Cities as Dynamic Adaptive Structures

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Urban Form

Vancouver

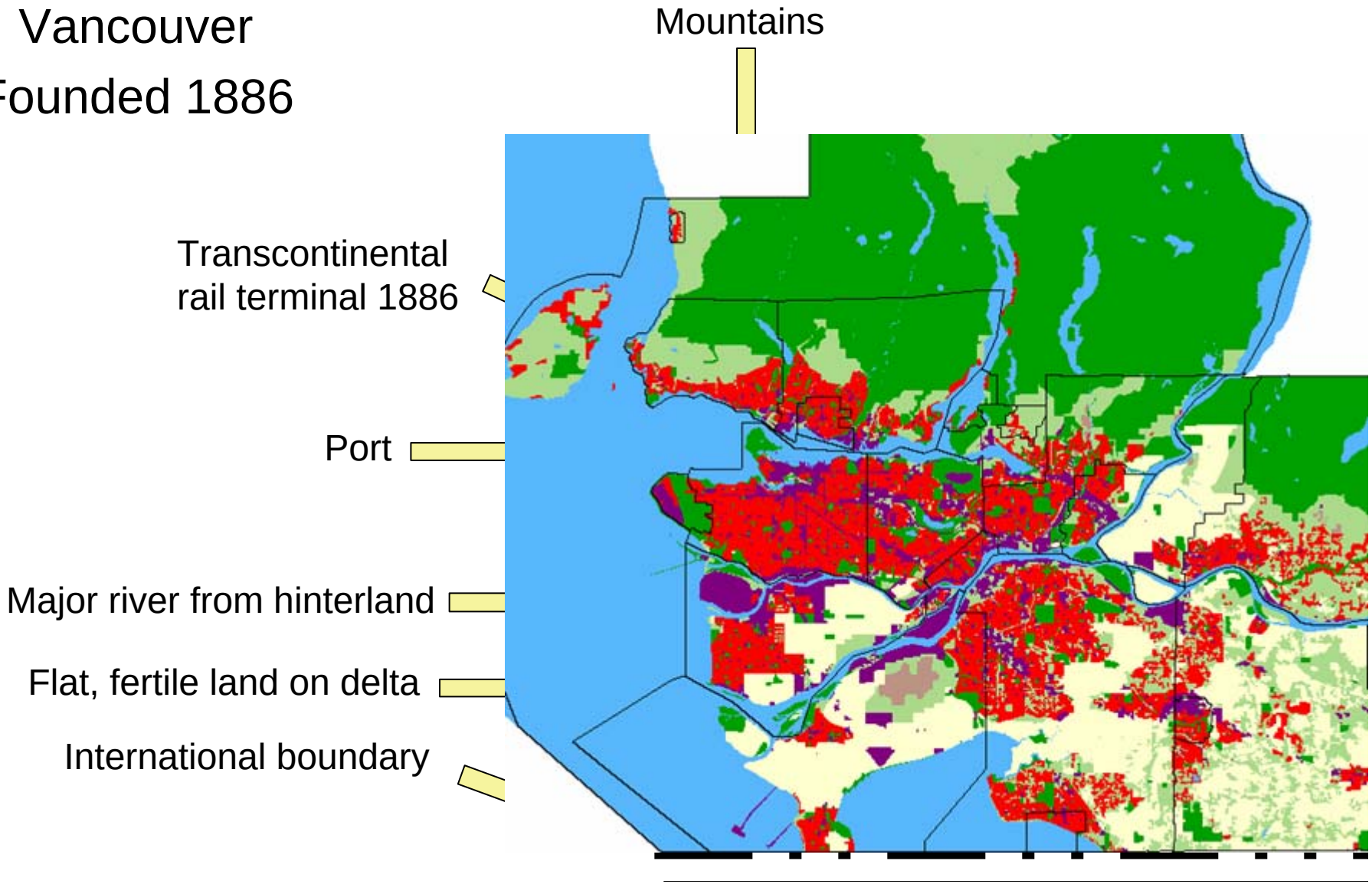
Two approaches:
Idiographic *vs* Nomothetic

…or is it three?

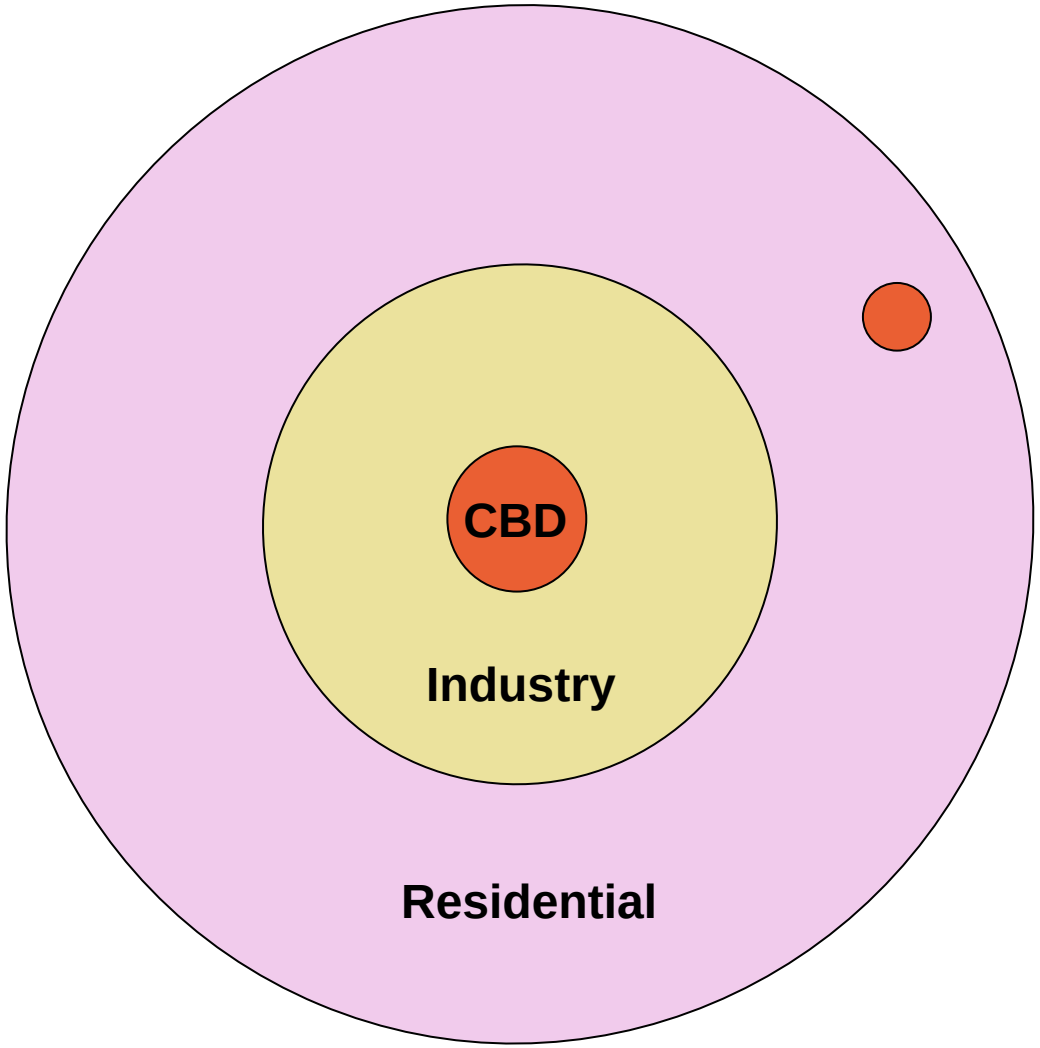
What we knew then (Idiographic)

Vancouver

Founded 1886

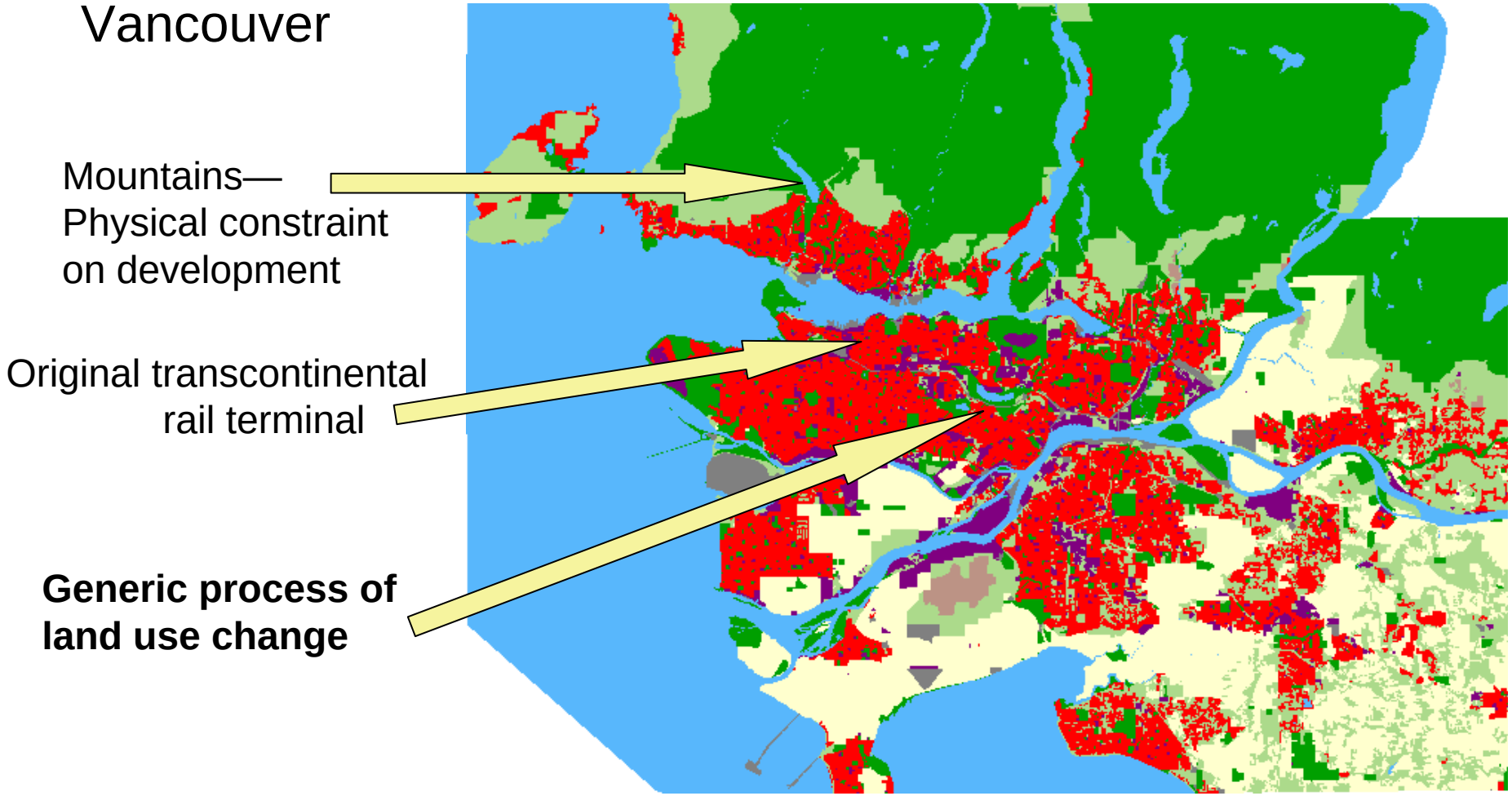


What we knew a bit later (Nomothetic)



What we know now
(Complexity and self-organization: the new nomothetic)

Vancouver



The Main Points:

Cities can be understood as complex, self-organizing systems.

This allows us to explore their possible futures and perform what-if experiments.

The New Nomothetic Approach

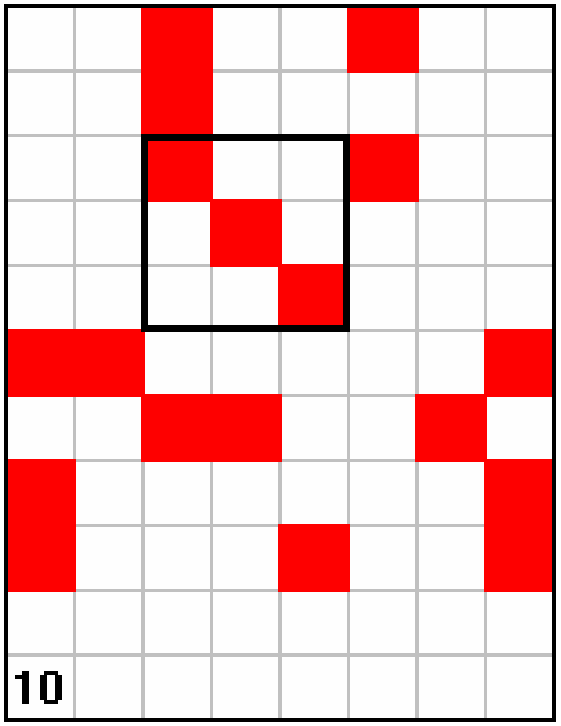
Focus on ***process***

Use ***algorithms.***

Algorithms are a ***performance*** of a process in a computer.

Land use is the key: everything comes together on the ground.

A simple algorithm—
The cellular automaton

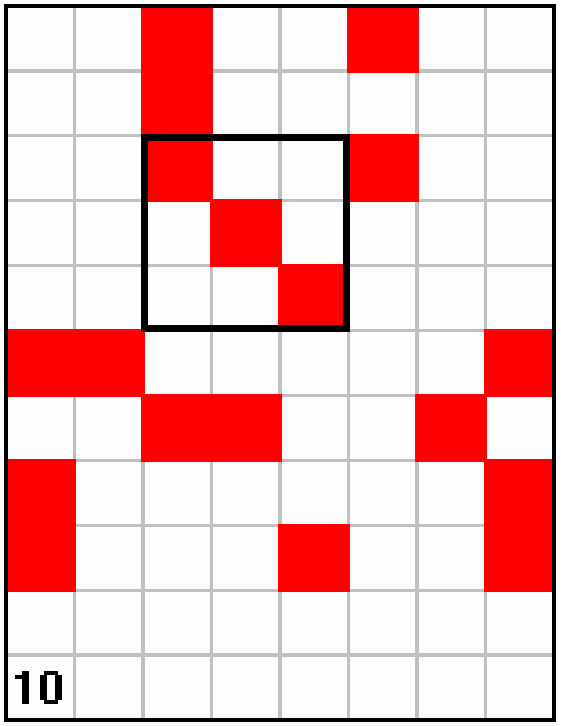


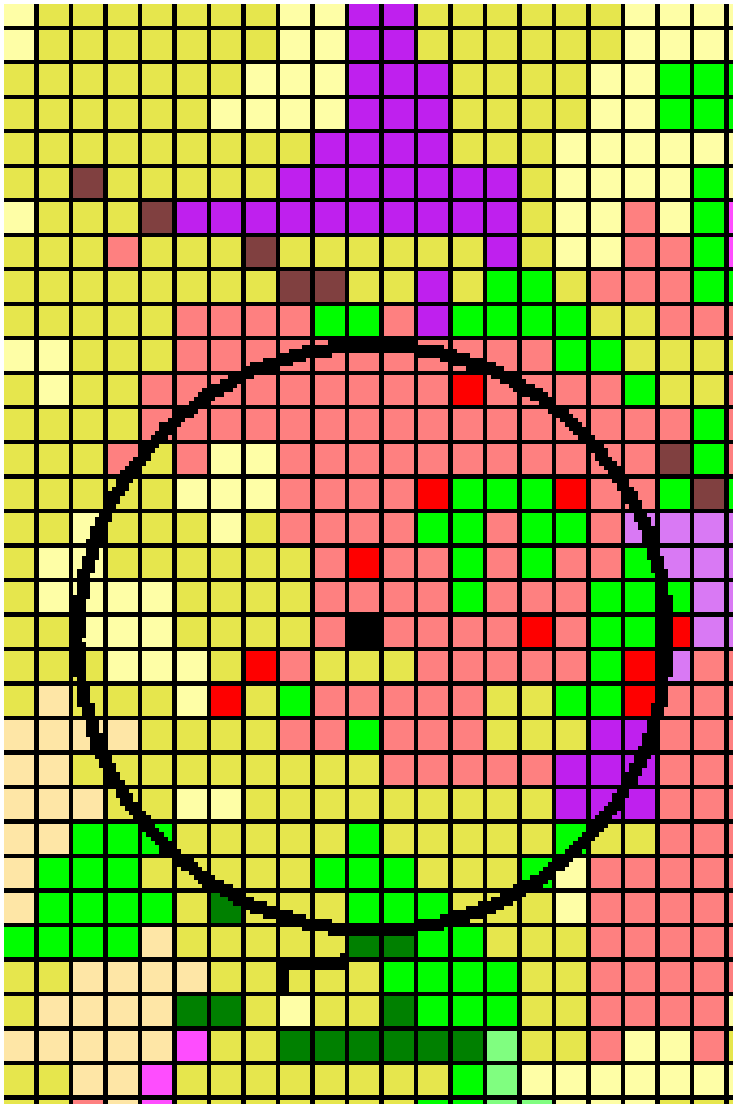
Rules:

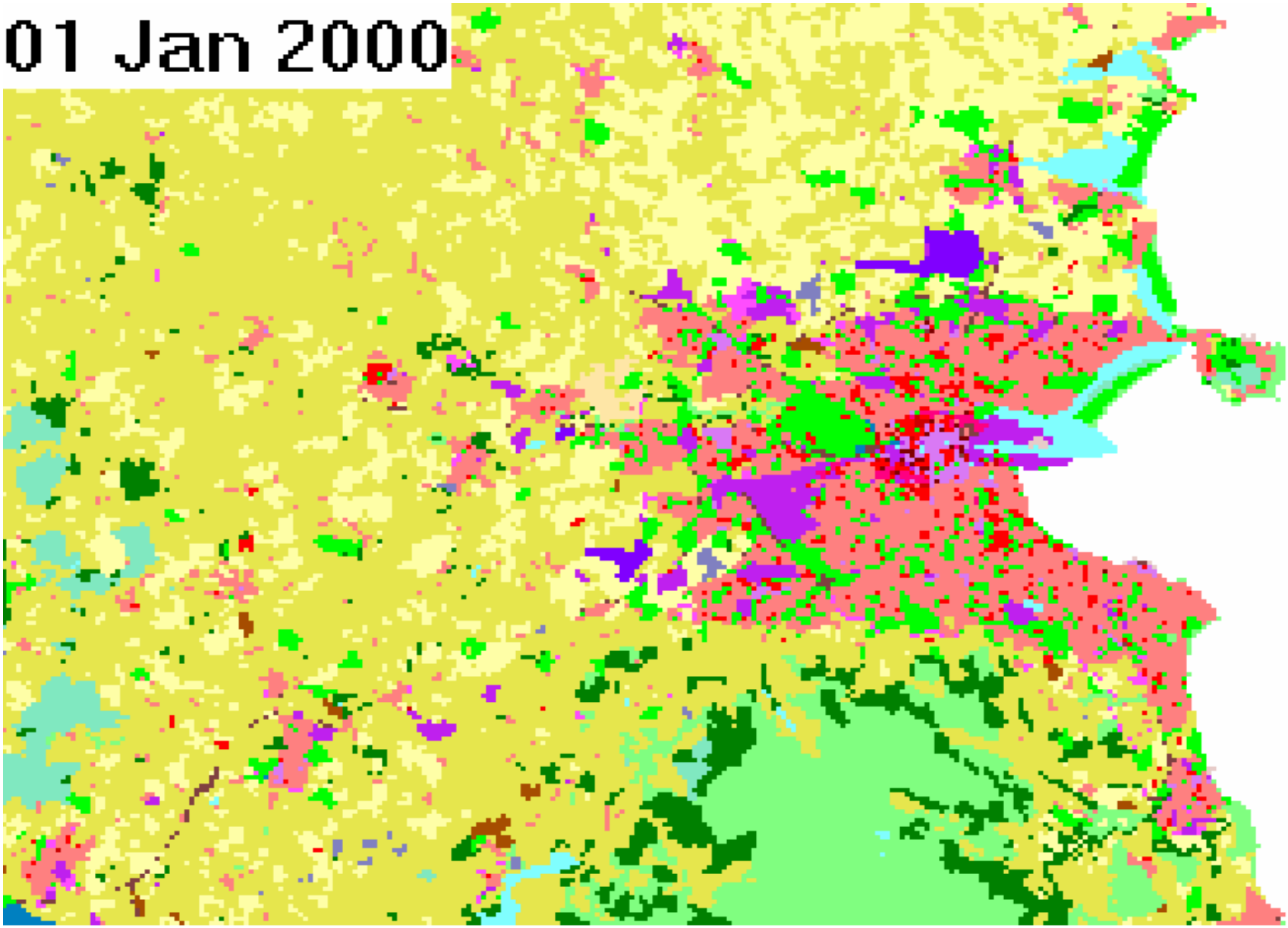
If a cell is red, it stays red if there are two or three red cells around it. Otherwise it turns white

If a cell is white, it stays white unless there are exactly three red cells around it.

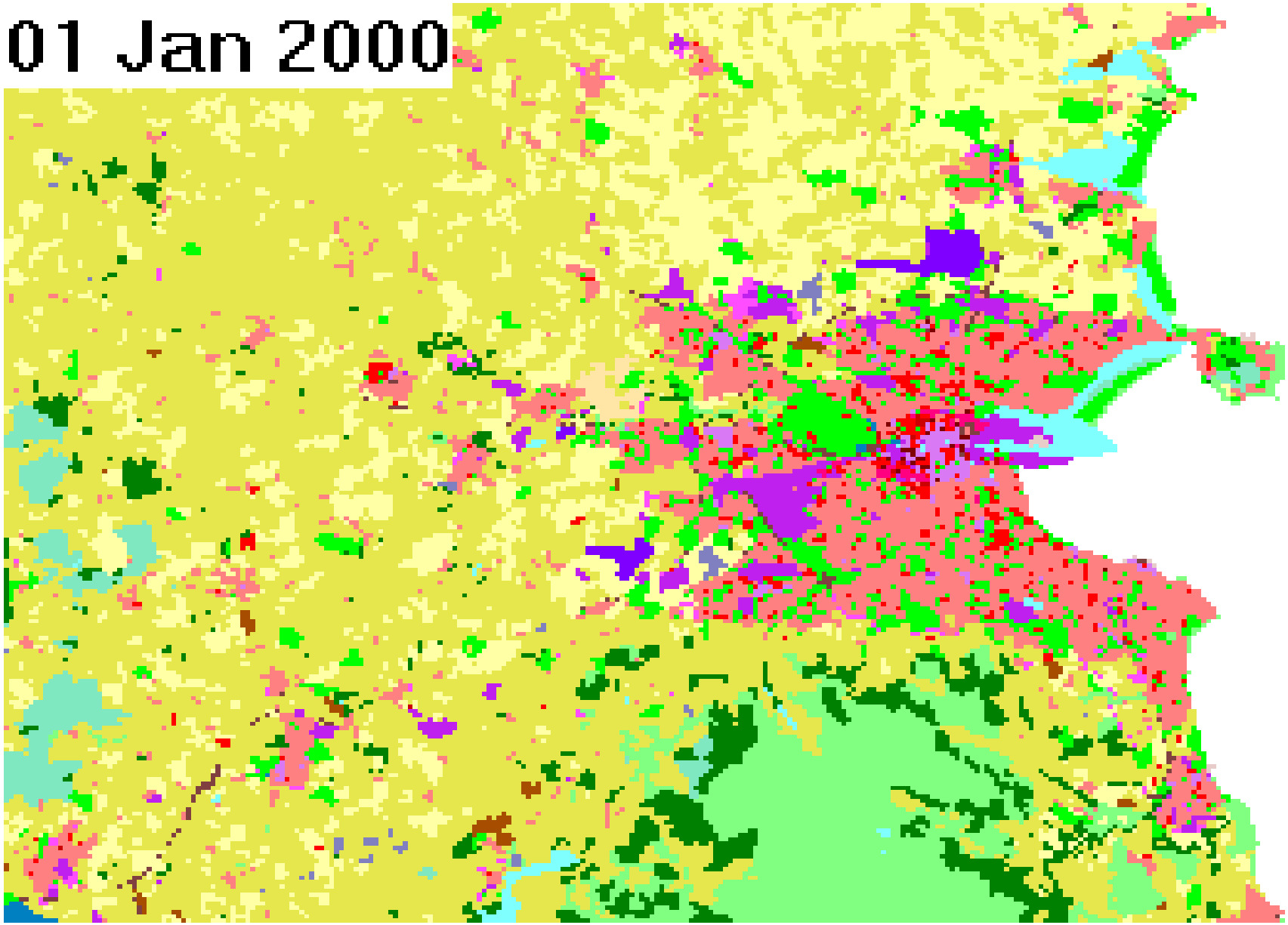
A more realistic algorithm







Credit: Land Management Unit of the Joint Research Centre of the European Commission

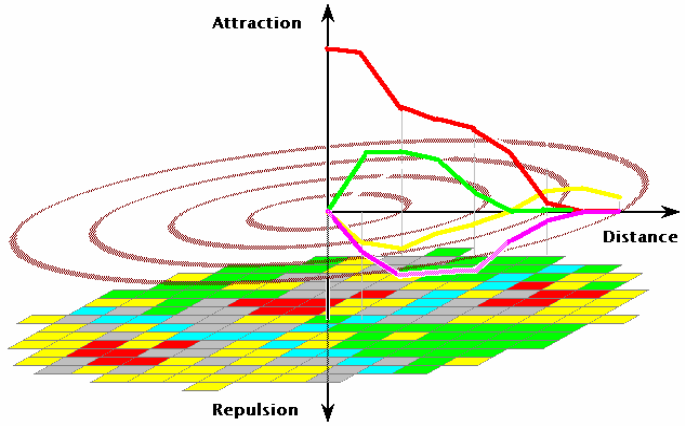


Credit: Land Management Unit of the Joint Research Centre of the European Commission

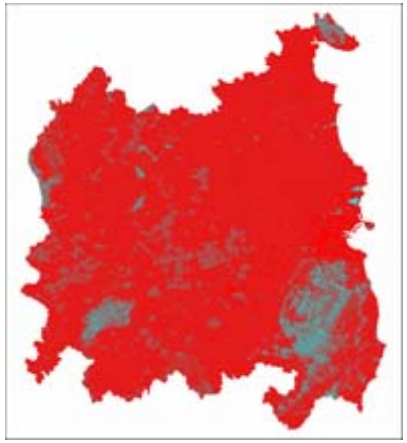
The Neighbourhood Effect

The neighbourhood effect expresses

- ***repulsion and attraction*** between pairs of land uses
- ***Agglomeration effects***
- ***Inertia***



Natural qualities



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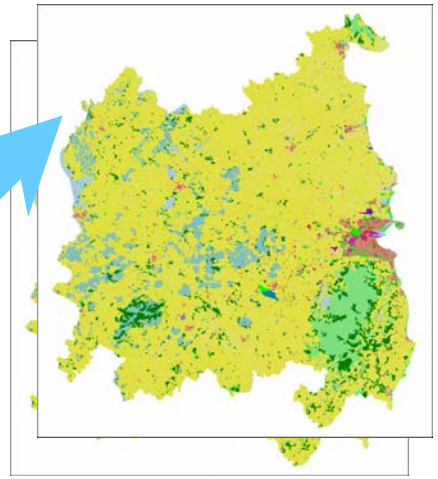
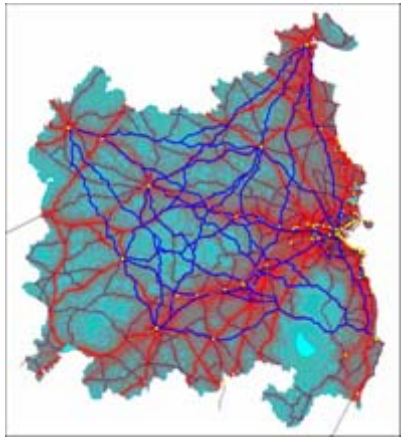
Land use and activity at time T+1



Accessibility



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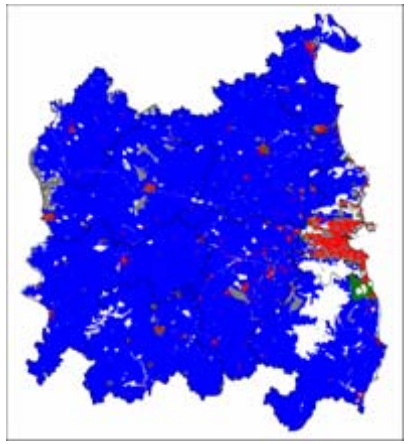
Change each cell to the land use for which it has the highest potential…

until all land use demands are met

Zoning



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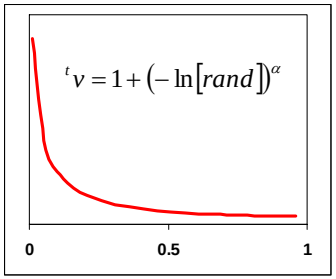
Individual differences



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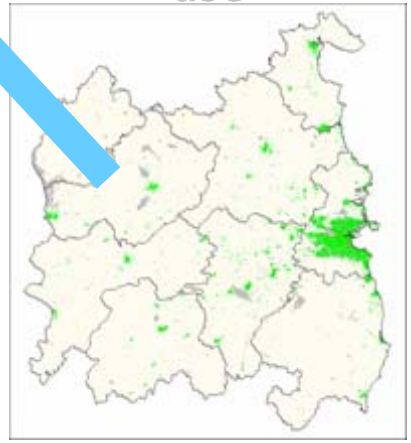
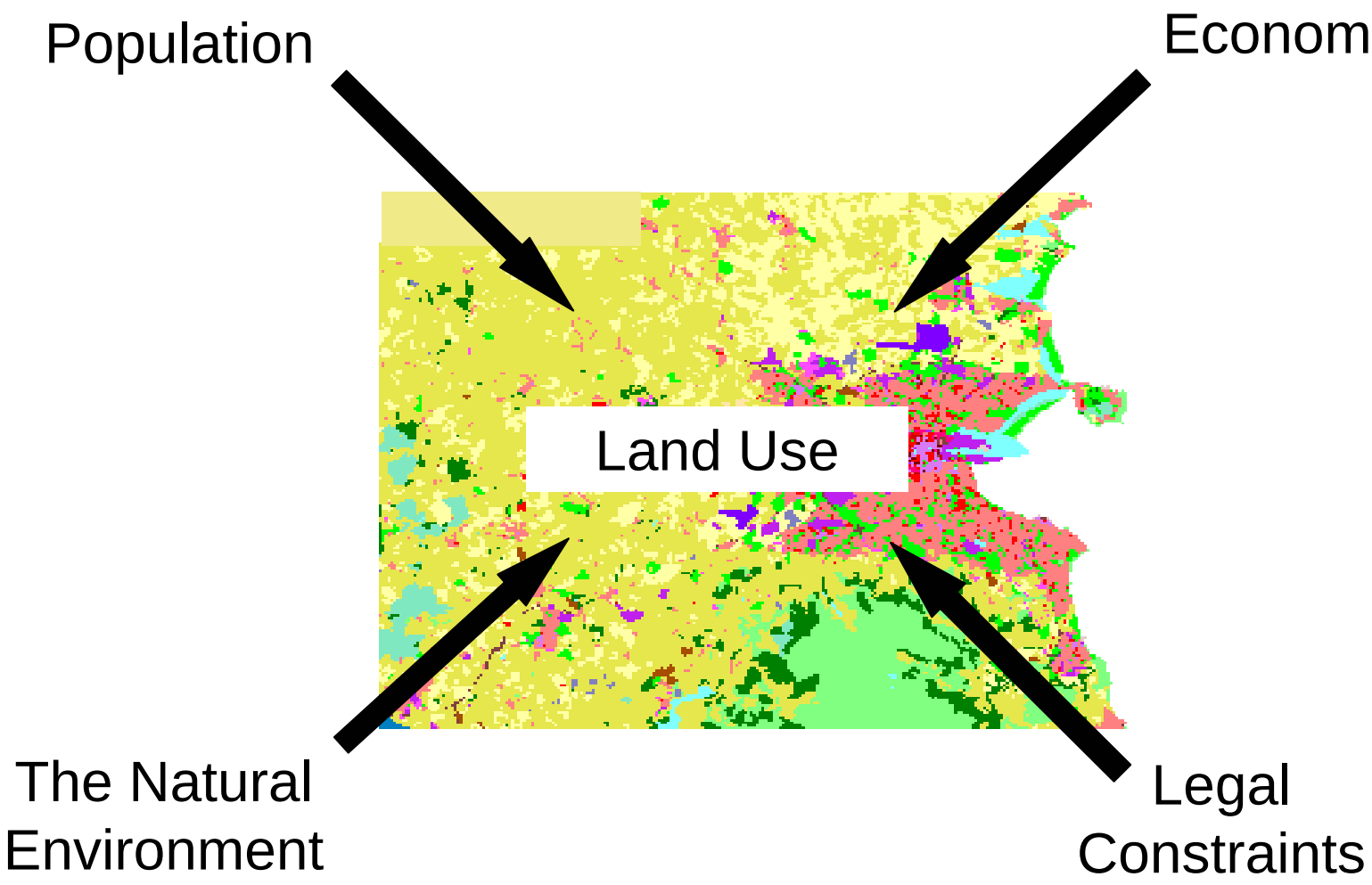
Potential for a particular land use

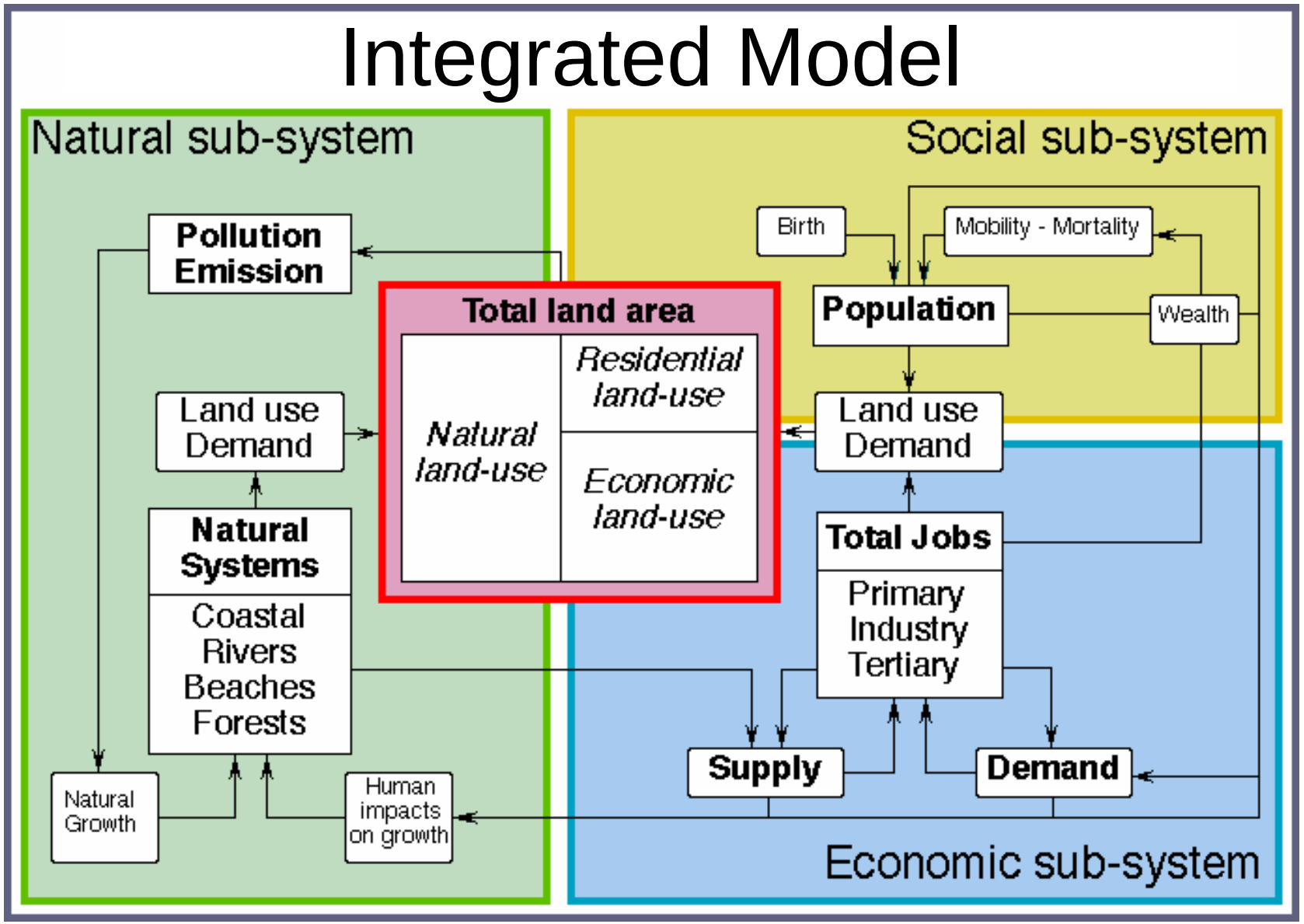


until all land use demands are met

Land Use Is an expression of activity



Integrated Model



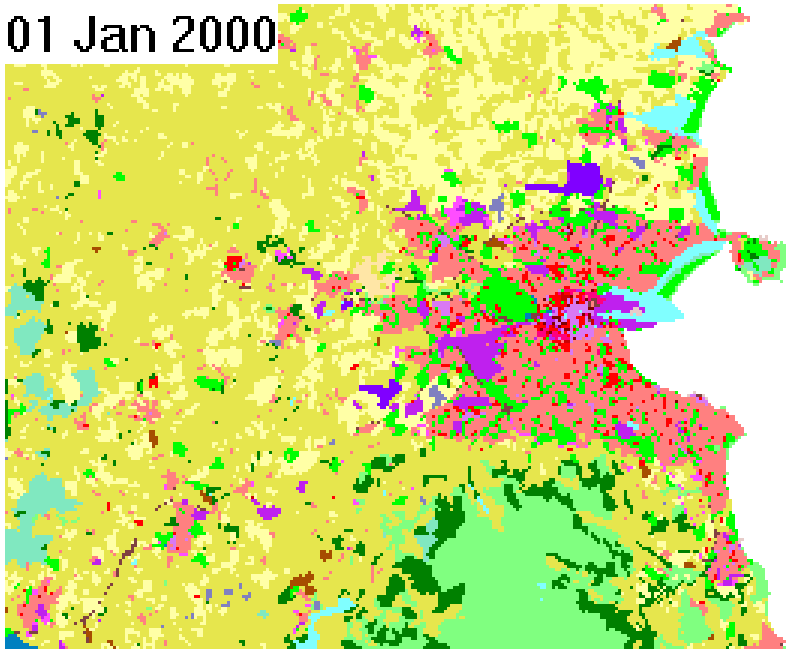
A city is a complex, self-organizing adaptive system.

Two signatures of complexity are present:

The patterns are

(1) fractal

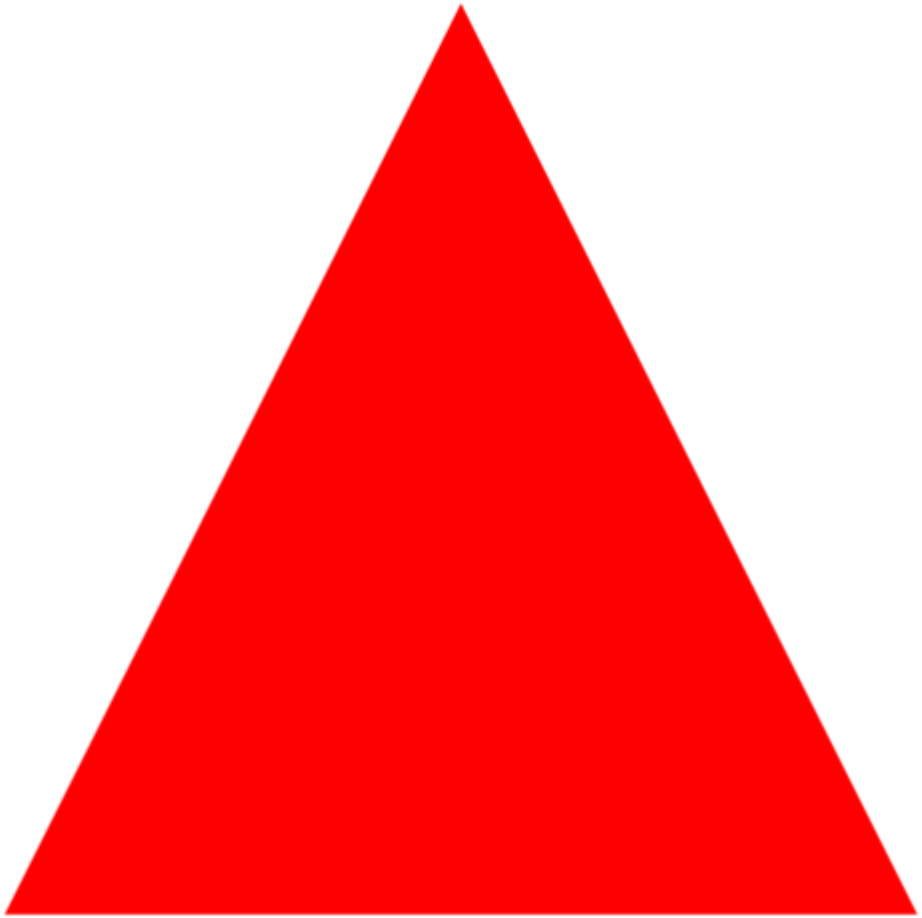
(2) non-deterministic



Fractals

Fractals are very complicated forms that have the same form at all scales.

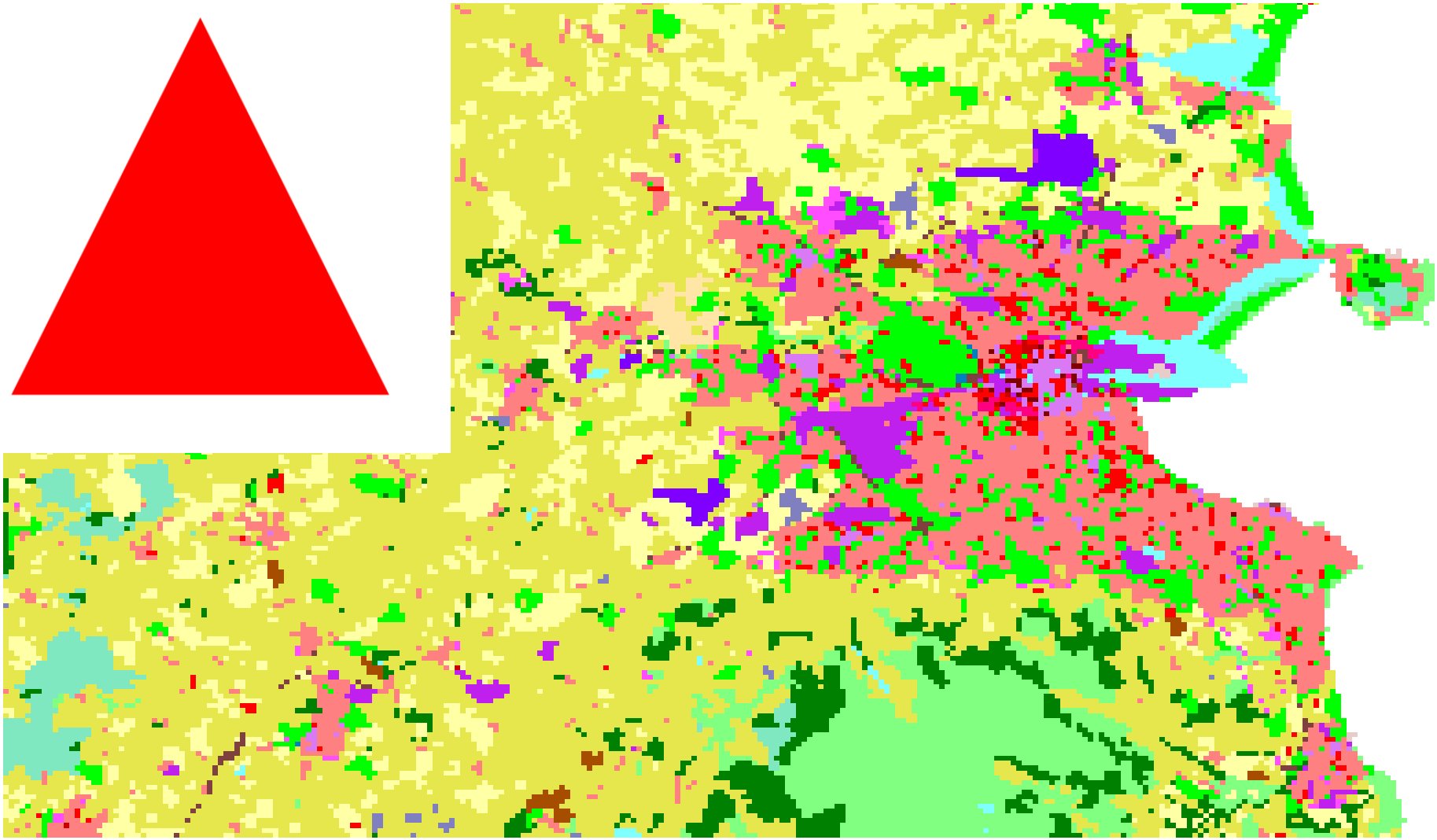
A Mathematical Fractal



Natural Fractals

– a shoreline with many bays
– river systems
– trees
– broccoli

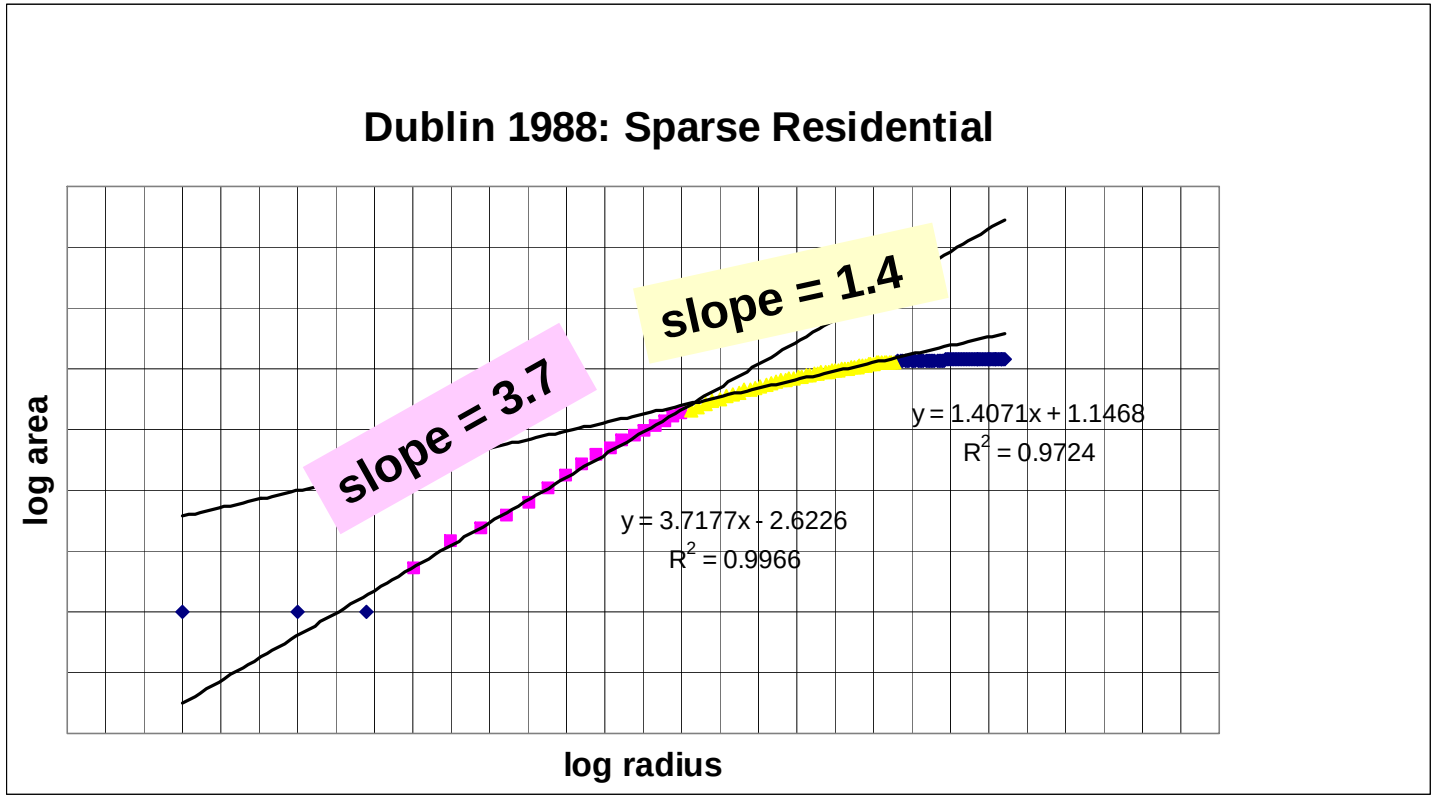
Urban land use patterns are fractals

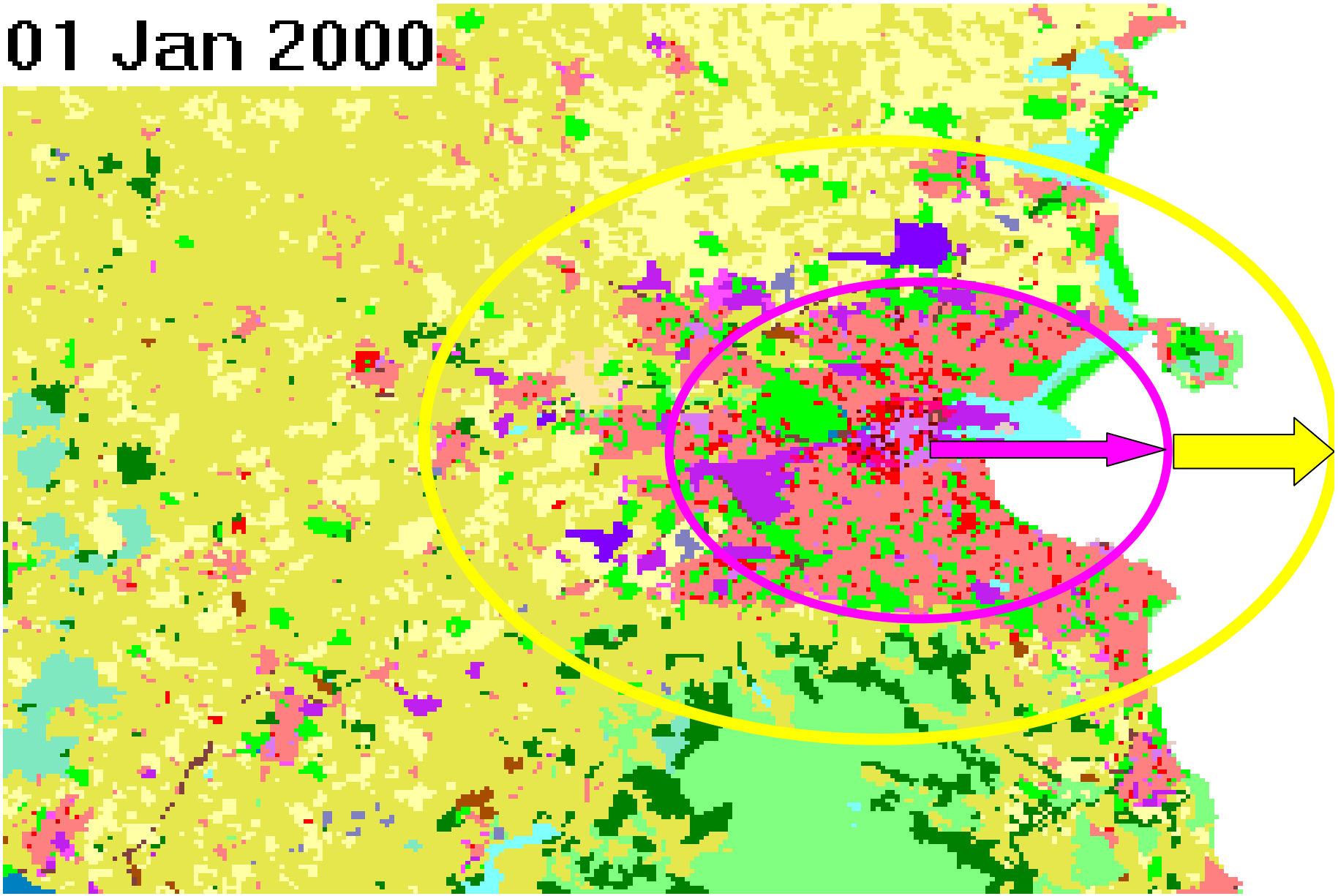


Urban land use patterns are fractals:

- The ***area-radius relationship*** is a bi-fractal.
- The ***cluster size distribution*** is fractal.

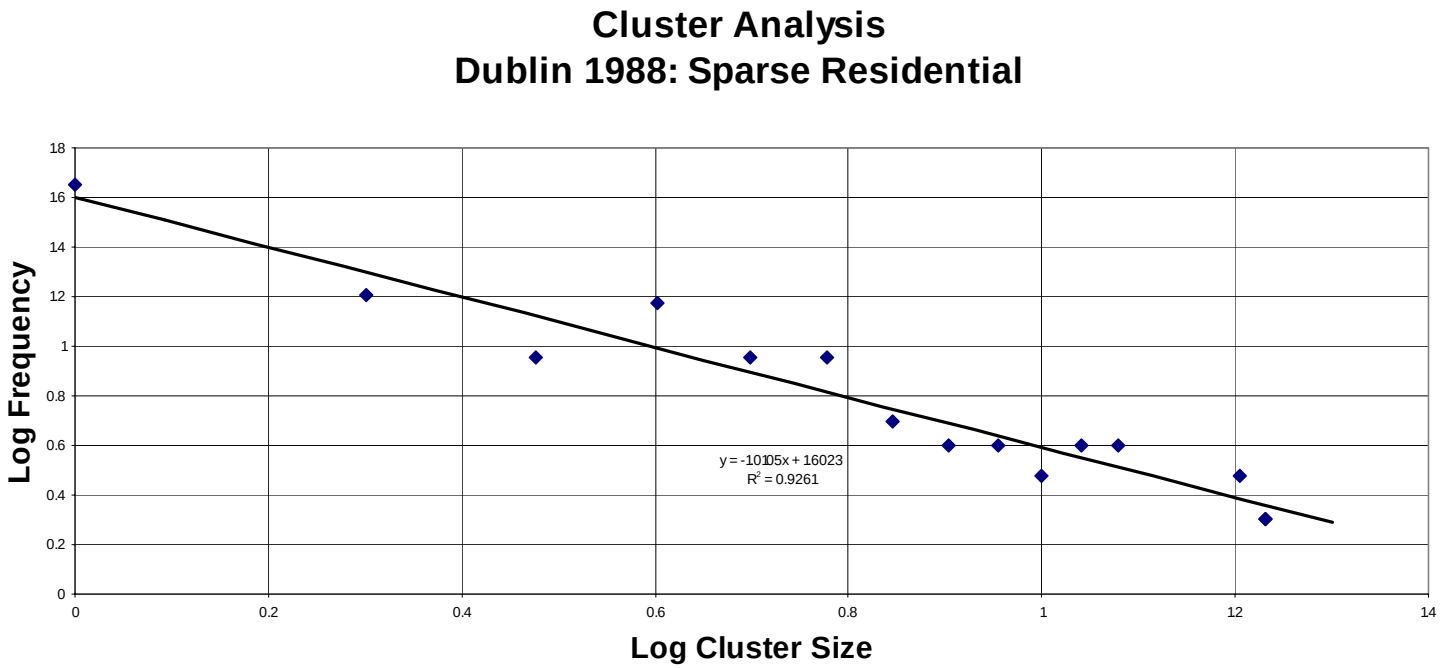
Radial dimension of sparse residential land use: Dublin





Credit: Land Management Unit of the Joint Research Centre of the European Commission

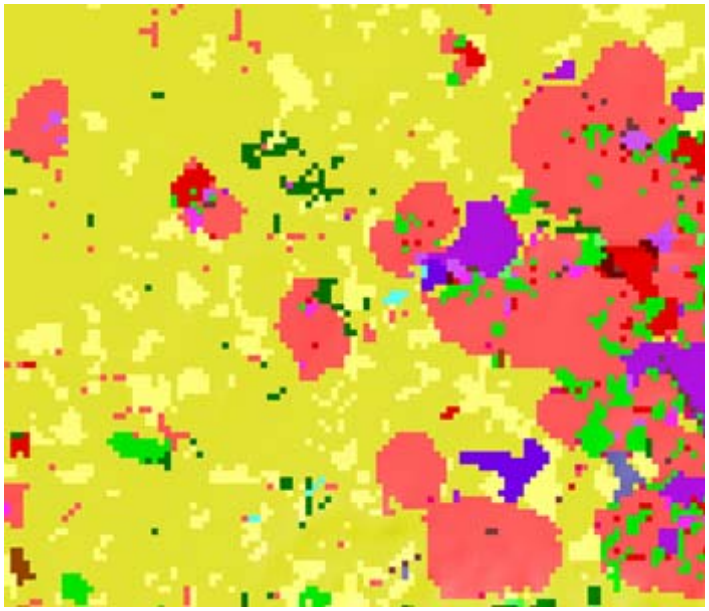
Cluster Size – Frequency Dimension: Dublin,1988, Sparse Residential



Maintaining a linear cluster size – frequency relationship

too few new clusters seeded:

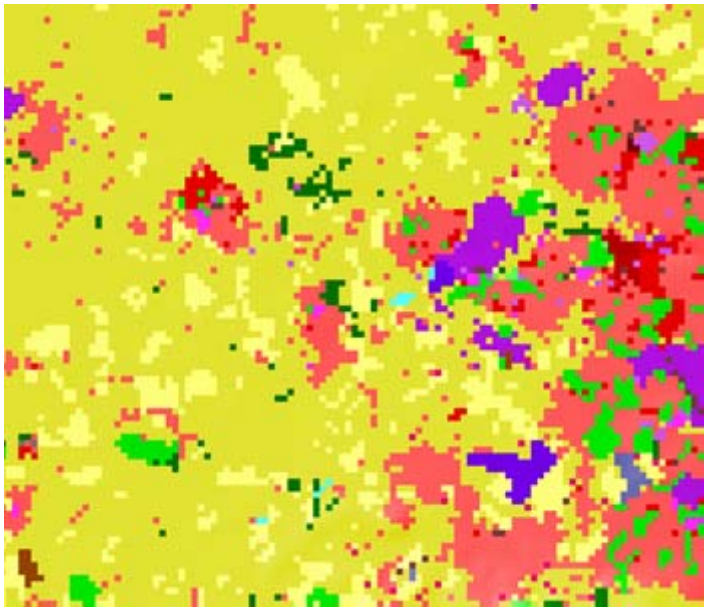
too few small clusters and too many large clusters



Low stochasticity

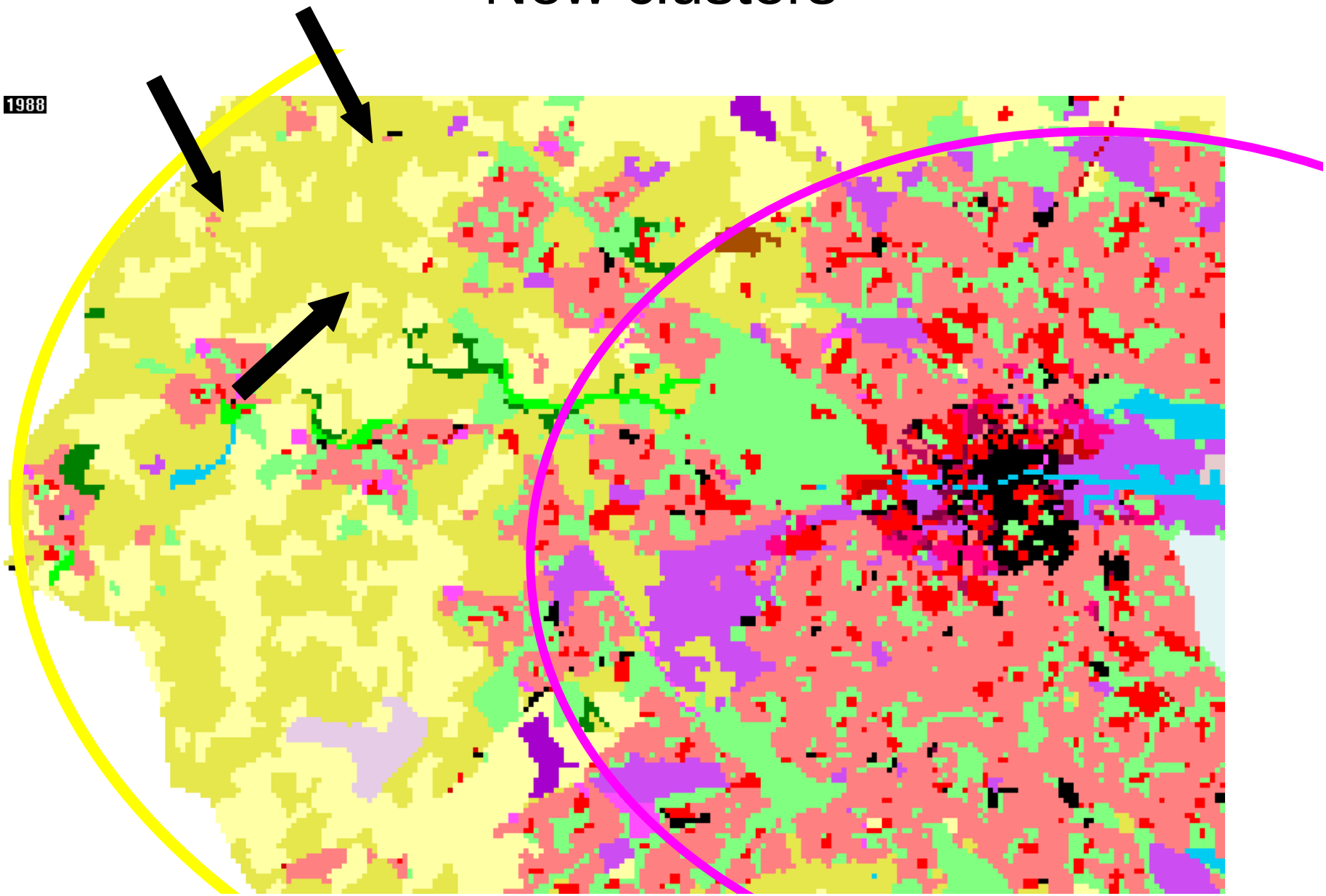
sufficient new clusters seeded:

many small clusters, only a few large clusters



High stochasticity

New clusters



Credit: Land Management Unit of the Joint Research Centre of the European Commission

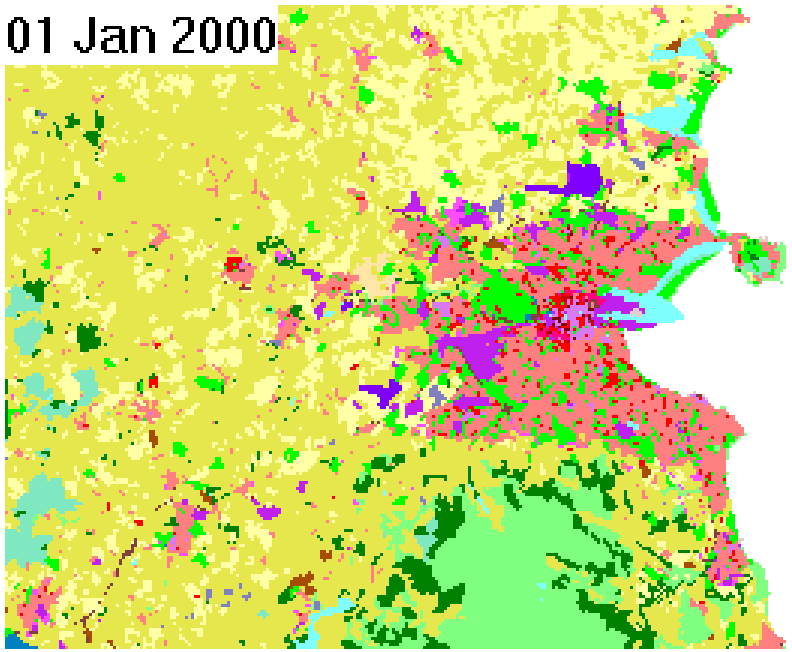
- Cities change in many ways, but these fractal dimensions do not.

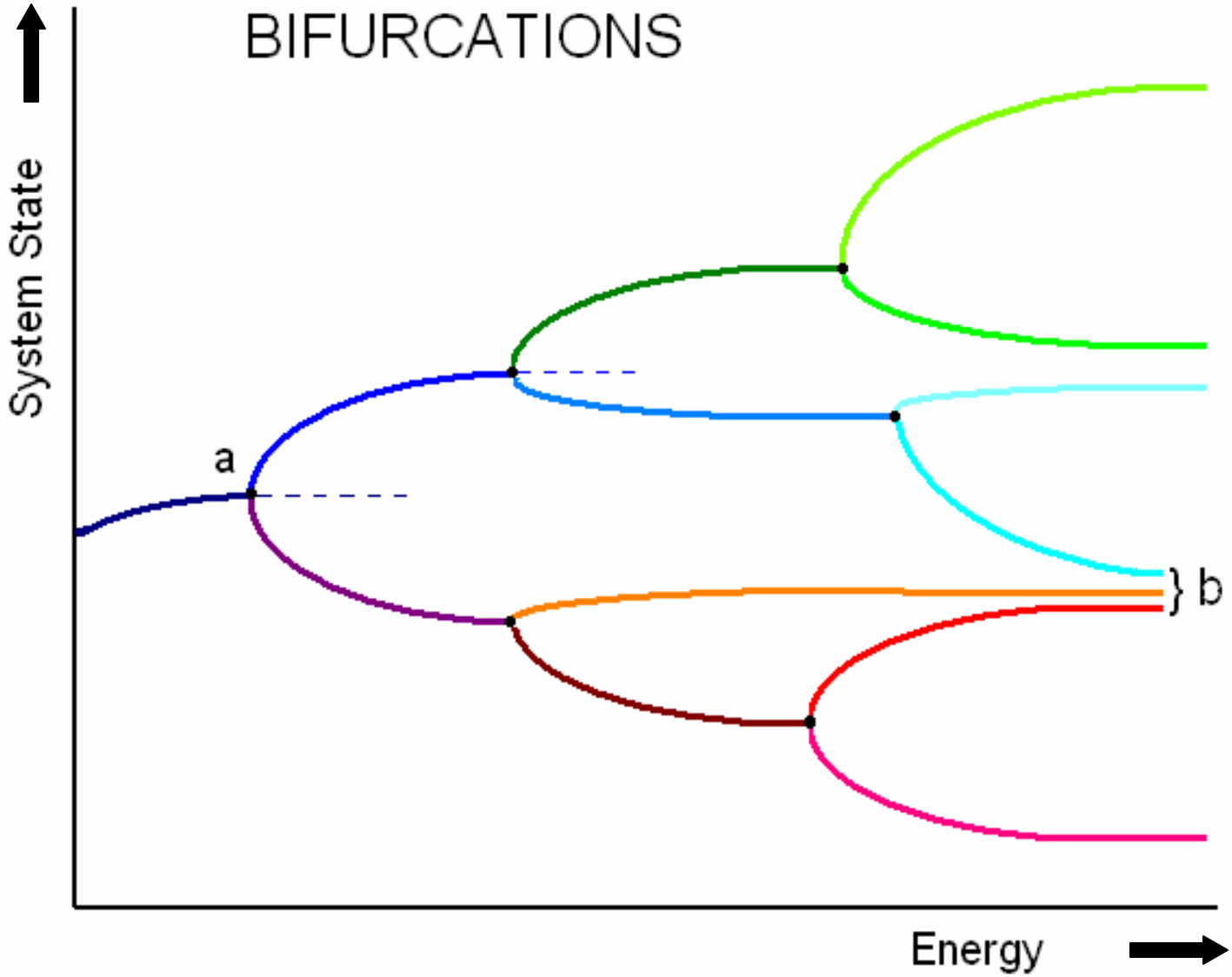
- This gives us confidence in the models that generate them correctly:

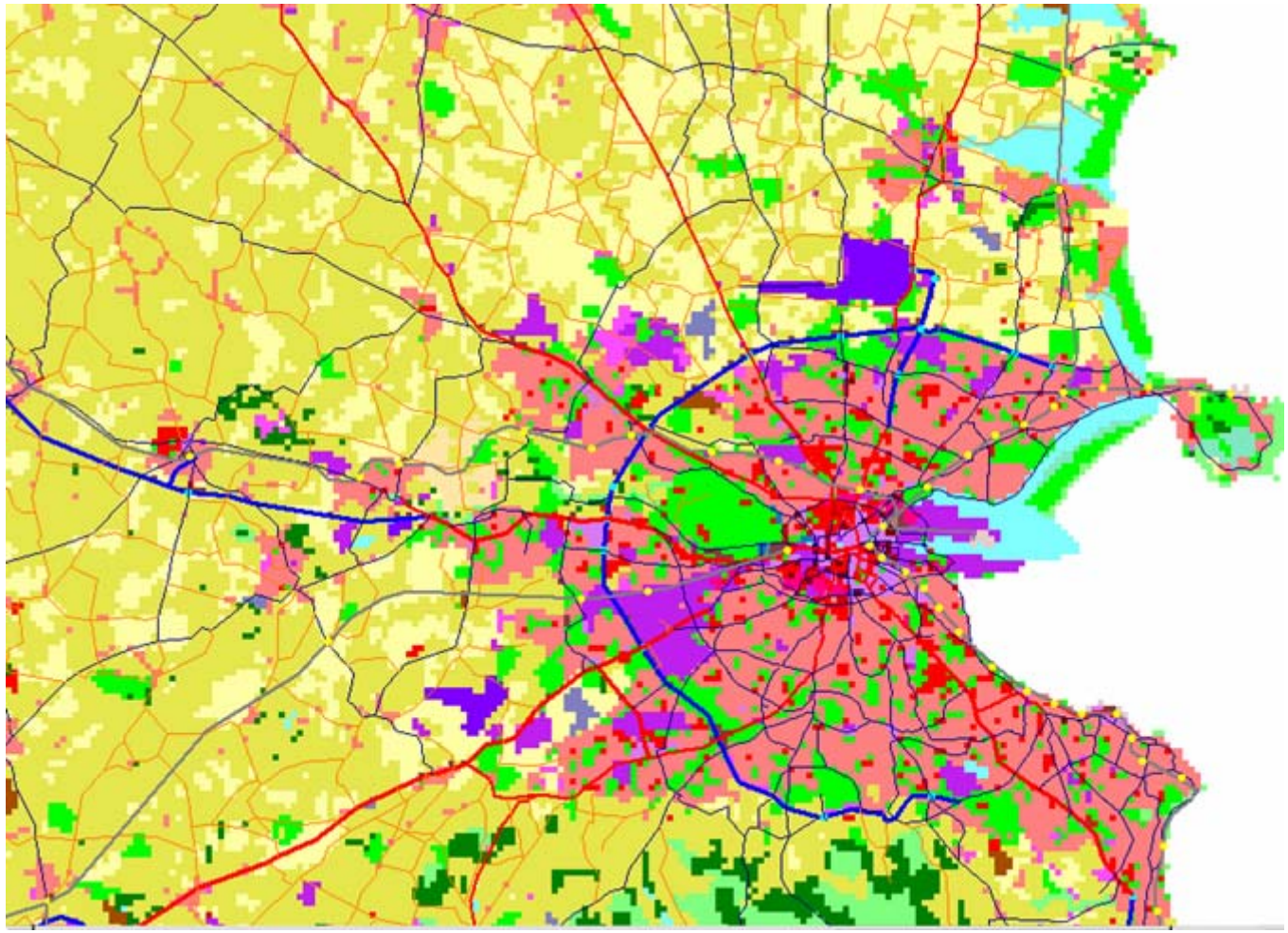
Non-deterministic, open futures

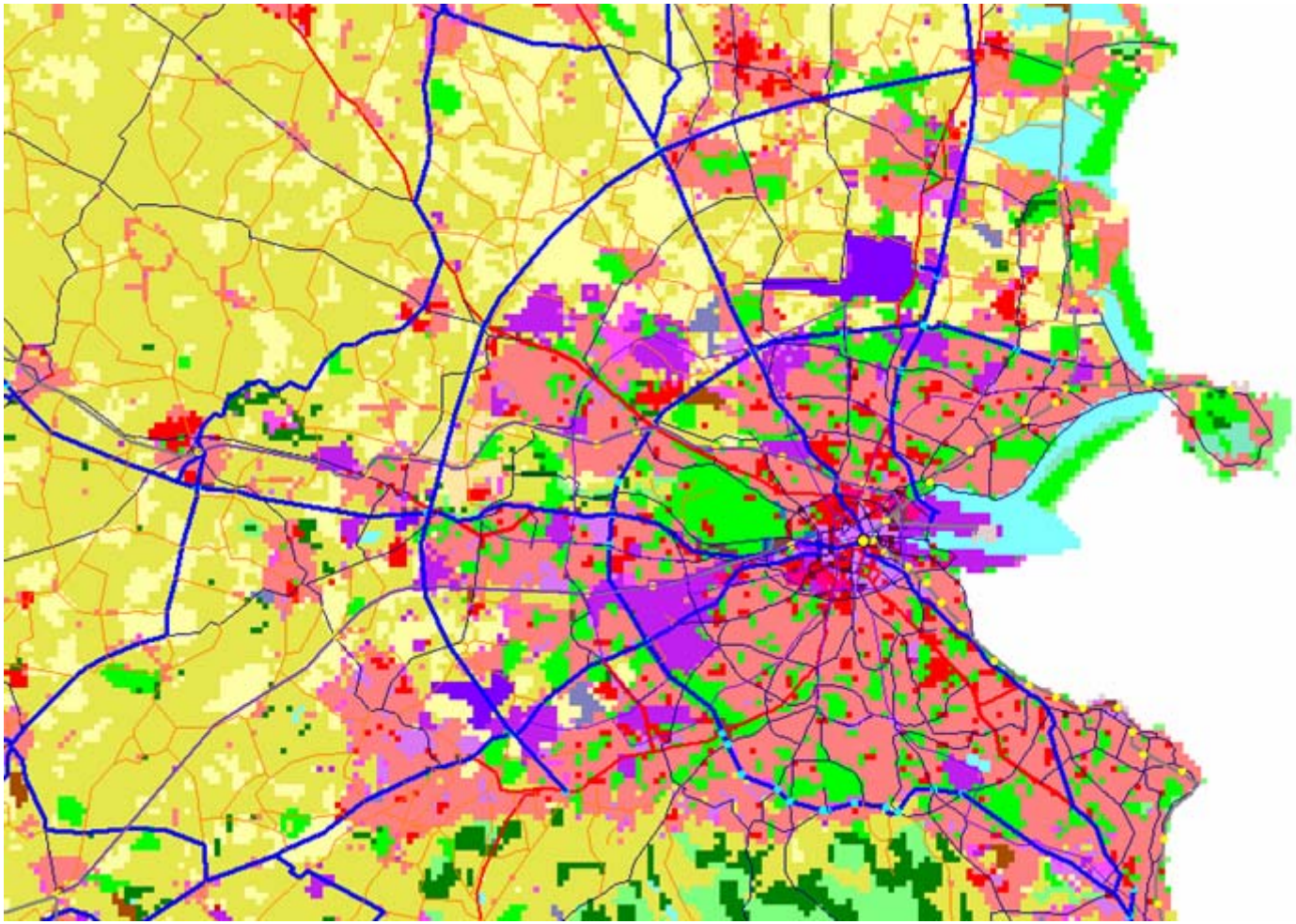
Model outcomes are non-deterministic because of

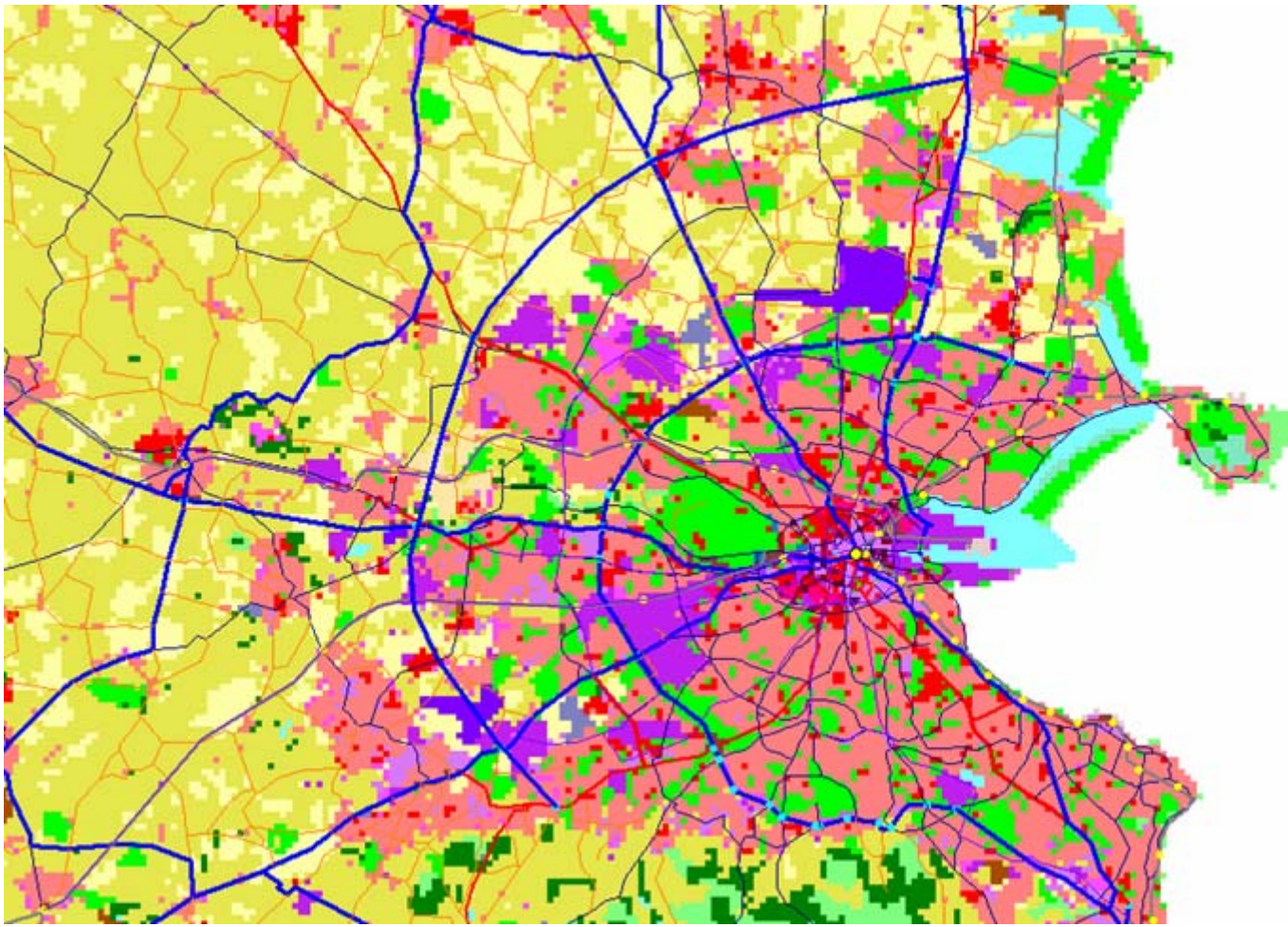
- stochastic perturbation
- non-linearity




BIFURCATIONS
System State
a
} b
Energy

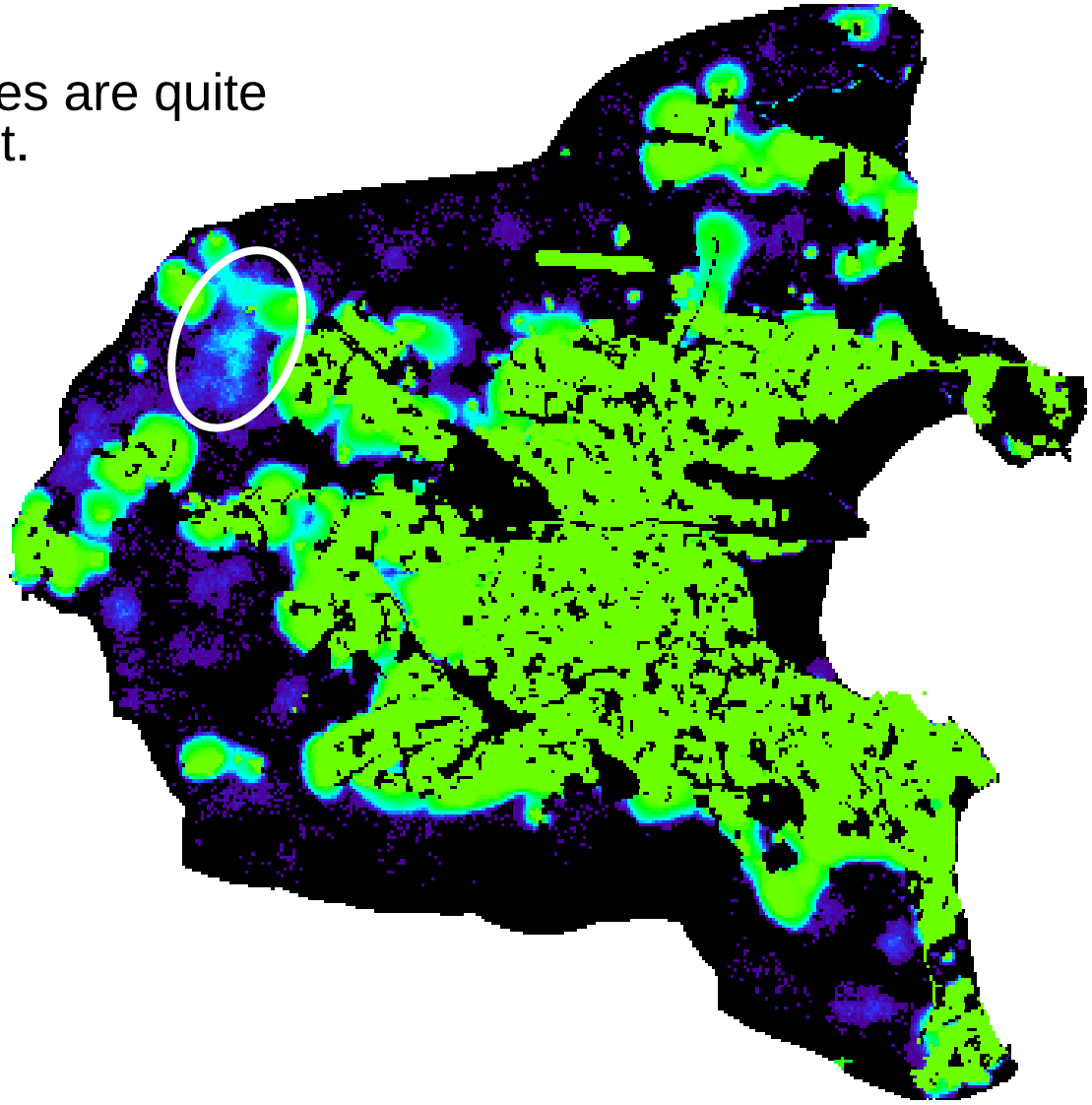






Ten year Probability of Urban Development

Some areas at some times are quite predictable; others not.



Higher probability

Lower Probability

Non-deterministic, open futures:

For both models and actual cities,

- Outcomes are non-deterministic because of
  - stochastic perturbations
  - non-linearity

- Some areas at some times are quite predictable; others not.

- General features like fractal dimensions are predictable.

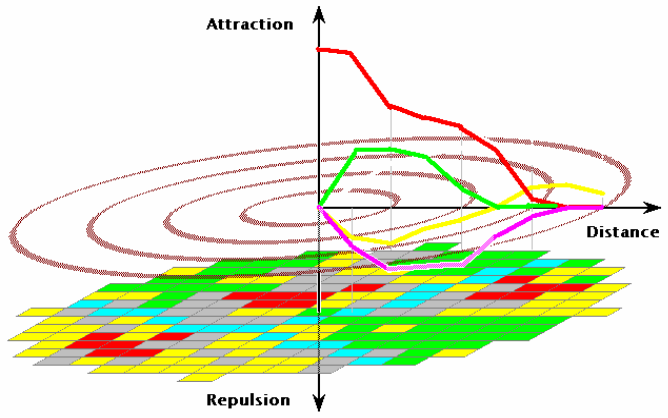
Universality

Are the processes generating urban and regional structure universal?

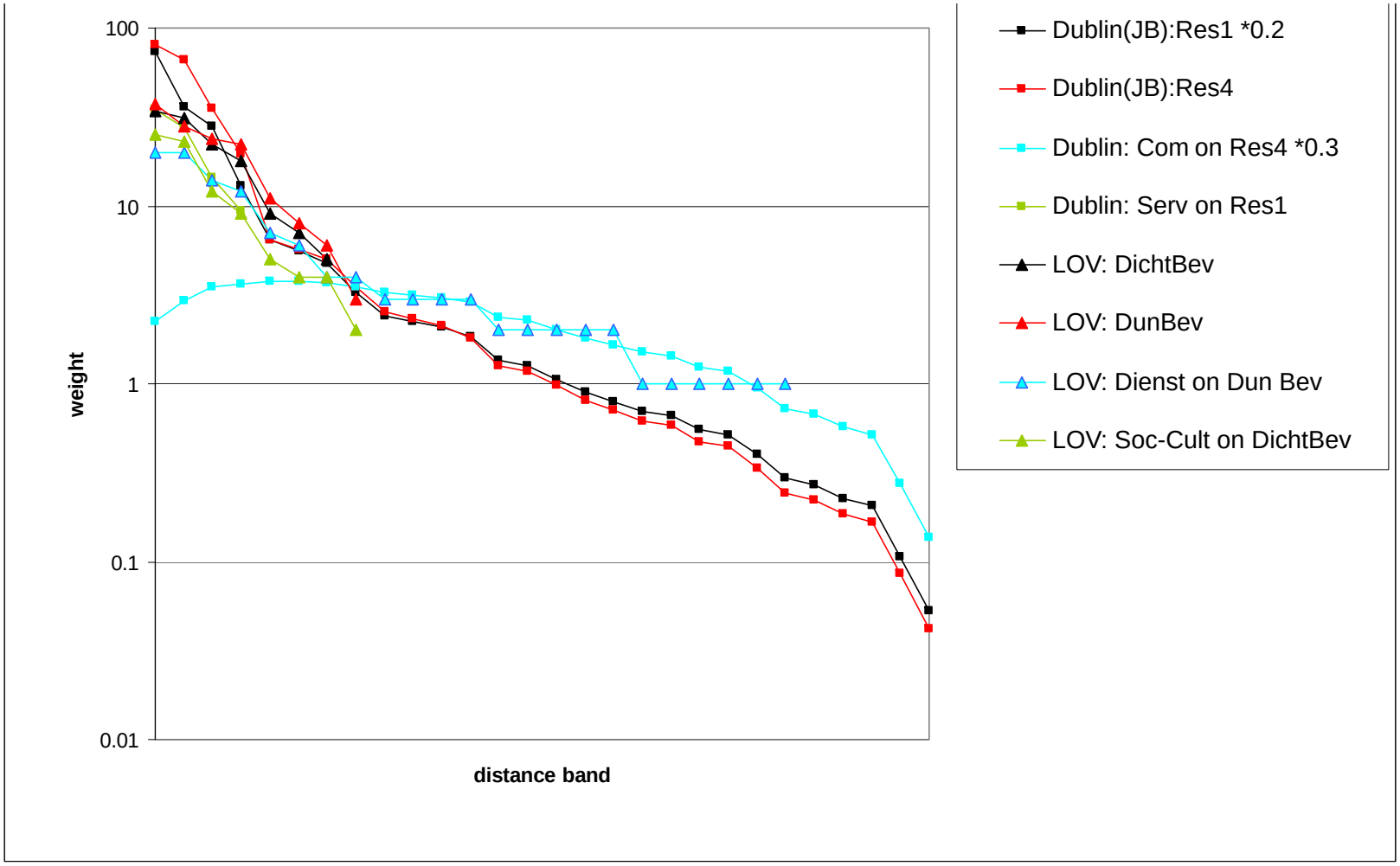
- The same model can be successfully applied to
  - different places
  - different scales.

- The calibrated parameter values tend to be very similar in the different applications.

- In particular the calibrated weights for evaluating the neighbourhood are similar across applications.



Selected neighbourhood weights for residential land uses Dublin and The Netherlands



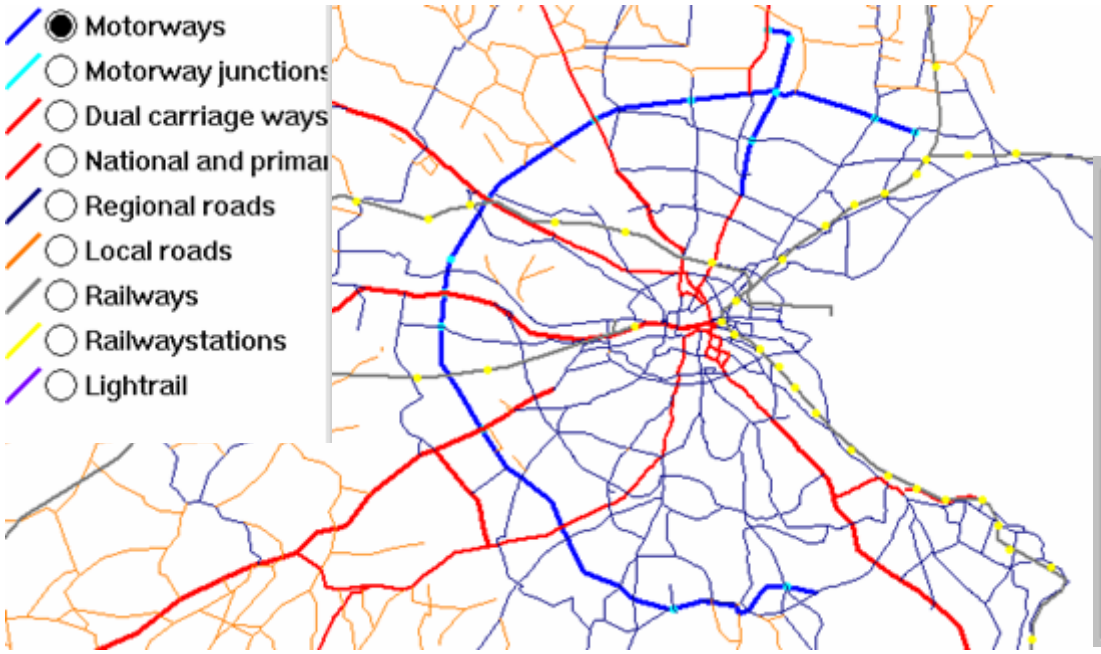
Applications

Use the models to experiment with the future:

- Explore various scenarios
- Test policy and planning options before they are implemented

Network Accessibility

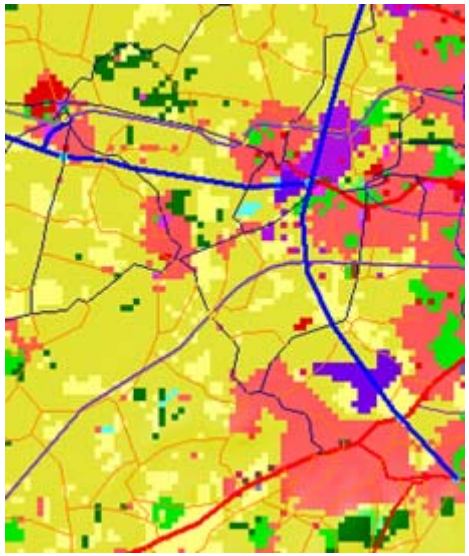
- Network weighting parameters
- Accessibility parameters



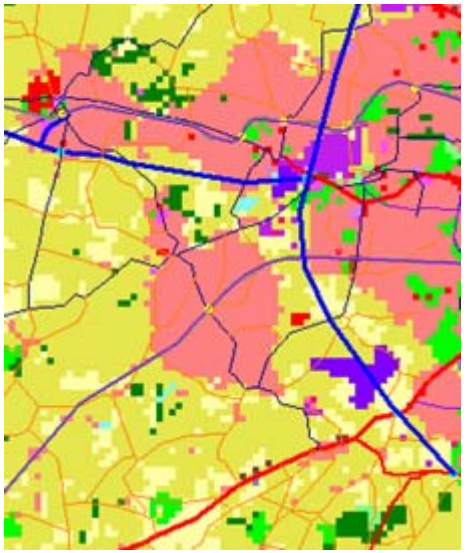
Accessibility to links and nodes

	Relative importance	Distance decay
Motorways	0.3	15
Motorway junctions	1	15
Dual carriage ways	1	15
National and primary routes	1	10
Regional roads	1	0.5
Local roads	1	0.5
Railways	0	0
Railwaystations	1	10
Lightrail	0.3	10

Changing the relative importance of network elements will shift land use toward the favoured elements:

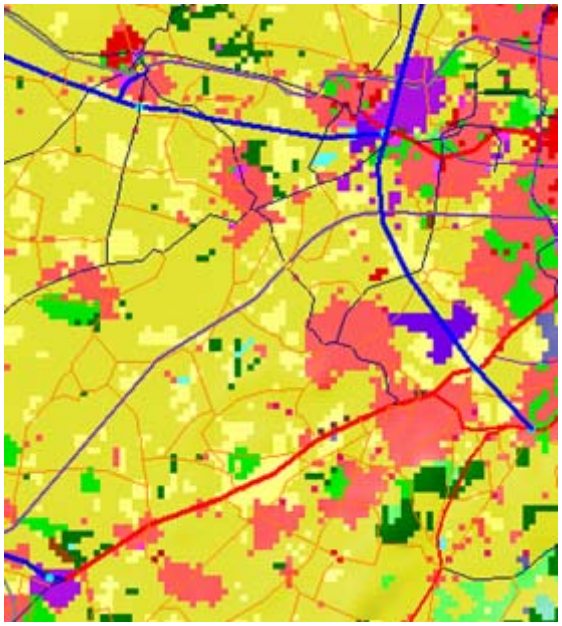


Roads important

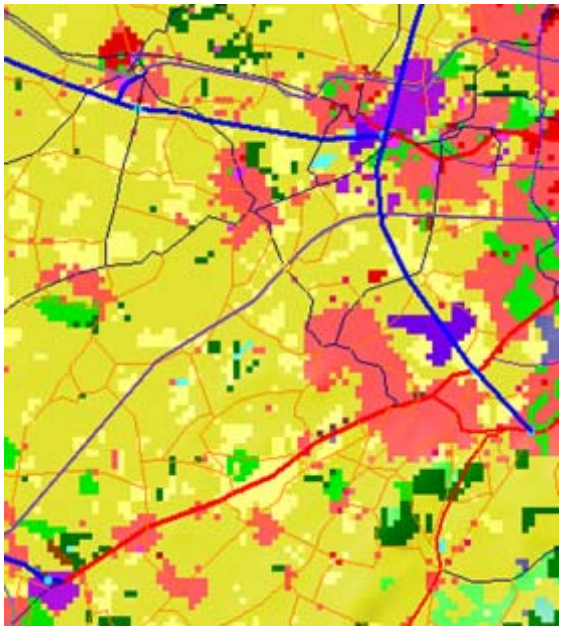


Rail important

Changing the desirability of access to the network will change locational patterns

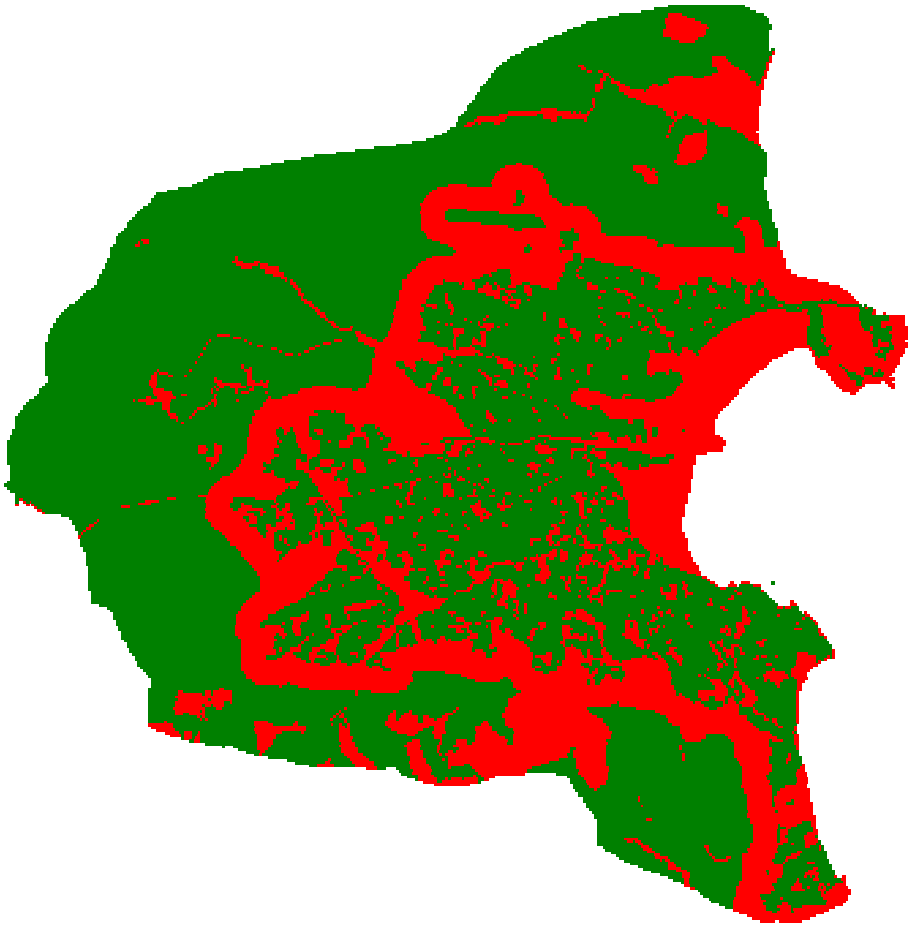


Lower desire to be near major roads



Higher desire to be near major roads

Greenbelts

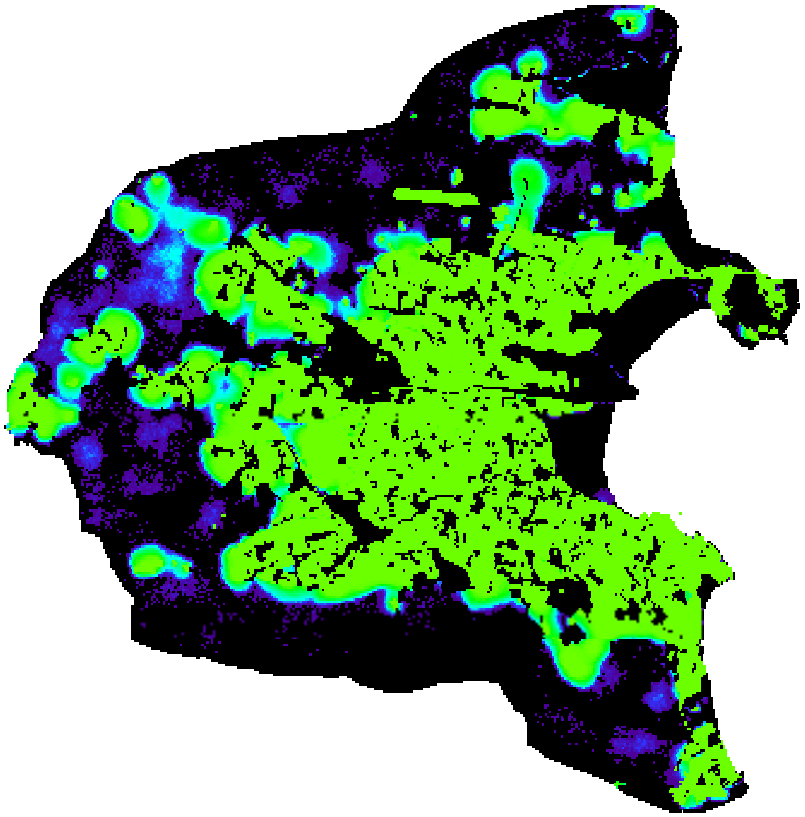


- Around existing urban land uses
- Around the City of Dublin only

Existing Urban Land / Free Establishment

Establishment Forbidden

Probability map of urban land uses: No Planning Constraints

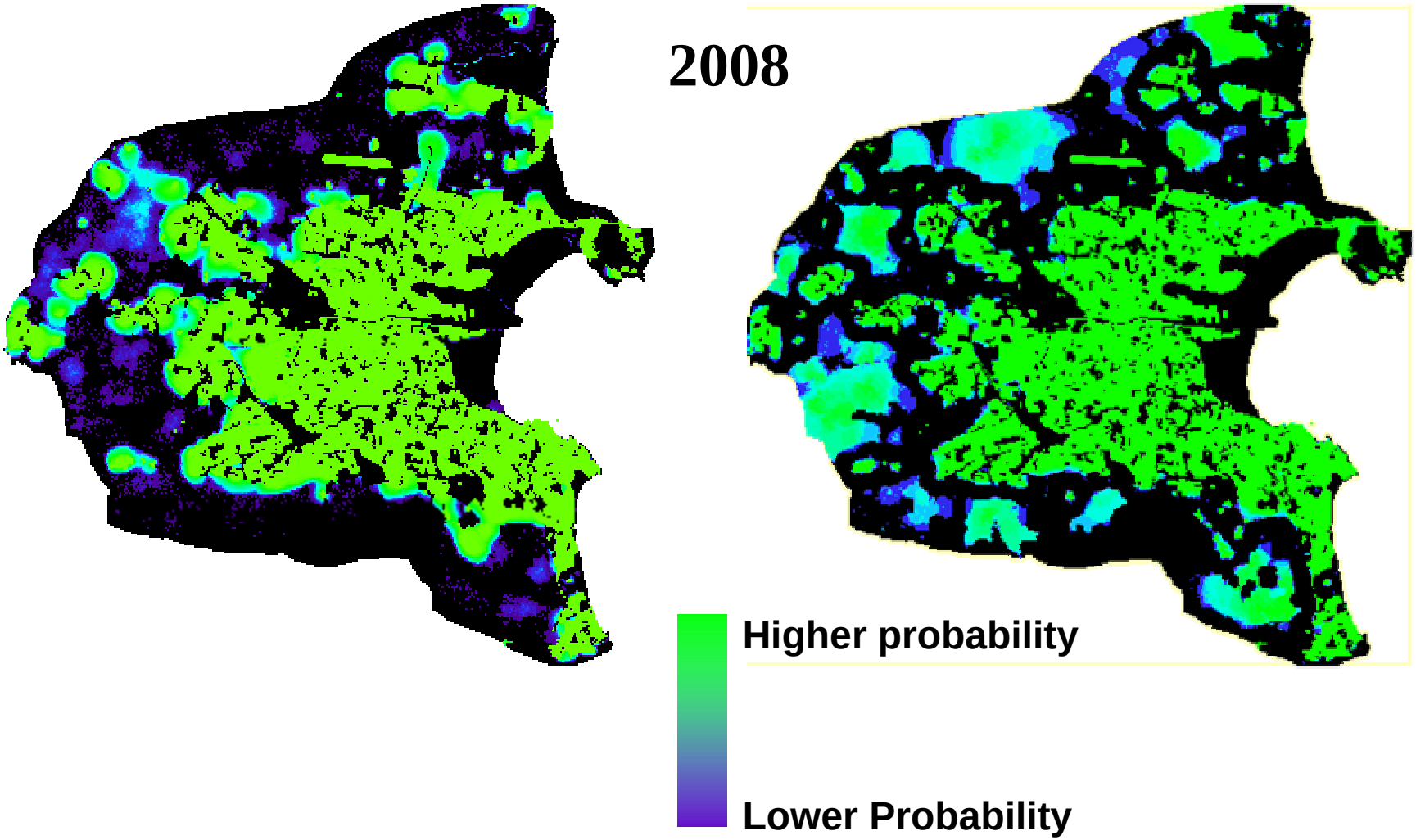


2008

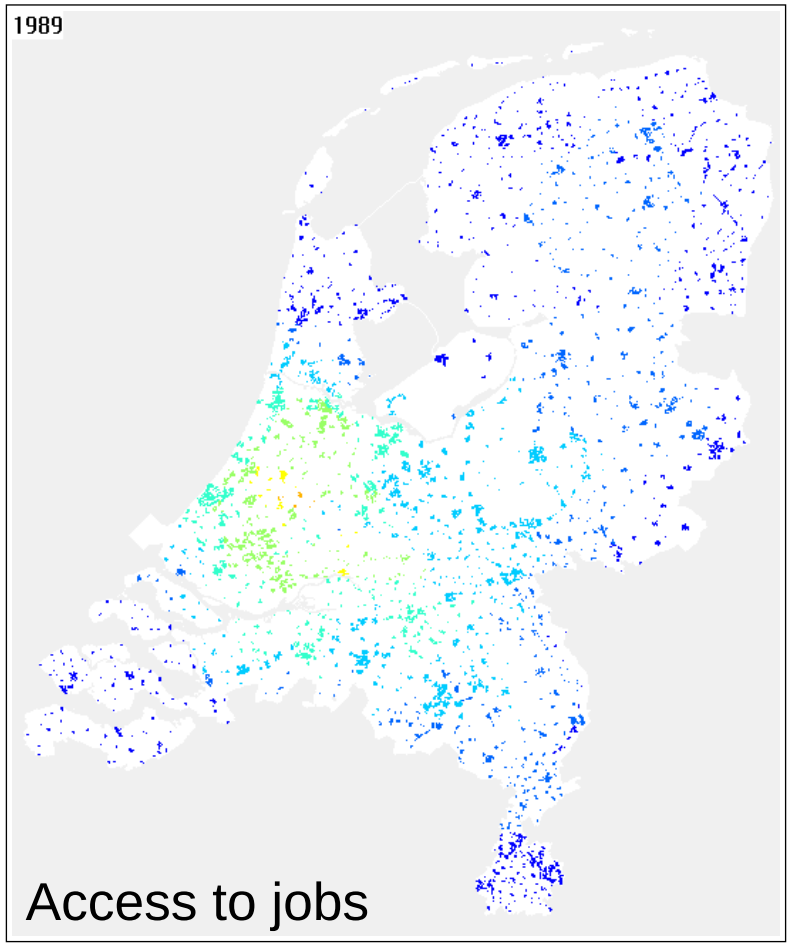
Higher probability

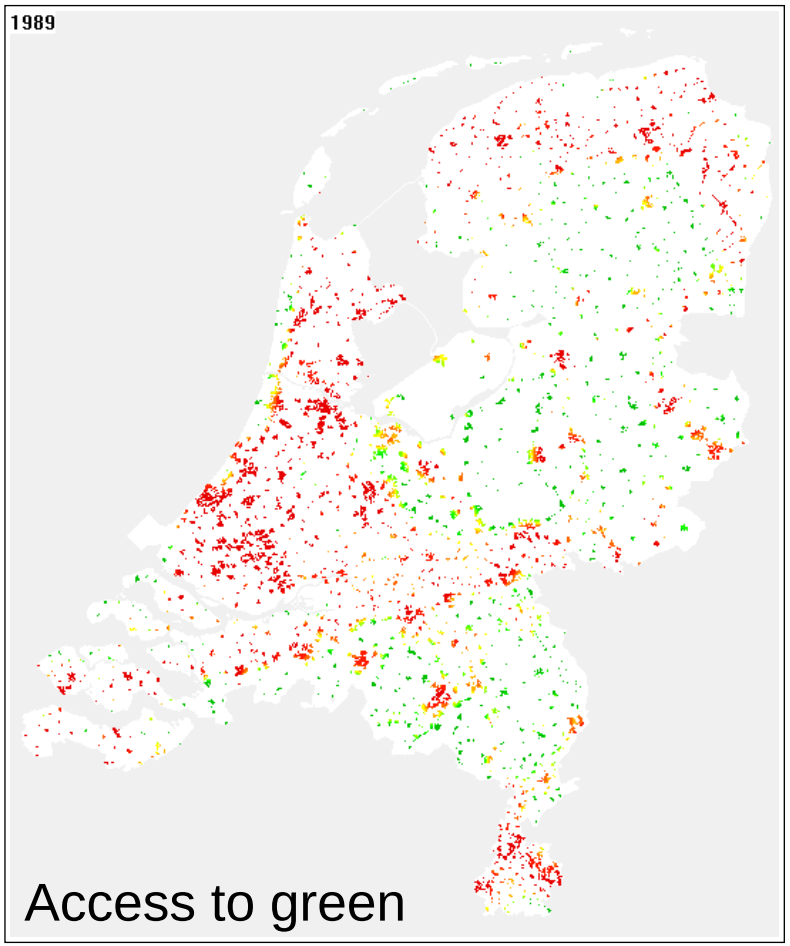
Lower Probability

No Planning Constraints *versus* Greenbelt Scenario

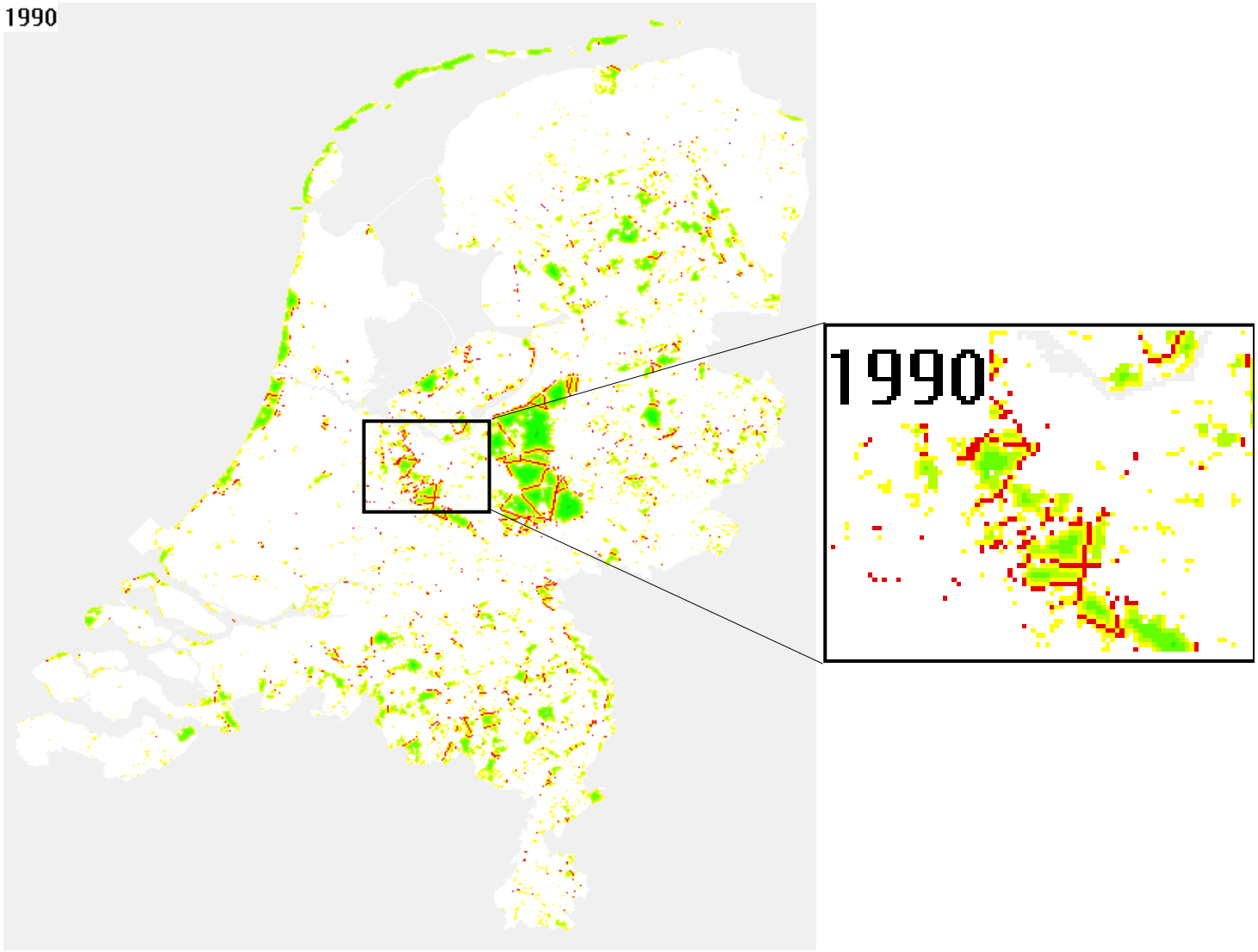


Various indicators are calculated from the land use and activity output.





These are dynamic



habitat fragmentation index

Conclusions

- A city is constantly creating and re-creating itself.
- Complexity theory based modeling can help us understand this process.
- The models are also a tool for experimenting with various possible futures for the city.

Thank You