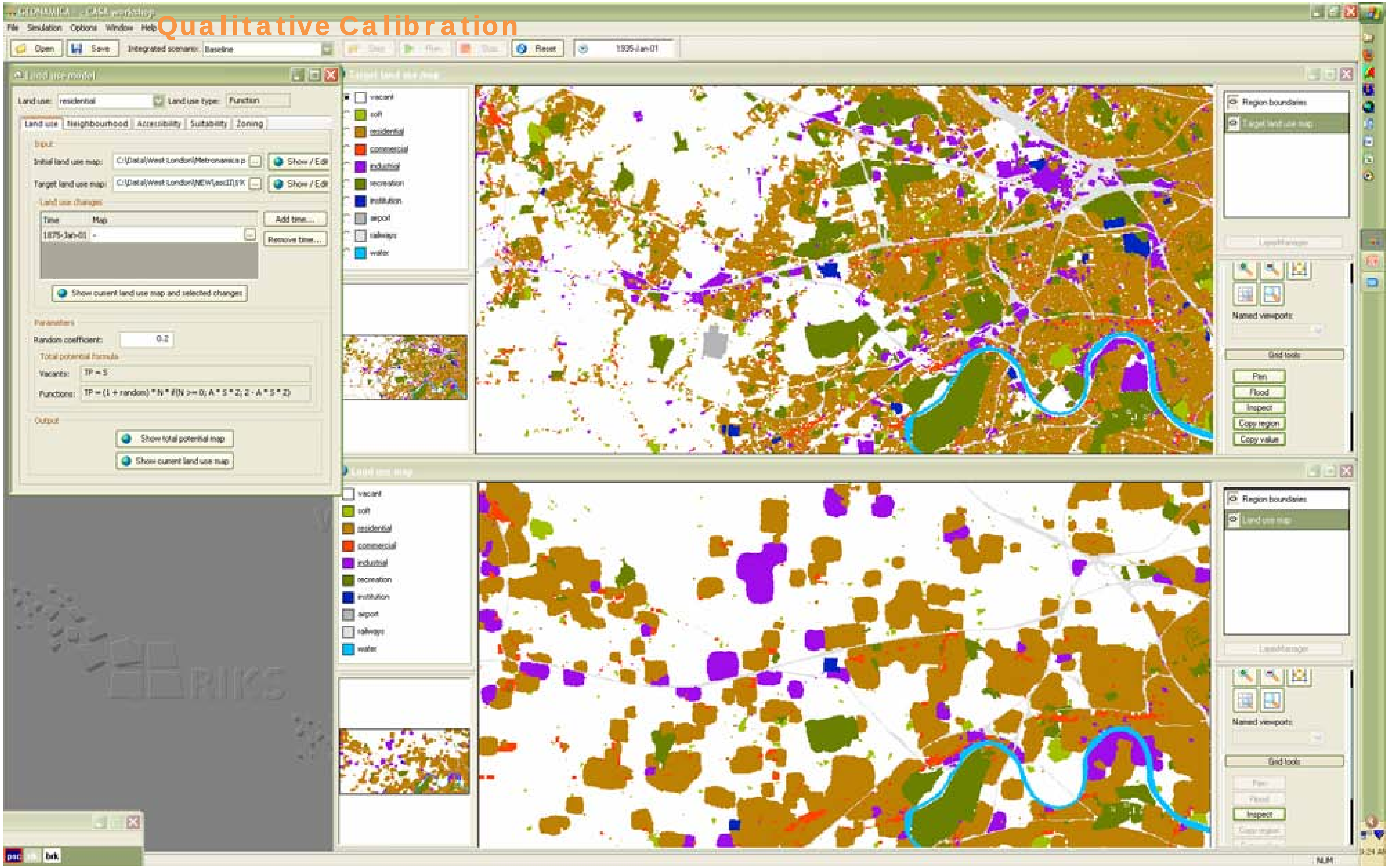
All of three dimensions are measured serving as the reference for the calibration.

Qualitative Calibration



Random coefficient = 0.9

Qualitative Calibration



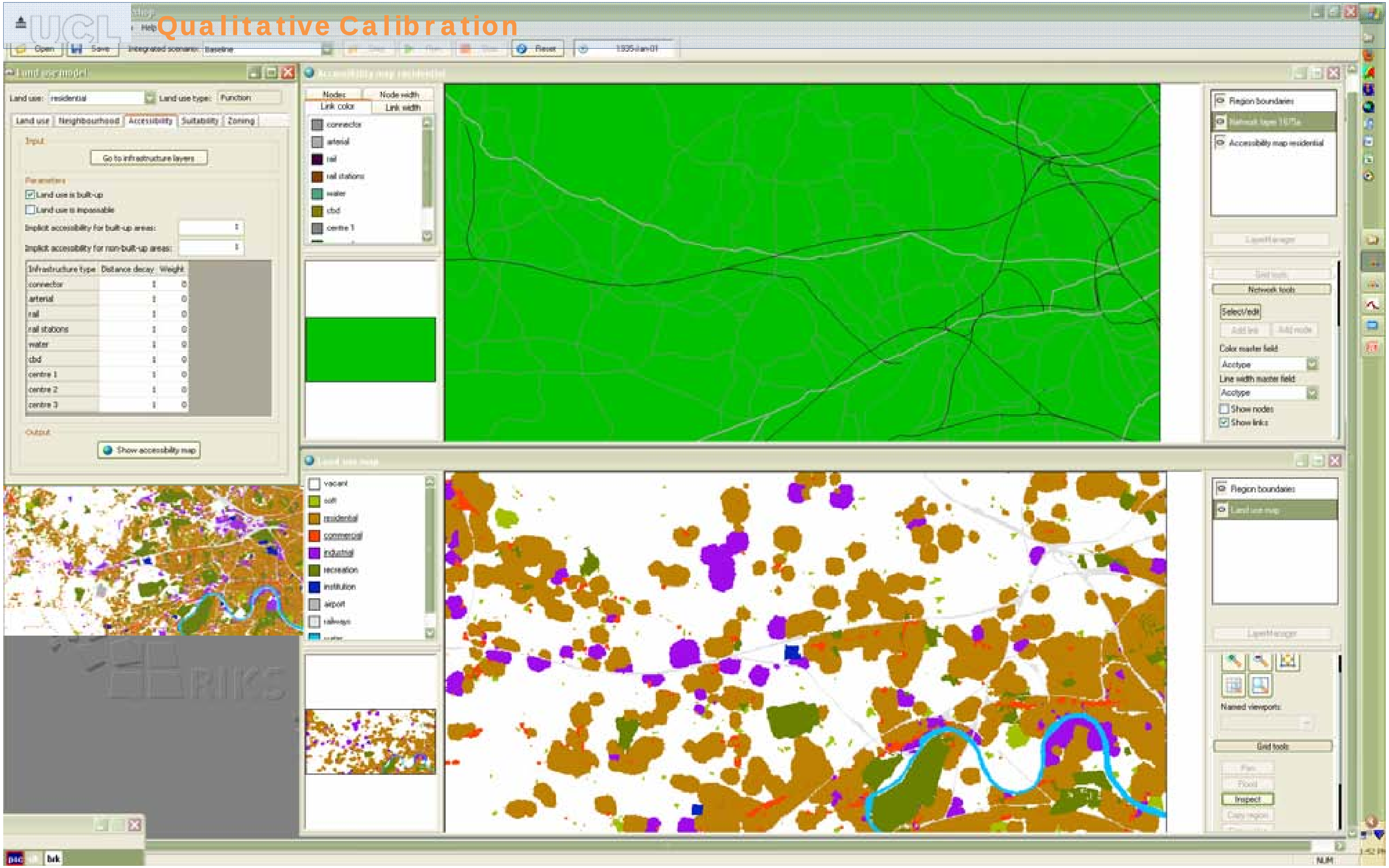
Random coefficient = 0.2

Step 3: accessibility

Two types of parameters:

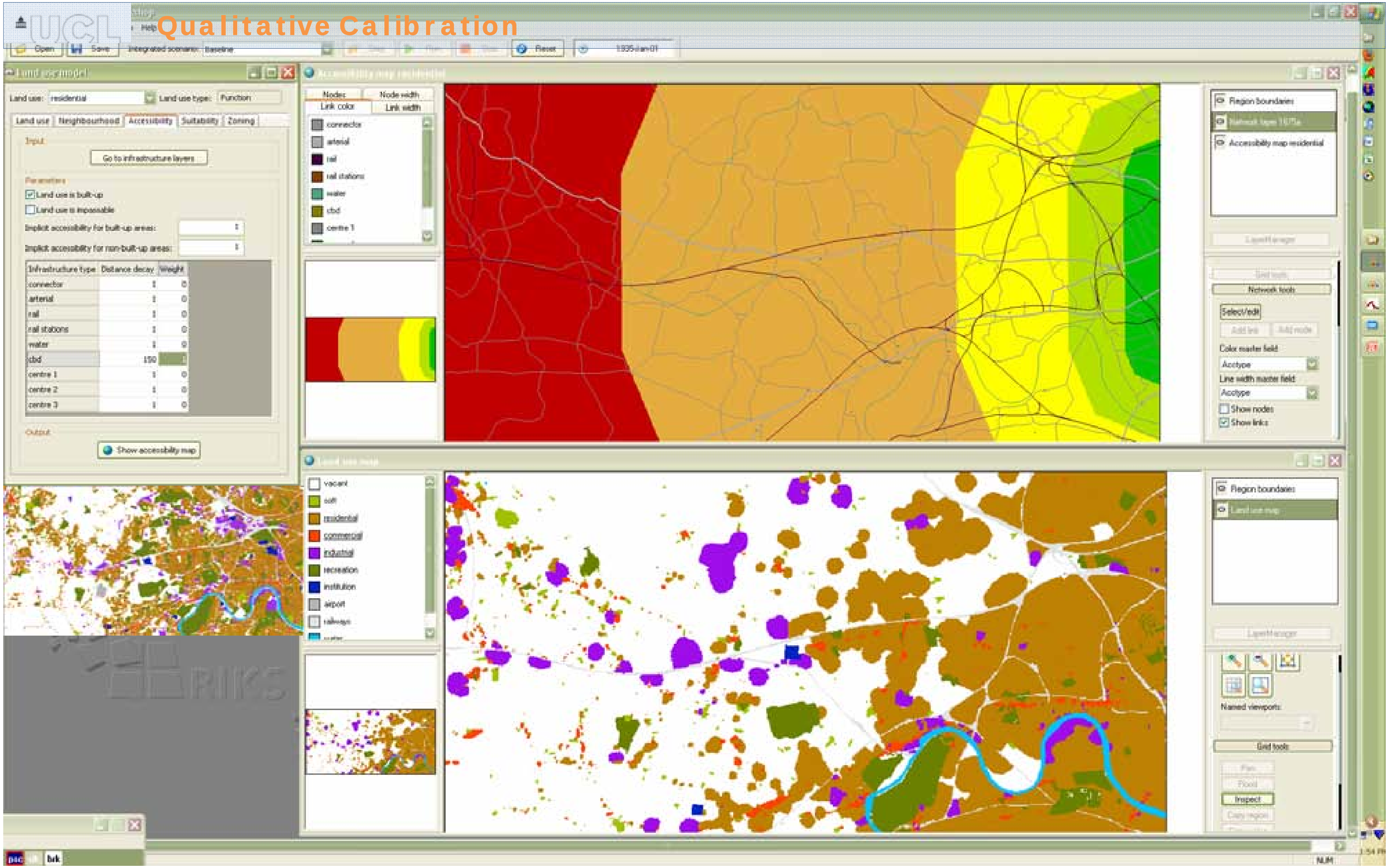
- *weighting parameters* - the relative importance of various network elements for particular land use
- *distance decay parameters* - specify the rate at which the inherent desirability of a cell for a particular land use declines as distance from the network element increases.

Qualitative Calibration



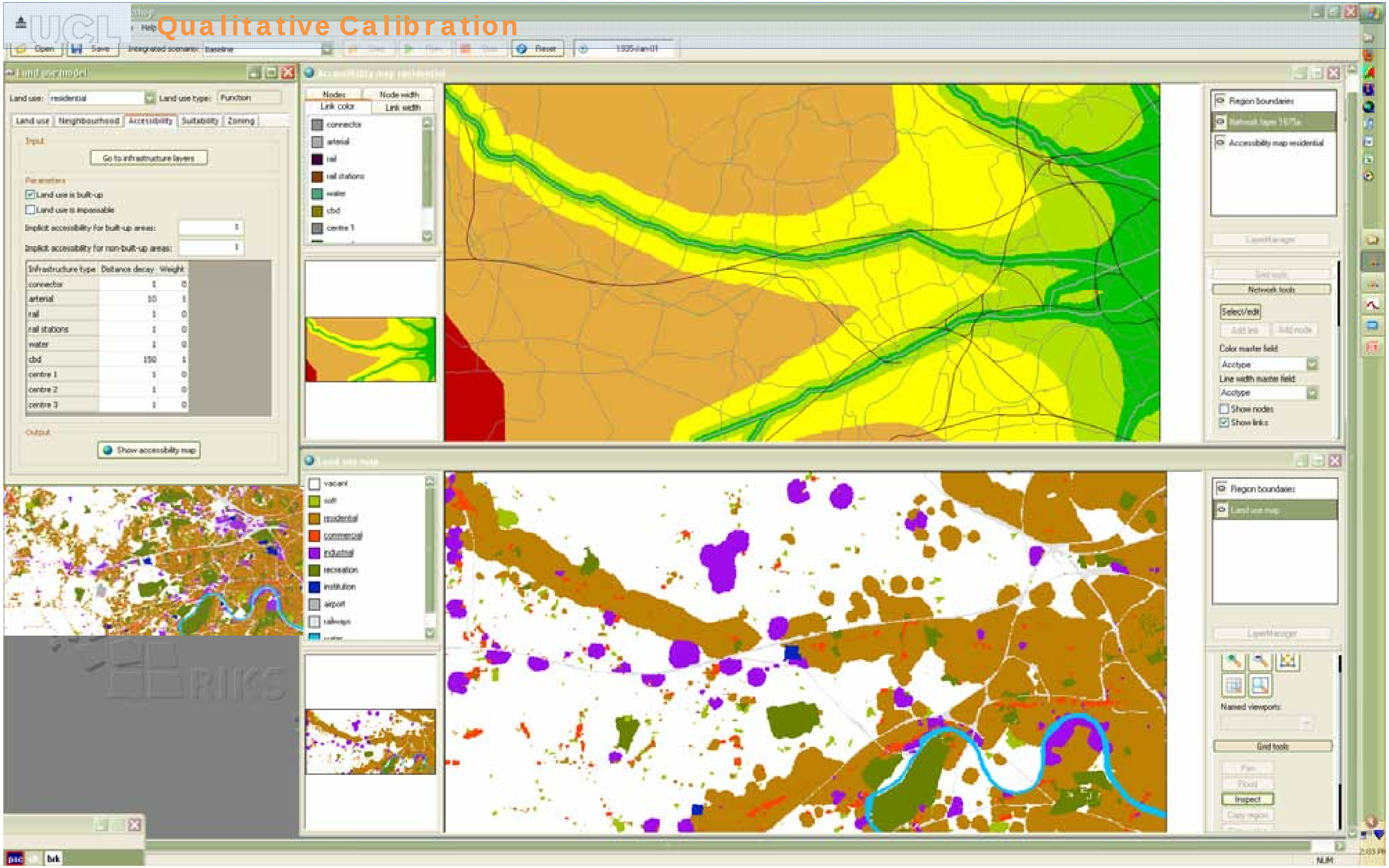
No accessibility

Qualitative Calibration



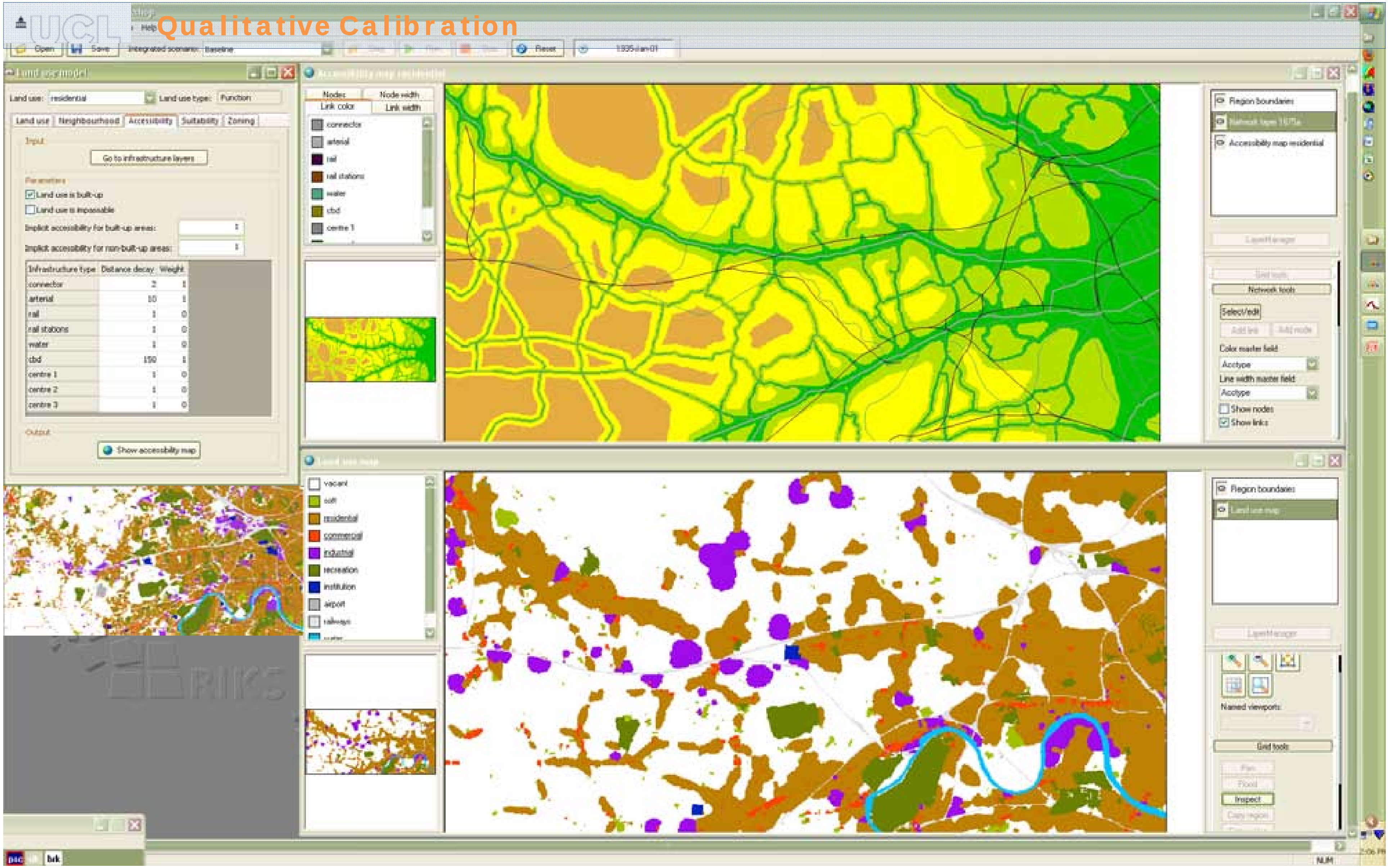
Access to CBD

Qualitative Calibration



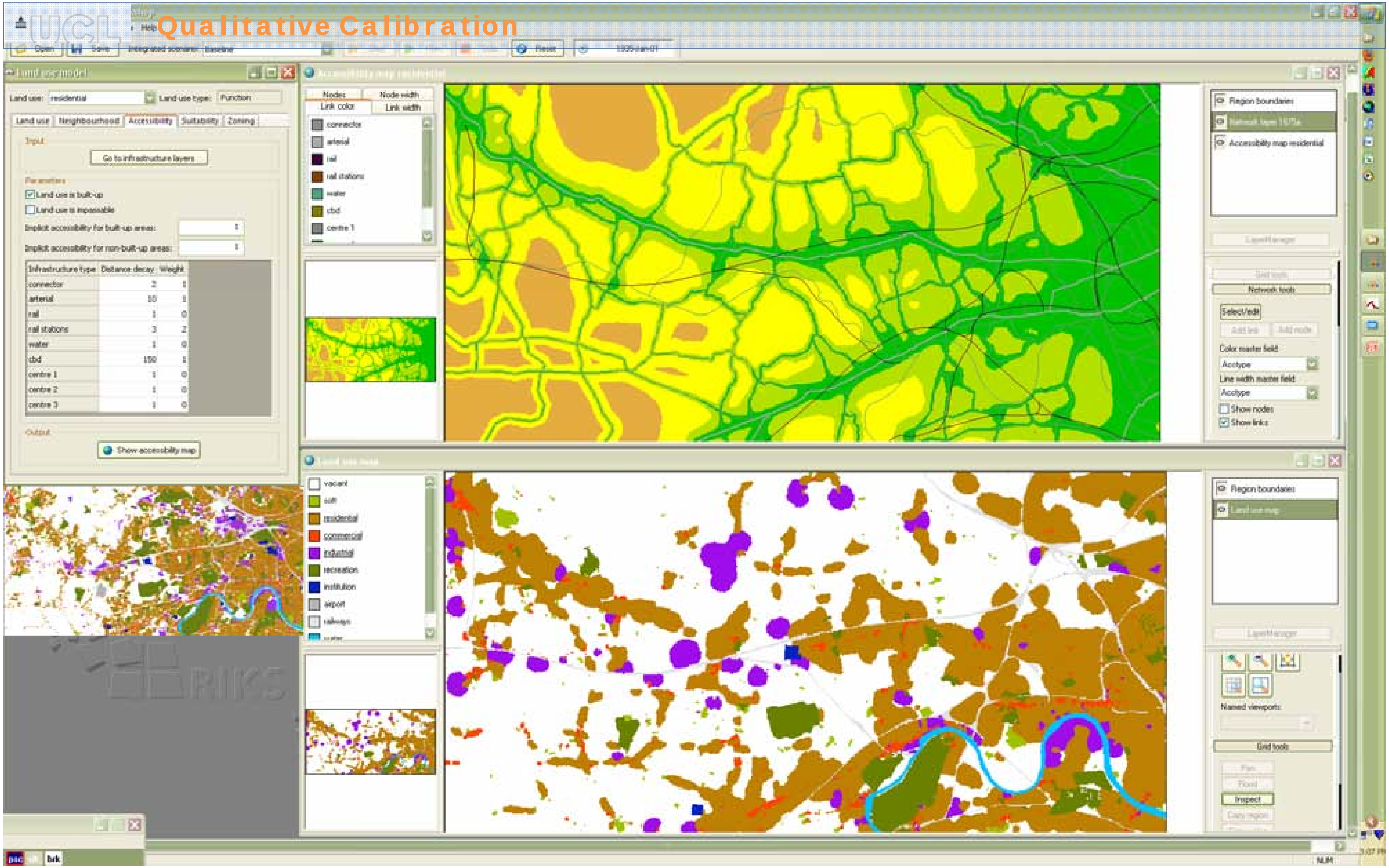
Access to CBD + arterial roads

Qualitative Calibration



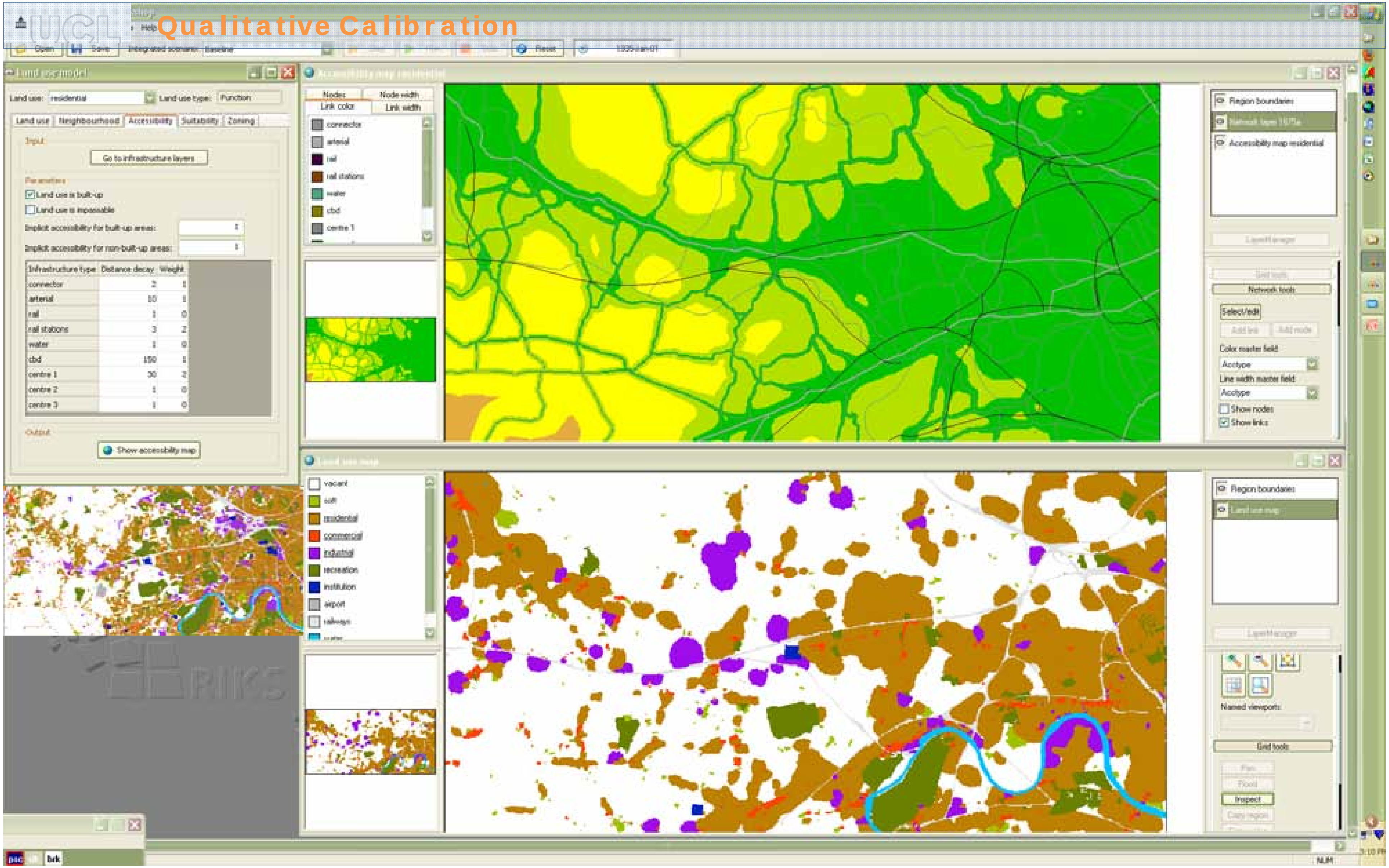
Access to CBD + arterial roads + connector roads

Qualitative Calibration



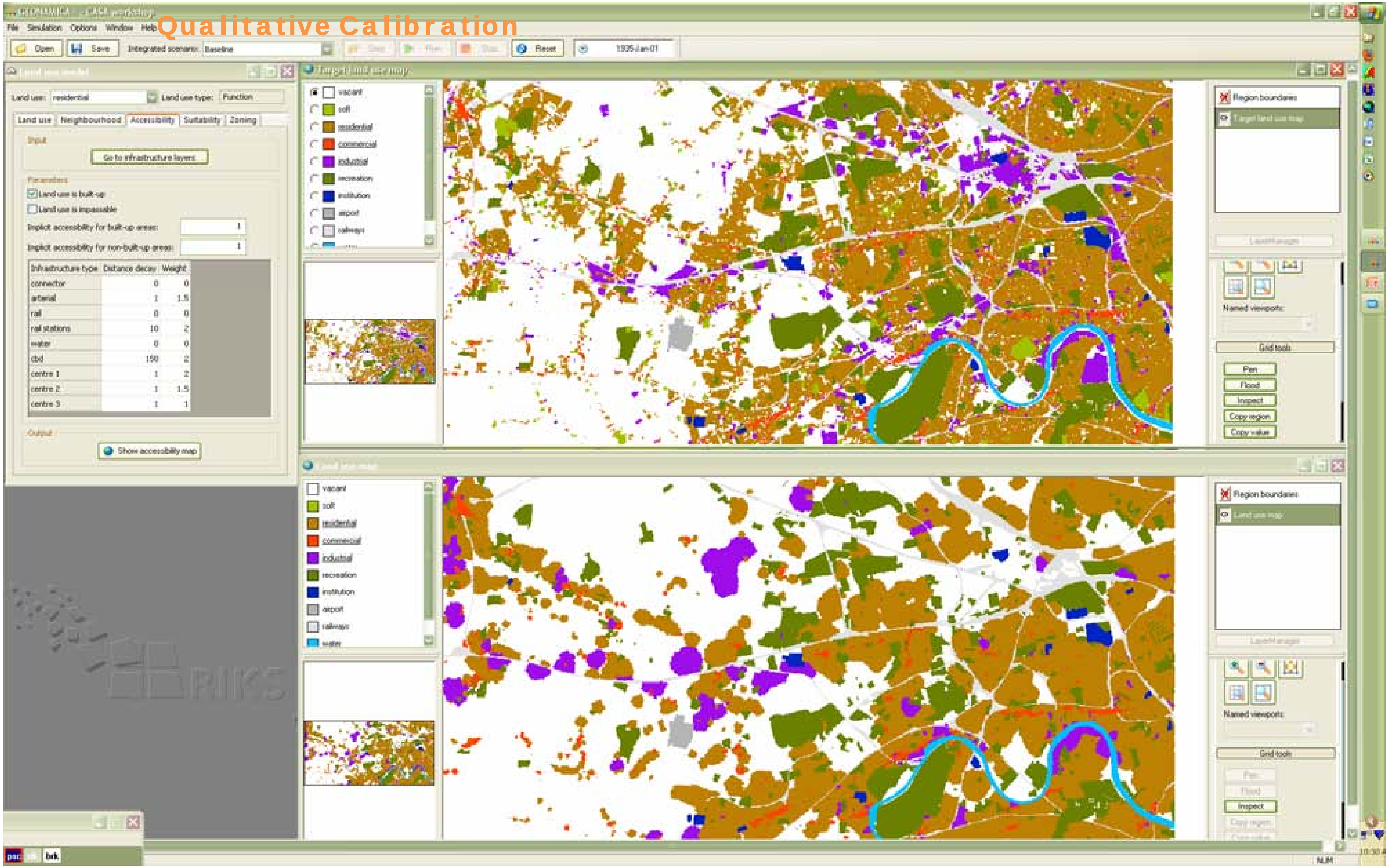
Access to CBD + arterial roads + connector roads + rail stations

Qualitative Calibration



Access to CBD + arterial roads + connector roads + rail stations + suburban centres

Qualitative Calibration



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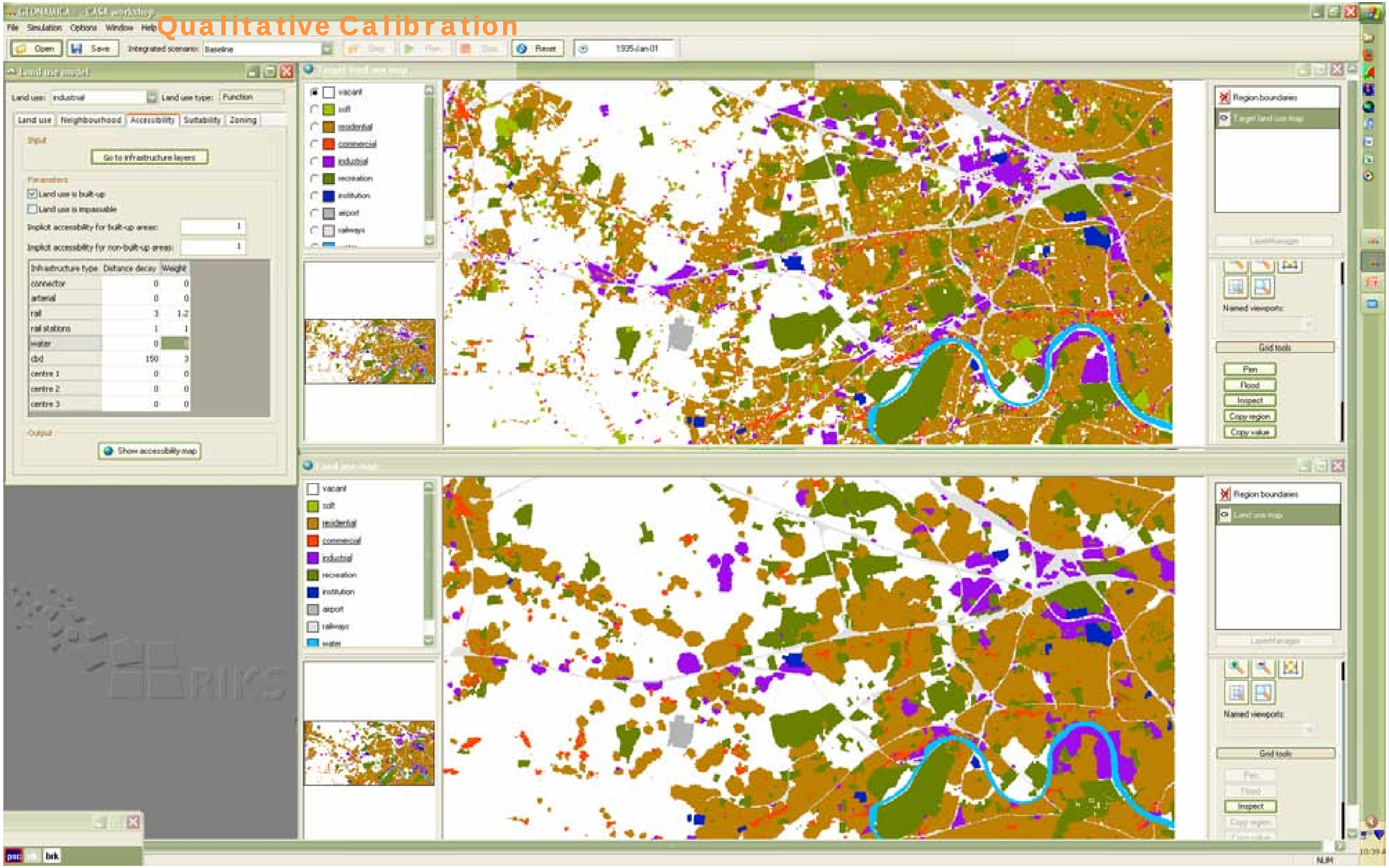
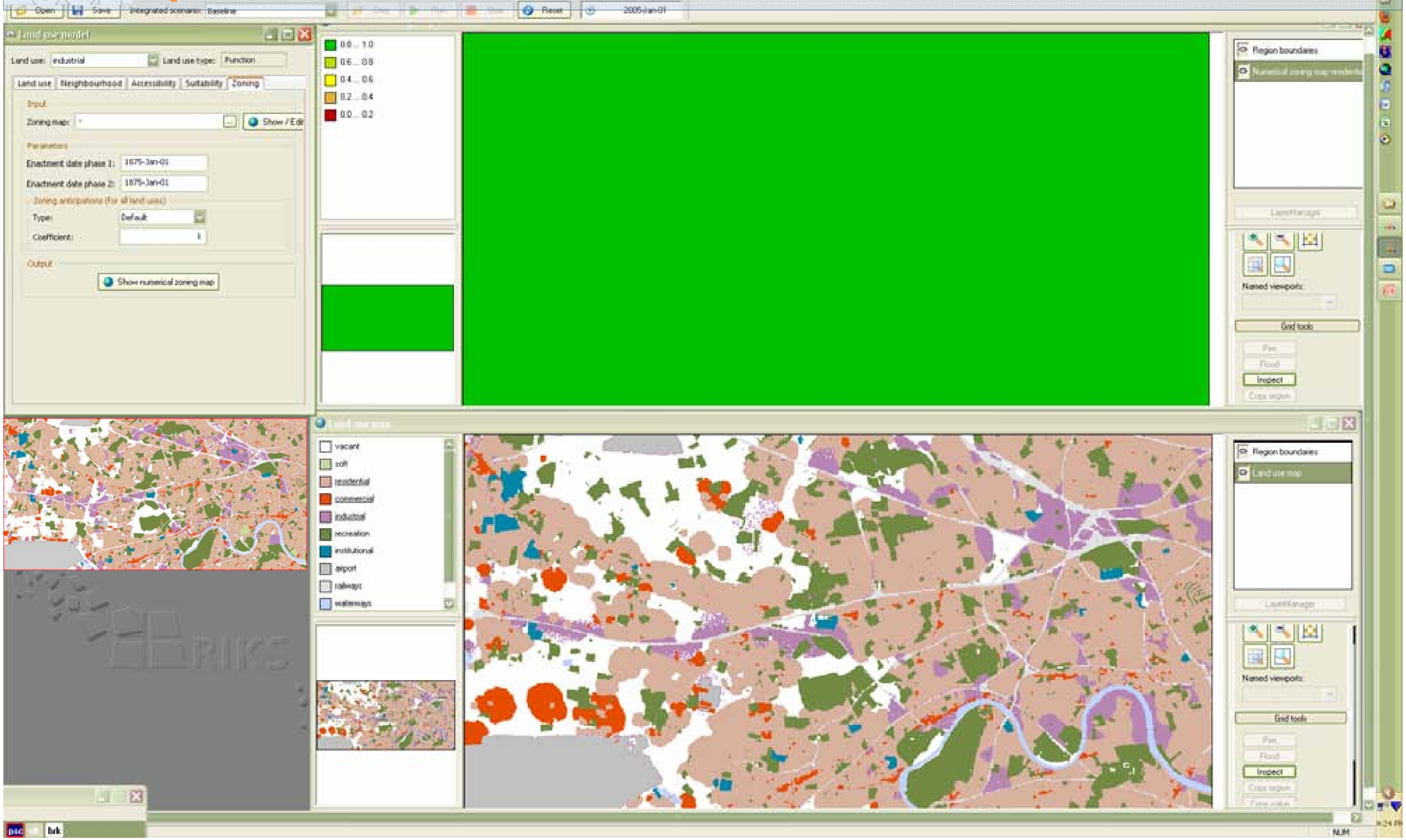


Step 4: Zoning

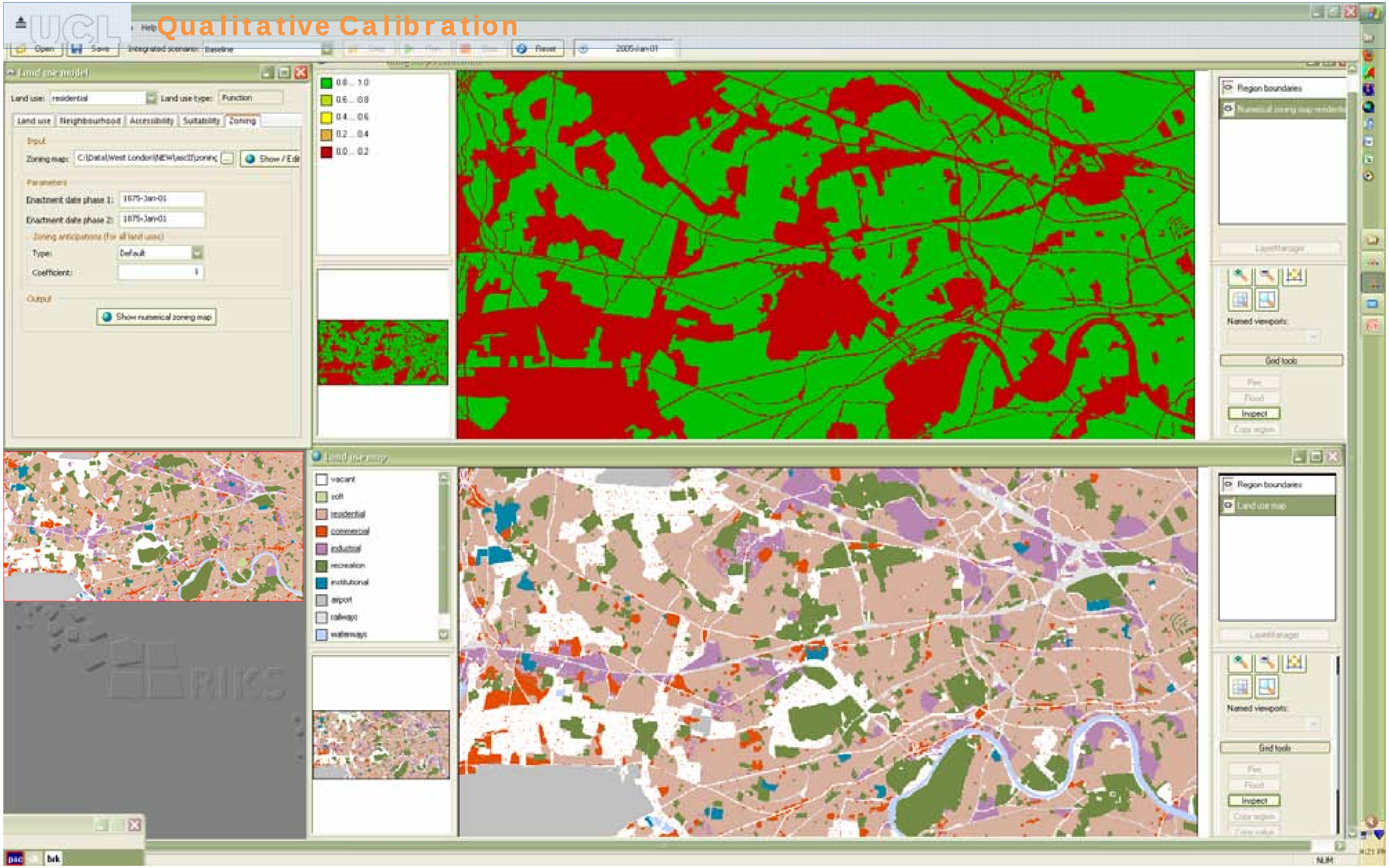
- Somewhat rigid integration – allows for little change over time
- Still better than most other CA-based systems

Qualitative Calibration



no zoning

Qualitative Calibration



protected open space

Qualitative calibration summary

What features/patterns are relevant to look for:

- Dispersal
- Scatteration
- Number of clusters
- Cluster sizes
- Cluster shape
- Raggedness of edges
- Land uses adjacencies

These are all qualities of pattern which cannot be captured in pixel by pixel comparisons.

Quantitative calibration

Evaluation of the degree of fit between two maps using the comparison matrices method
Provides a basis for choosing between calibrations which, according to a visual comparison, are of similar quality.

Main techniques

- Kappa statistics
- fuzzy Kappa statistics
- polygon based fuzzy map comparison

The MAP COMPARISON KIT is an instrument enabling the pair-wise comparison of the many maps generated in particular runs of METRONAMICA

To Do list

- Fine-tuning the calibration
- Sensitivity analysis
- Spatial resolution analysis
  - cell size
  - land use classification

Conclusions

- METRONAMICA is cool … and it works!
- Strong evidence that the complexity of urban land use patterns is generated by underlying processes which are relatively simple in qualitative terms and consistent across time