Understanding Cities and Regions As Complex Self-organizing Systems

Roger White

Memorial University of Newfoundland, Canada

roger@mun.ca

1.

The science of complex self-organizing systems:

The end of certainty

A Very Brief History of Science

- Conservative systems
  (*e.g. planetary motions*) — NEWTON
- Equilibrium or entropy maximizing systems
  (*e.g. classical thermodynamics*) — BOLTZMANN
- Far-from-equilibrium systems
  (*e.g. the earth's atmosphere, life, human society*) — PRIGOGINE
- Evolutionary systems
  (*e.g. life, human society*) — DARWIN

A Very Brief History of Science

- Conservative systems
  (*e.g. planetary motions*)
- Equilibrium or entropy maximizing systems
  (*e.g. classical thermodynamics*)

Successful law based science

- Far-from-equilibrium systems
  (e.g. the earth's atmosphere, life, human society)
- Evolutionary systems
  (e.g. life, human society)

A Very Brief History of Science

- Conservative systems
  (*e.g. planetary motions*)
- Equilibrium or entropy maximizing systems
  (*e.g. classical thermodynamics*)
- Far-from-equilibrium systems
  (e.g. the earth's atmosphere, life, human society)
- Evolutionary systems
  (e.g. life, human society)

Science that doesn't seem quite "scientific"

A Very Brief History of Science

- Conservative systems

  (*e.g. planetary motions*)

- Equilibrium or entropy maximizing systems

  (*e.g. classical thermodynamics*)

- Far-from-equilibrium systems

  (e.g. the earth's atmosphere, life, human society)

- Evolutionary systems

  (e.g. life, human society)

BOLTZMANN

PRIGOGINE

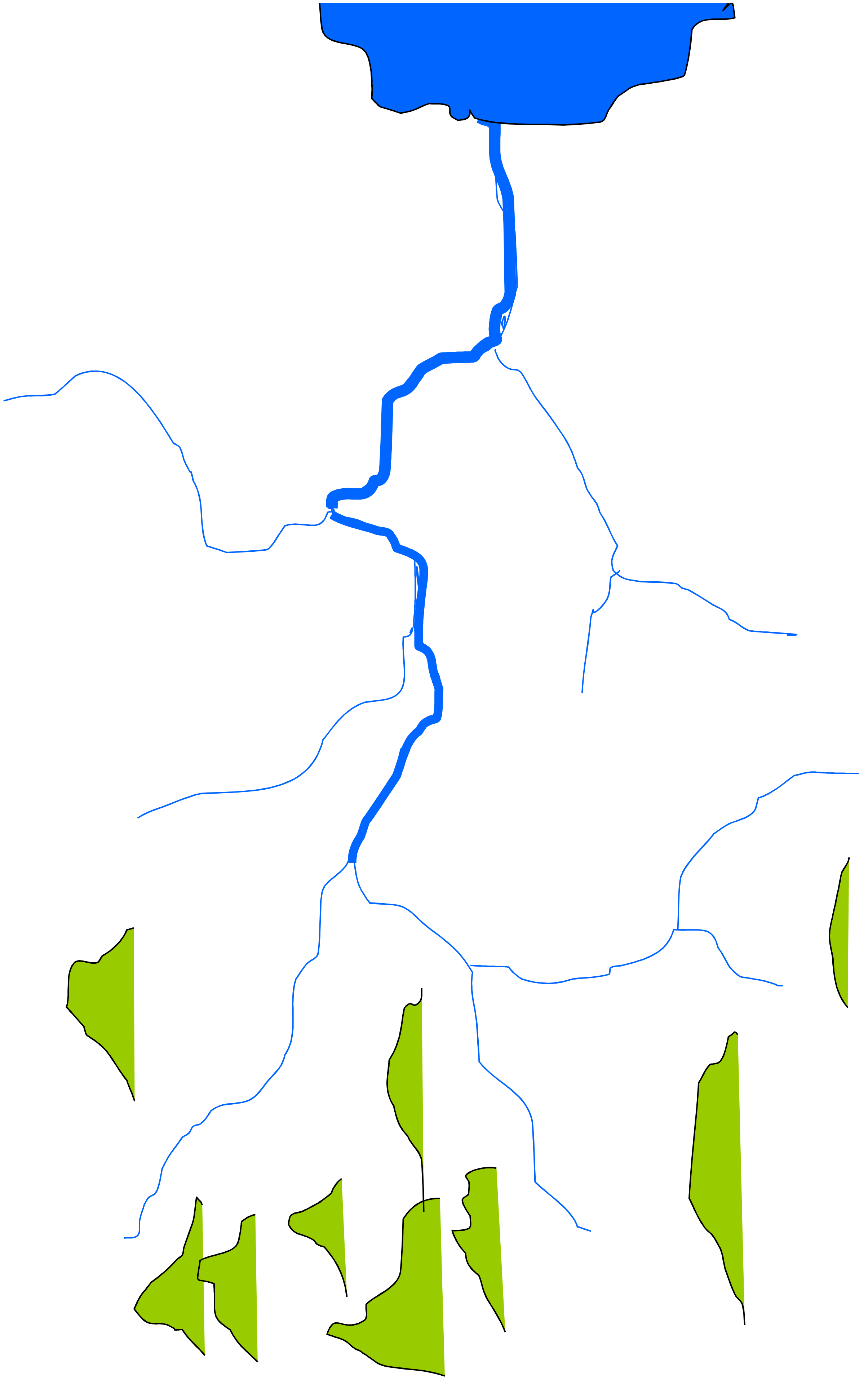
Thermodynamics: the science of our world

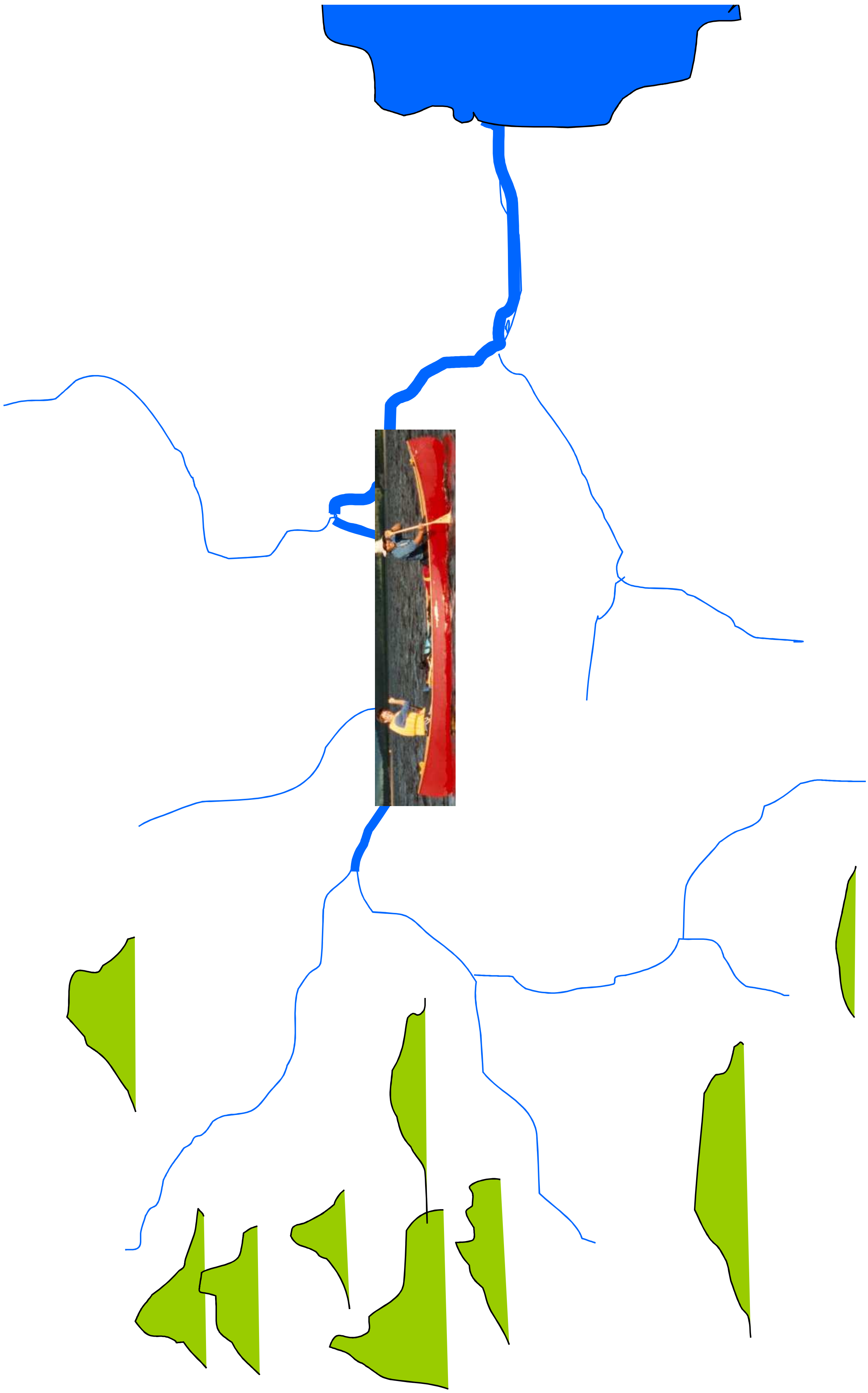
- Equilibrium or entropy maximizing systems (*classical thermodynamics*)

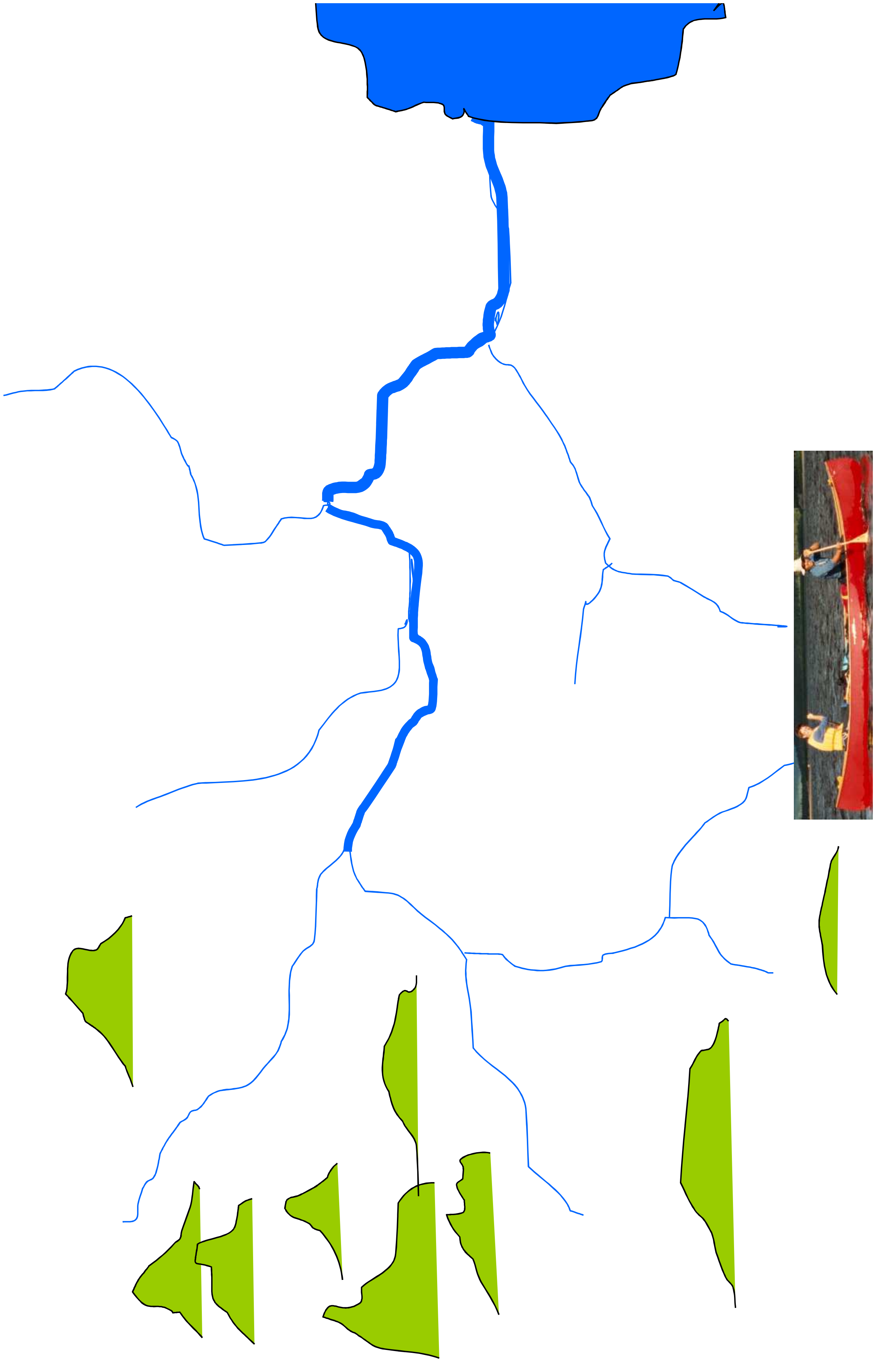
BOLTZMANN

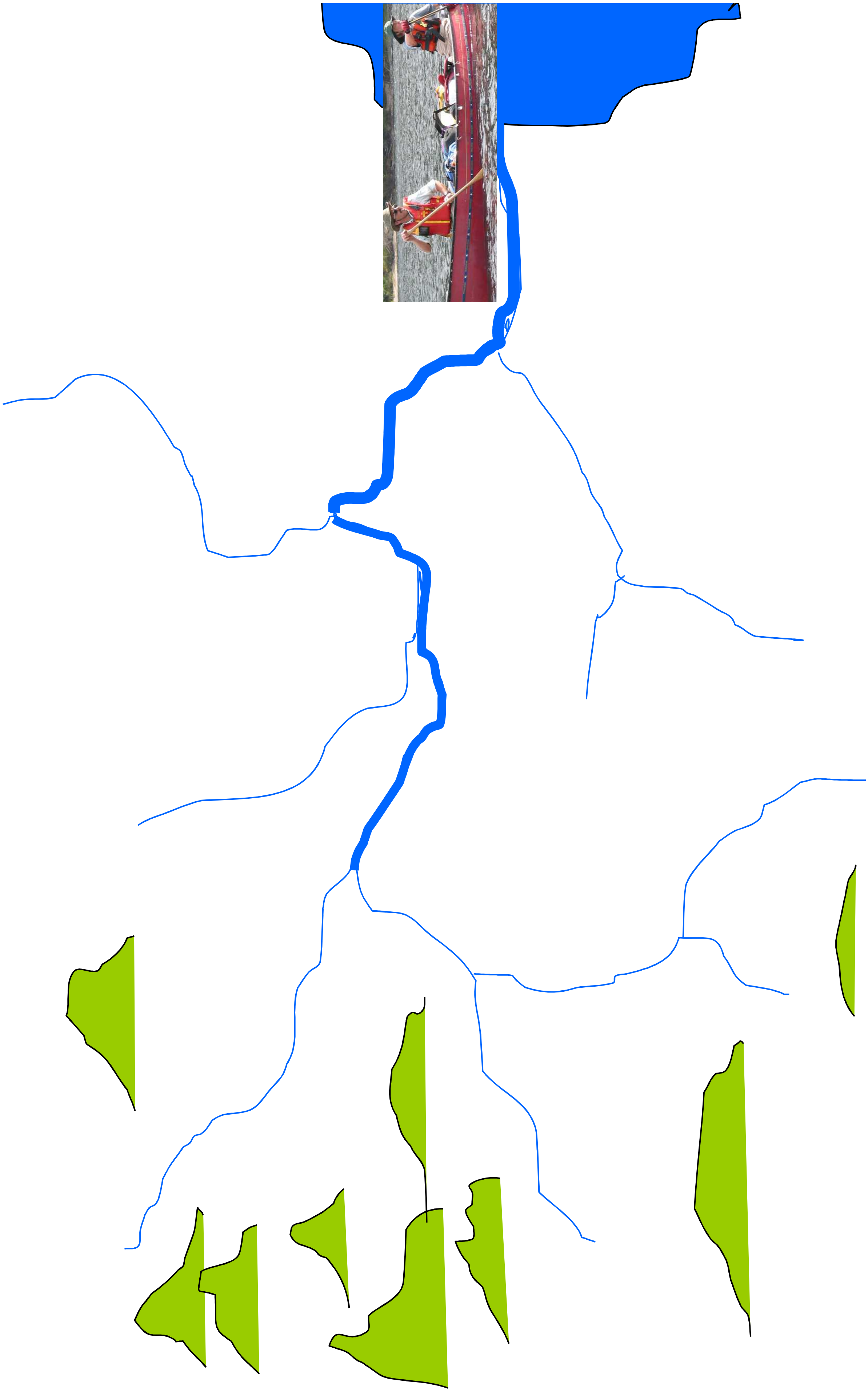
- Far-from-equilibrium systems
  (e.g. the earth's atmosphere, life, human society)

PRIGOGINE



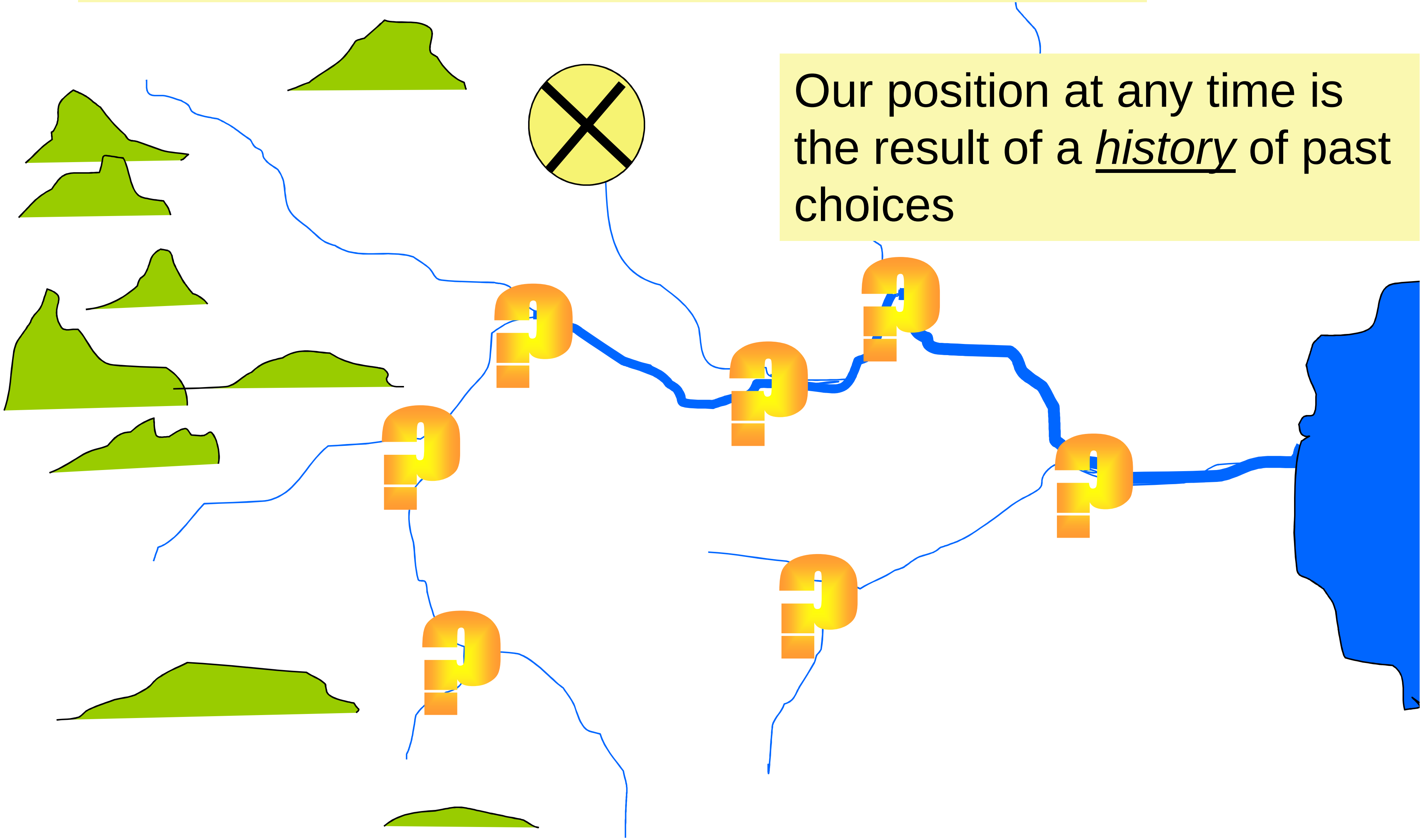






Chance, or *choice* or *context* determines the direction at each fork.

Our position at any time is the result of a *history* of past choices



Whether we go downstream or upstream, we are looking at the same system.

But the science is different. There is no law of upstream behaviour.

In equilibrium systems,

history is eliminated.

In far-from-equilibrium systems

—*i.e. self-organizing systems*—

history is generated.

There are many possible histories

--i.e. there are many possible futures

Far-from-equilibrium systems must generally be represented by algorithms, because algorithms can generate alternative futures:

i.e. they can *generate history*.

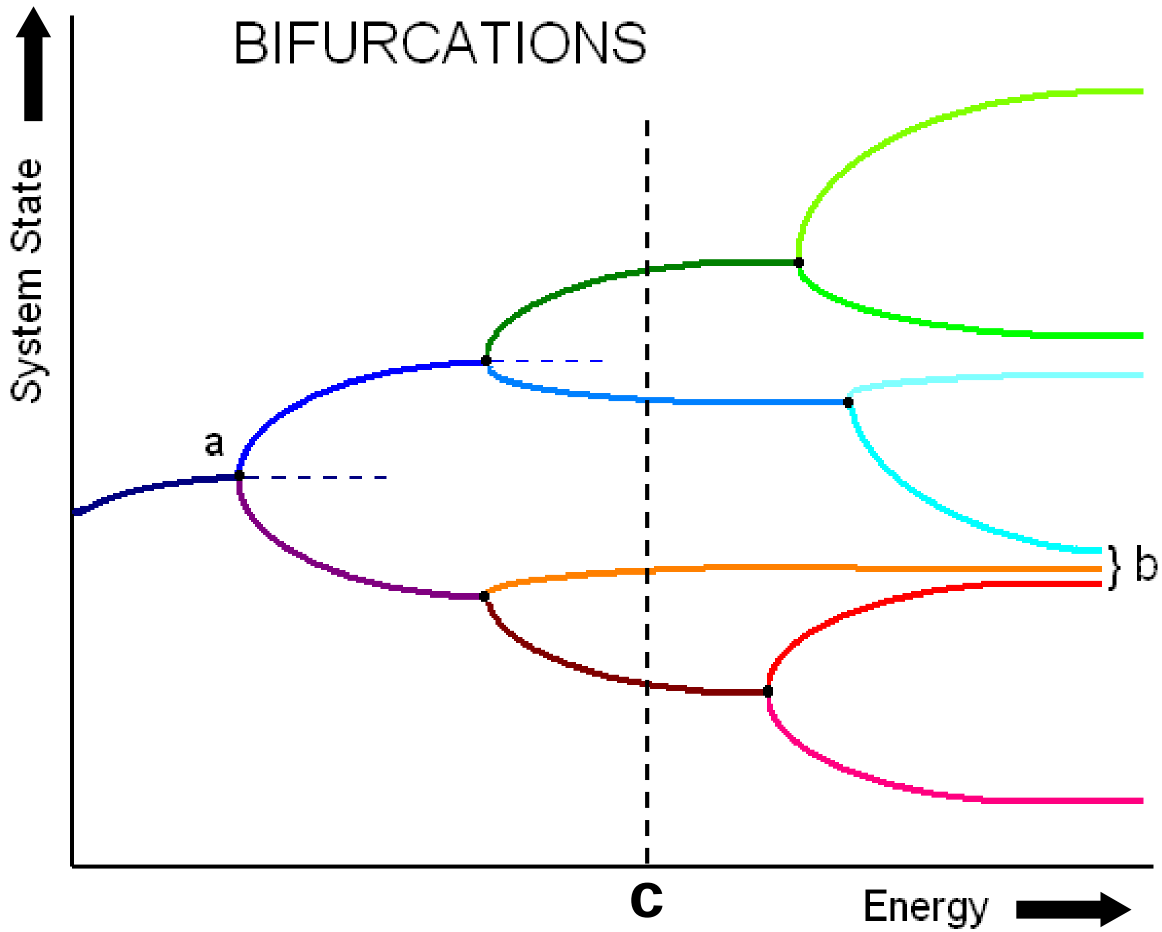
An algorithm is a performance.

It can only exist in time.

To see what it does, we must participate in its performance.

Non-deterministic, open futures

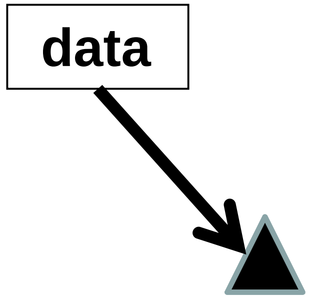
Bifurcations are the mathematical representation of the river system



Problem:

Orthodox science says that theories must be tested by comparing a prediction with an observation.

Validation

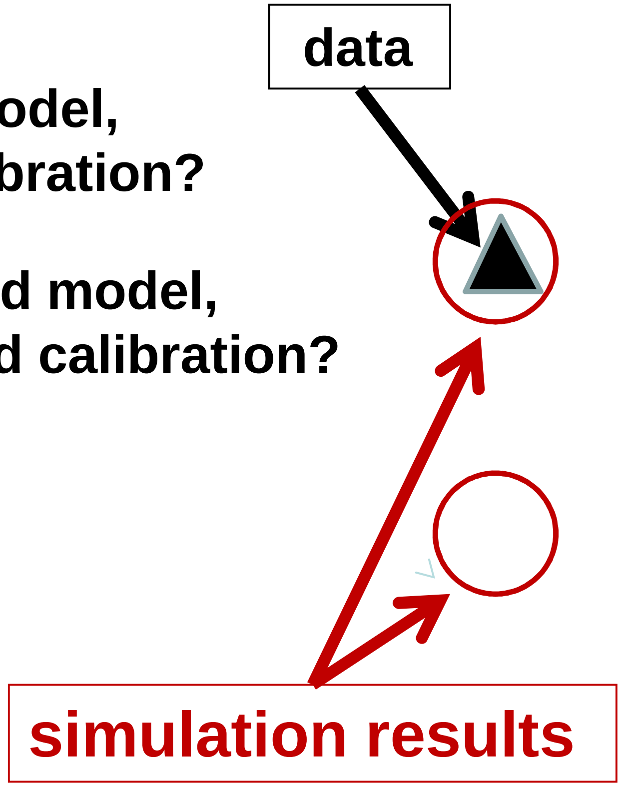


Validation

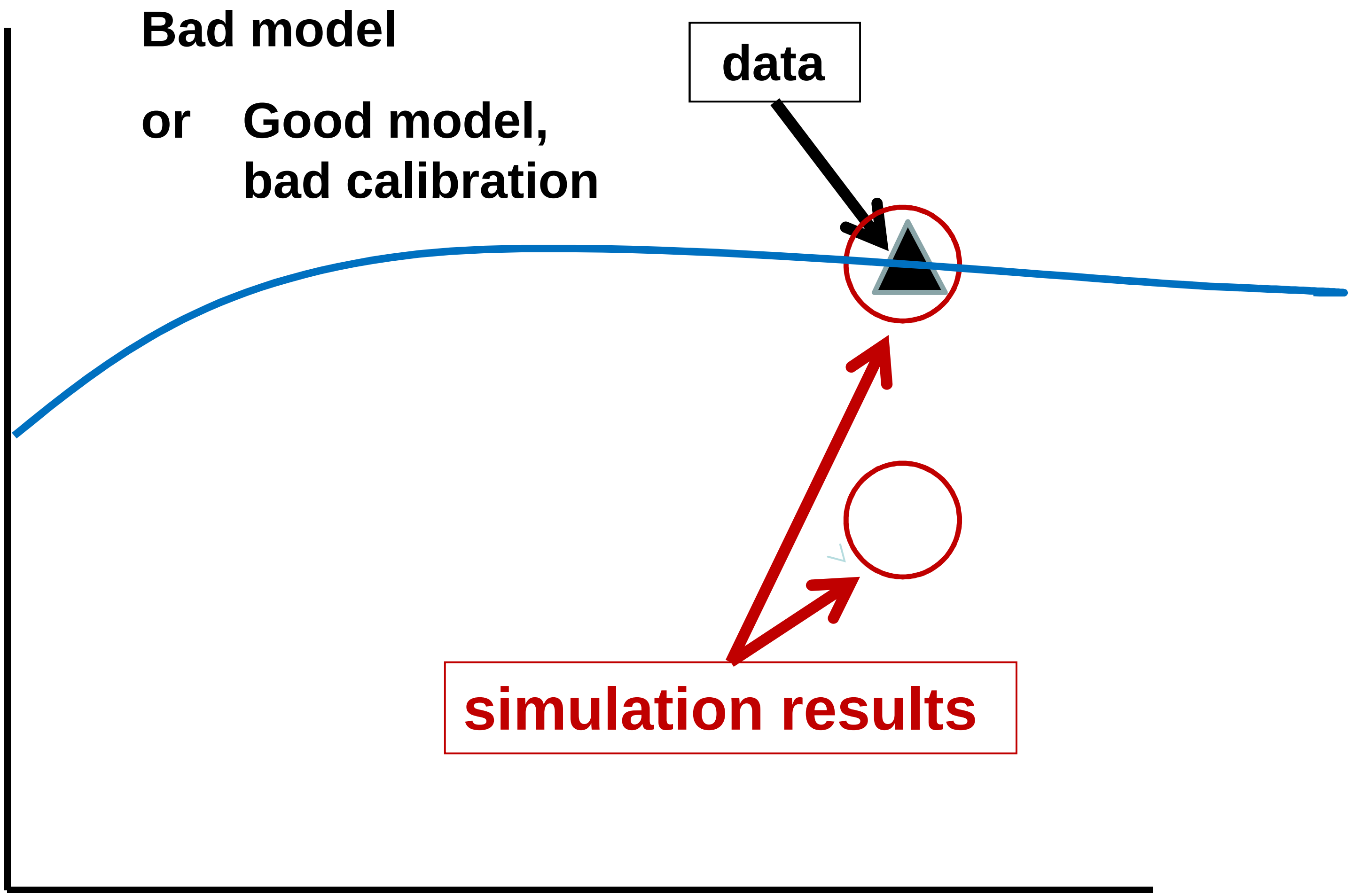
Bad model?

Good model,
bad calibration?

Good model,
good calibration?

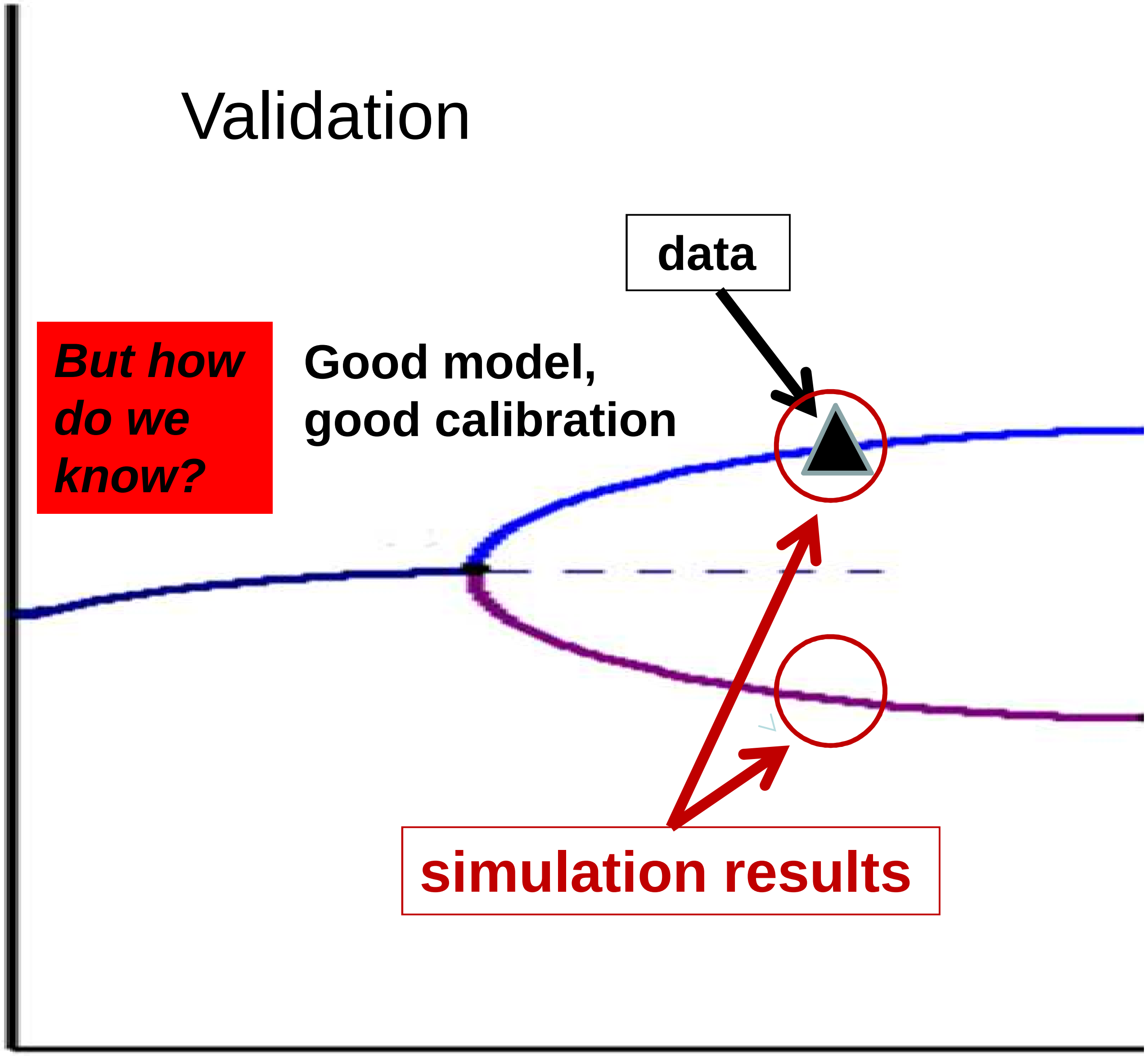


Validation



Bad model
or Good model,
bad calibration
data
simulation results

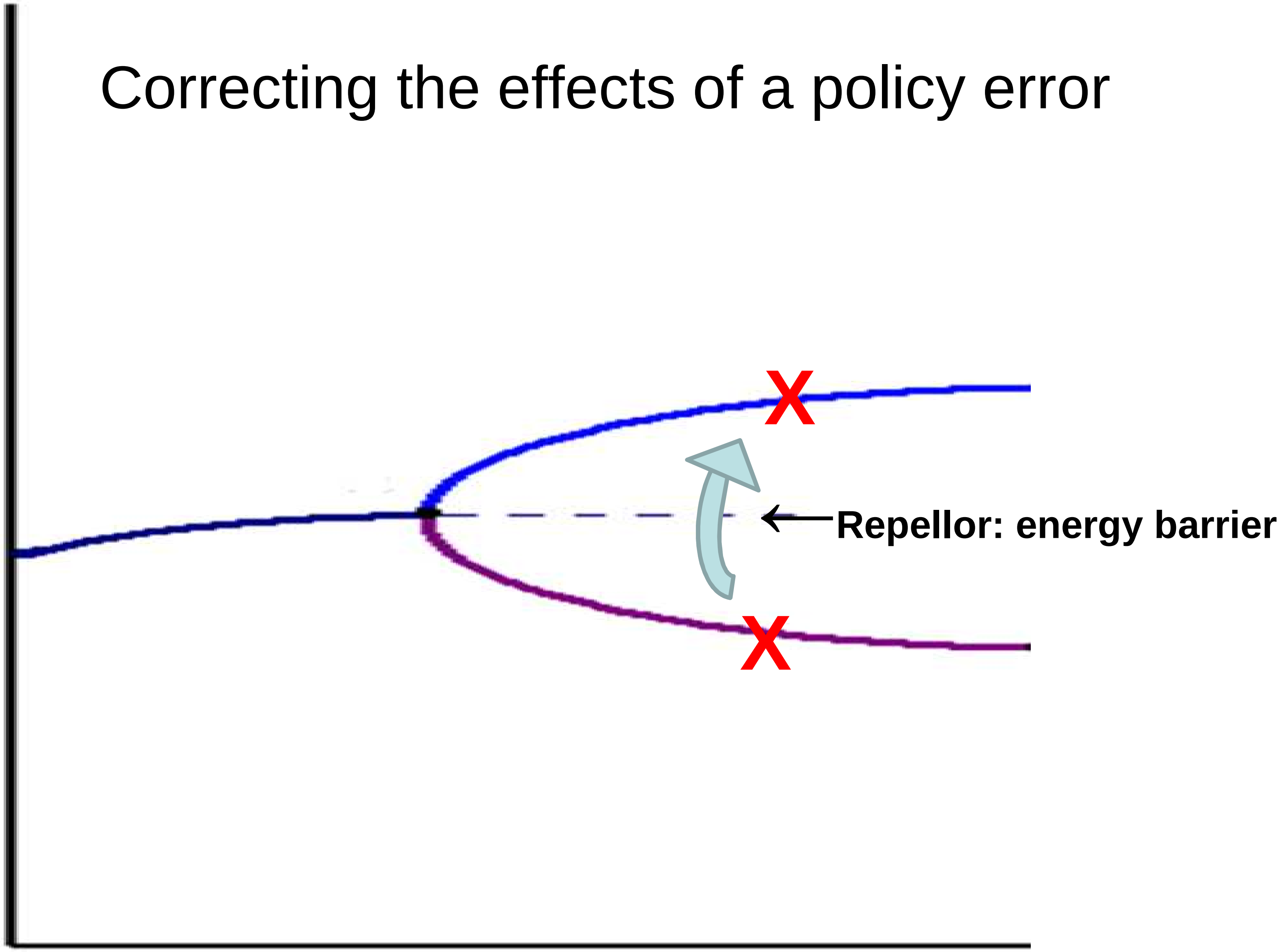
Validation


But how do we know?
Good model,
good calibration
data
simulation results

A model of a system with bifurcations is hard test.

A major role of an open-systems model is to allow us to anticipate approaching bifurcations.

Correcting the effects of a policy error



Klaus Kinski in Werner Herzog's *Fitzcarraldo*

2.

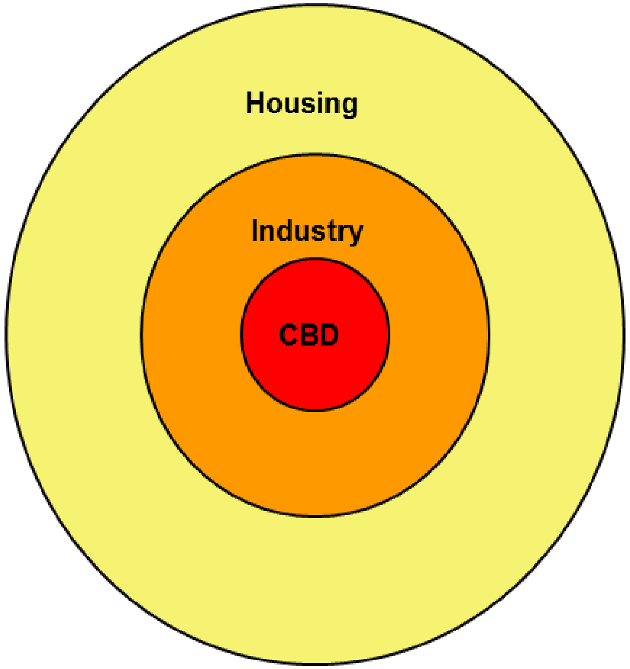
Modelling cities and regions:

A self-organising systems approach

Two approaches to modelling urban land use

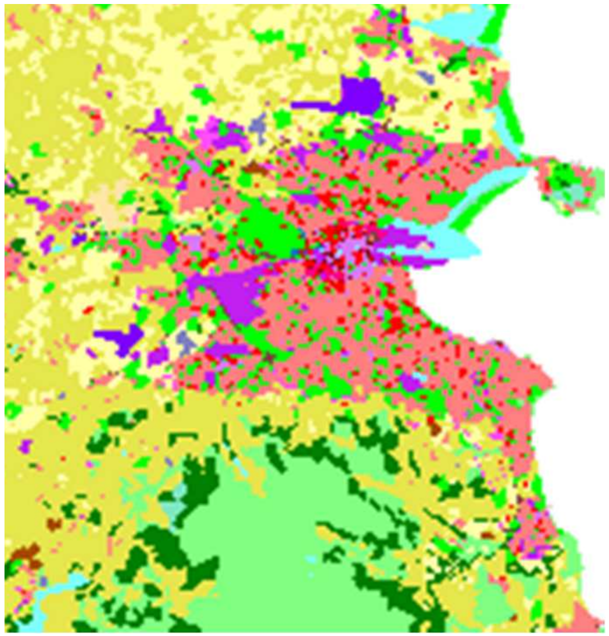
Equilibrium approach

(Alonso-Muth model)



Far from equilibrium approach

(self-organizing systems model)

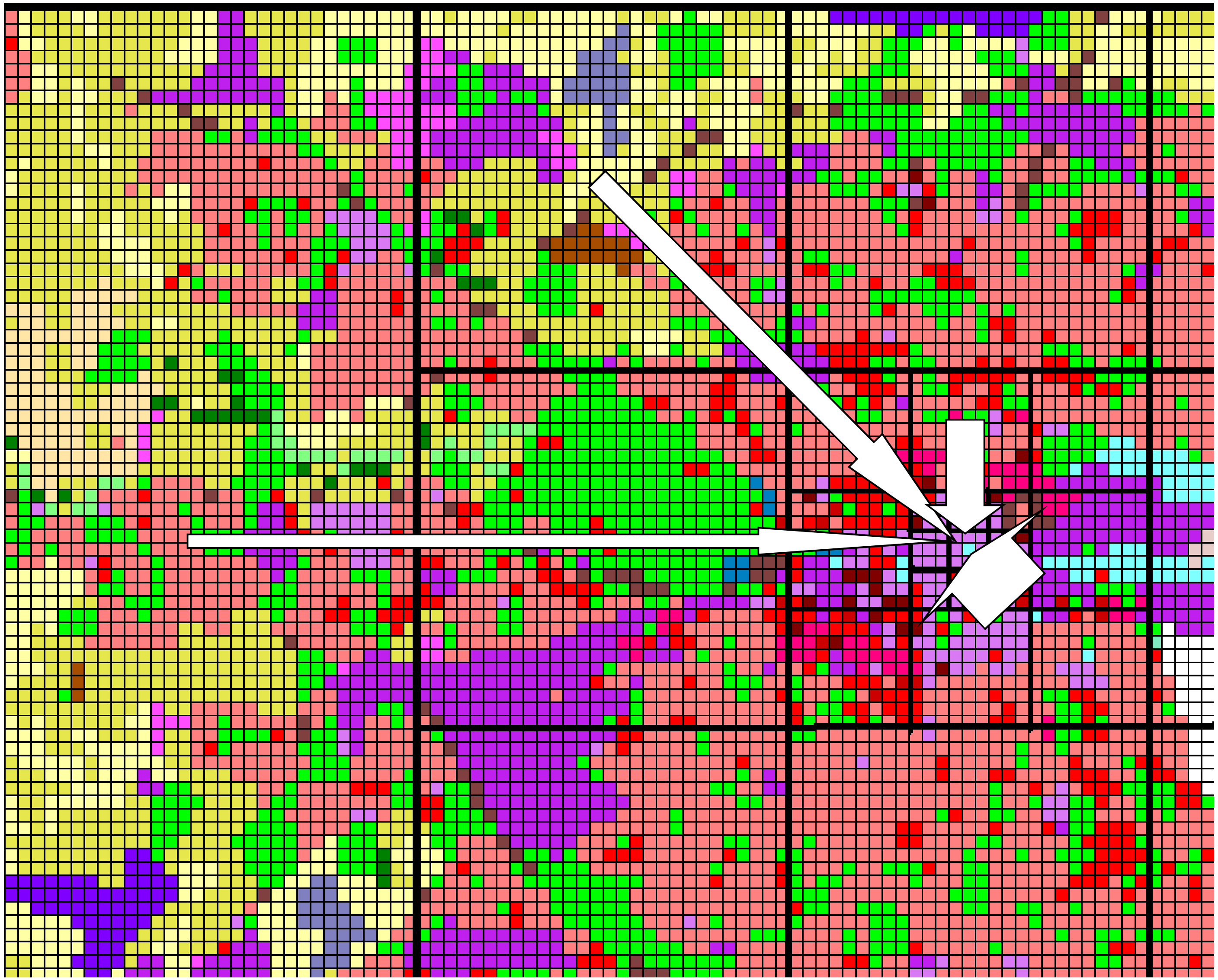


The Model

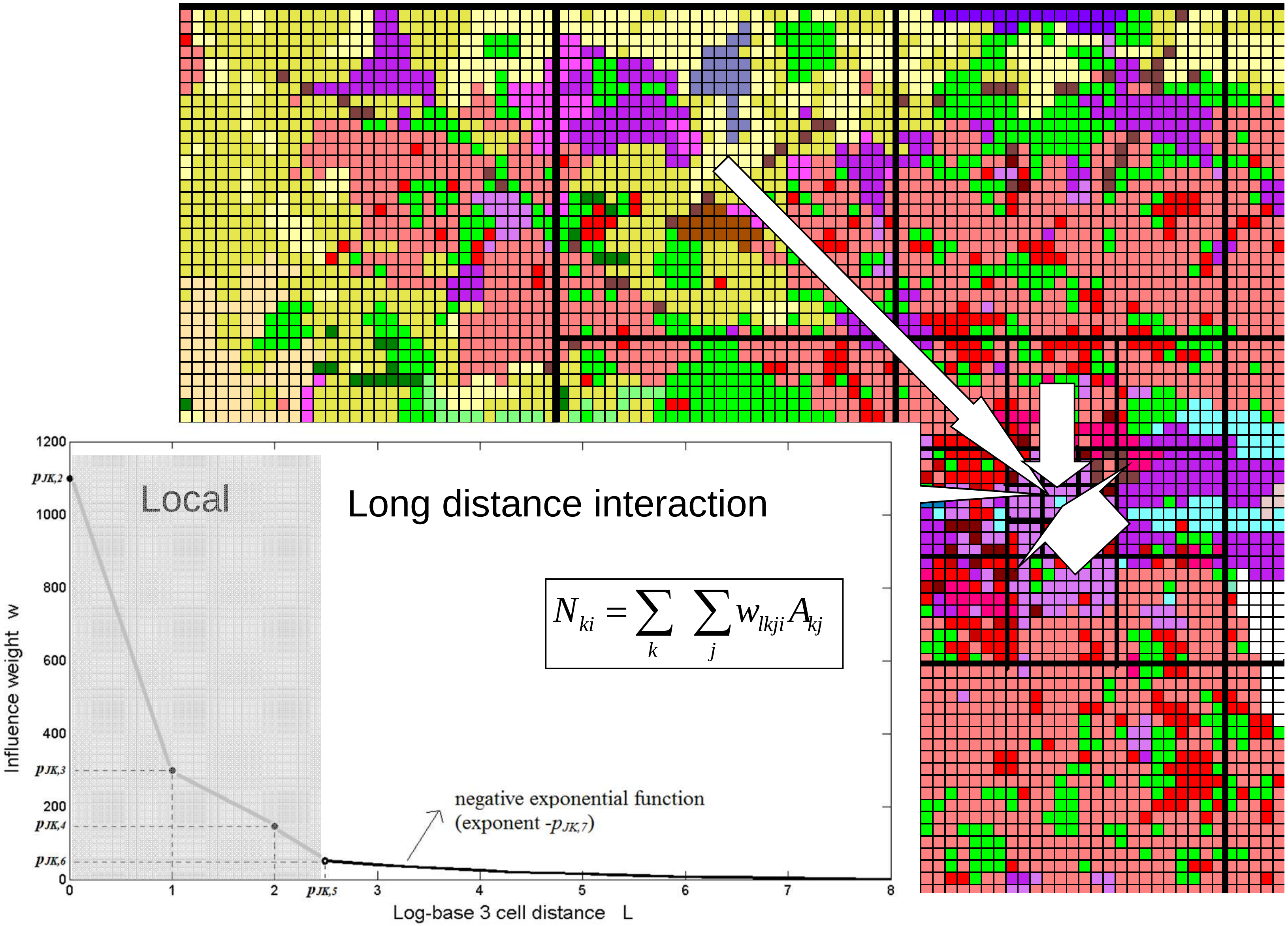
- Both land cover and activity location (e.g. population, employment) are treated as results of a single process**.**

- Land cover and activity levels at each site are influenced by land cover and activity throughout the modelled region—the **neighbourhood effect**.

The neighbourhood effect captures the results of interactions at all distances using weighting functions.



The neighbourhood effect captures the results of interactions at all distances using weighting functions.



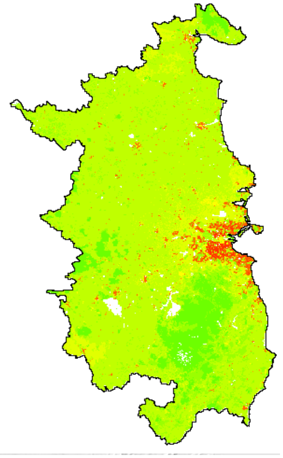
Other factors are also important

- **Negative externalities** (congestion, high land costs, etc.)
- **Suitability of the land** (slope, soil type, drainage, etc.)
- **Accessibility** to transportation and other infrastructure
- **Zoning** and other land use regulations
- **Individual differences** among people and businesses

We combine the neighbourhood effect with other factors that determine land use and activity to calculate a score (an activity or transition potential) for every cell on the map.

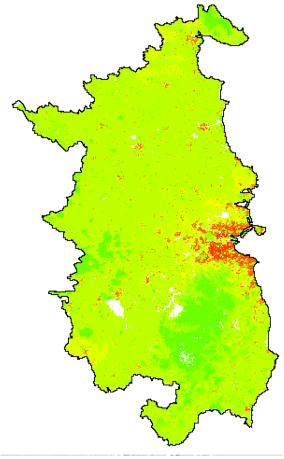
(calculations for every cell on the map)

Population Density



(calculations for every cell on the map)

Population Density



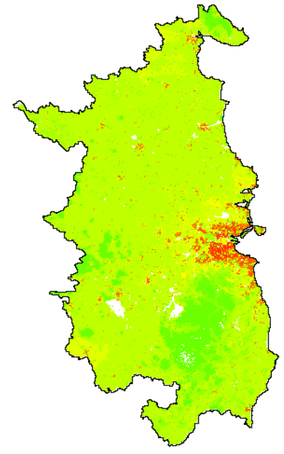
\+

Neighbourhood effect

$$N_{ki} = \sum_{k} \sum_{j} w_{lkji} A_{kj}$$

(calculations for every cell on the map)

Population Density



Neighbourhood effect

$$N_{ki} = \sum_{k} \sum_{j} w_{lkji} A_{kj}$$

+

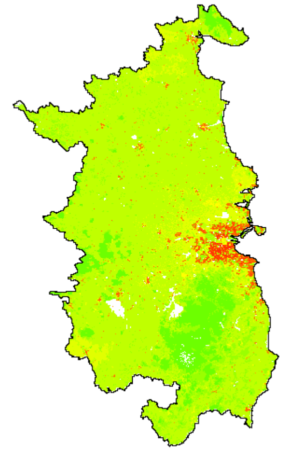
Negative externalities

$$D_{Ki} = \frac{1}{\max\left(K_K, \left(1 + V_{i,pop} - V_{crit}\right)\right)^{\lambda_K}}$$

$$with: \quad V_{crit} = \varepsilon < V_{init} >$$

(calculations for every cell on the map)

Population Density



+

Neighbourhood effect

$$N_{ki} = \sum_k \sum_j w_{lkji} A_{kj}$$

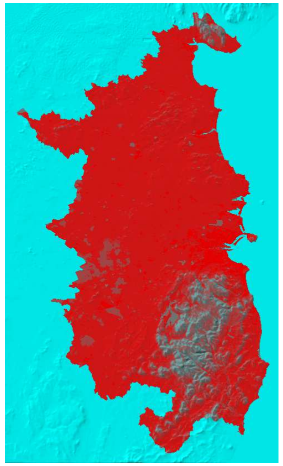
Negative externalities

$$D_{Ki} = \frac{1}{\max\left(K_K, \left(1 + V_{i,pop} - V_{crit}\right)\right)^{\lambda_K}}$$

$$with: \quad V_{crit} = \varepsilon < V_{init} >$$

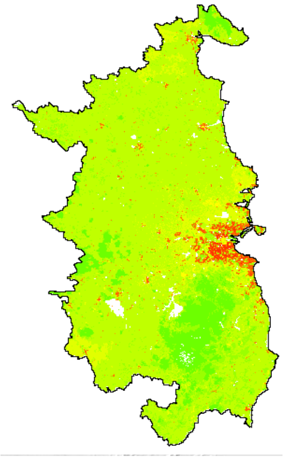
+

Suitability



(calculations for every cell on the map)

Population Density



+

Neighbourhood effect

$$N_{ki} = \sum_{k} \sum_{j} w_{lkji} A_{kj}$$

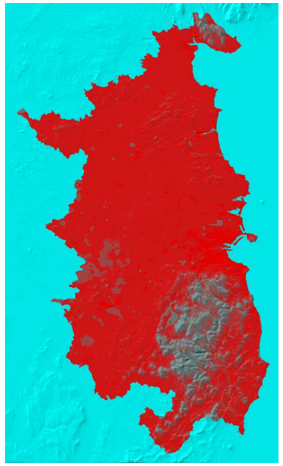
Negative externalities

$$D_{Ki} = \frac{1}{\max\left(\mathrm{K}_{\mathrm{K}}, \left(1 + V_{i,pop} - V_{crit}\right)\right)^{\lambda_{K}}}$$

$$with: \quad V_{crit} = \varepsilon < V_{init} >$$

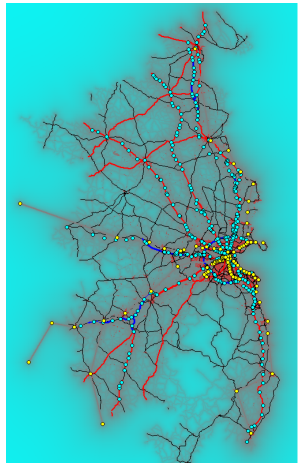
+

Suitability



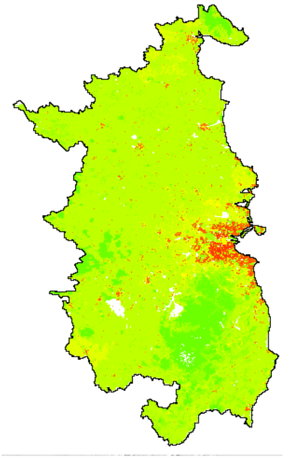
+

Accessibility



(calculations for every cell on the map)

Population Density



+

Neighbourhood effect

$$N_{ki} = \sum_{k} \sum_{j} w_{lkji} A_{kj}$$

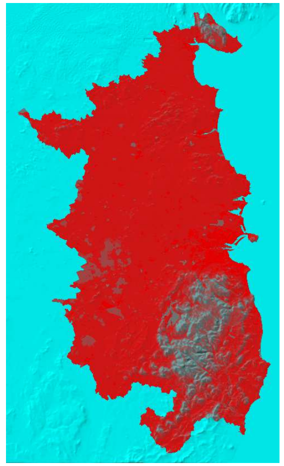
Negative externalities

$$D_{Ki} = \frac{1}{\max\left(K_K, \left(1 + V_{i,pop} - V_{crit}\right)\right)^{\lambda_K}}$$

$$with: \quad V_{crit} = \varepsilon < V_{init} >$$

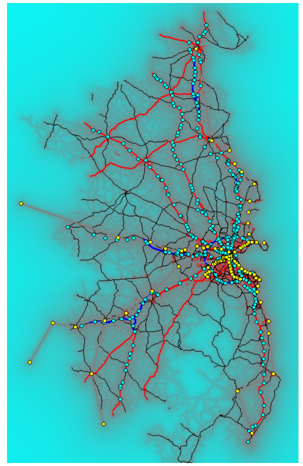
+

Suitability



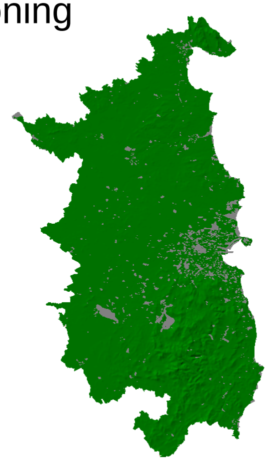
+

Accessibility



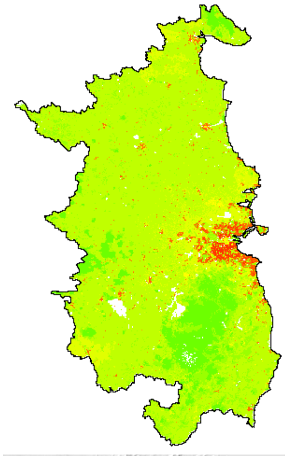
Zoning

+



(calculations for every cell on the map)

Population Density



+

Neighbourhood effect

$$N_{ki} = \sum_{k} \sum_{j} w_{lkji} A_{kj}$$

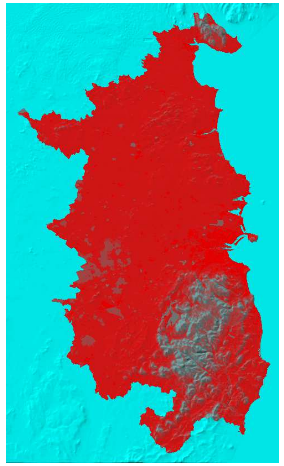
Negative externalities

$$D_{Ki} = \frac{1}{\max\left(K_K, \left(1 + V_{i,pop} - V_{crit}\right)\right)^{\lambda_K}}$$

$$with: \quad V_{crit} = \varepsilon < V_{init} >$$

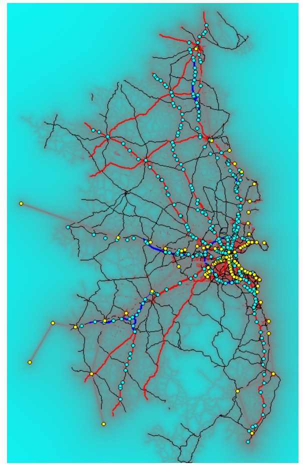
+

Suitability



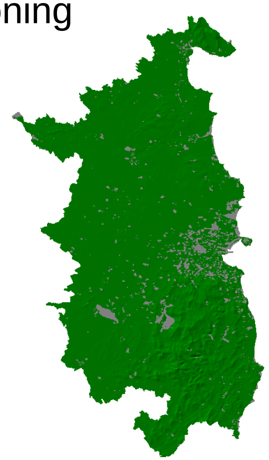
+

Accessibility



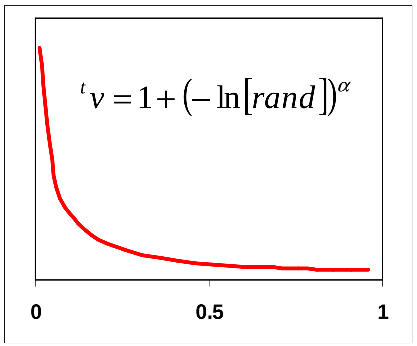
+

Zoning



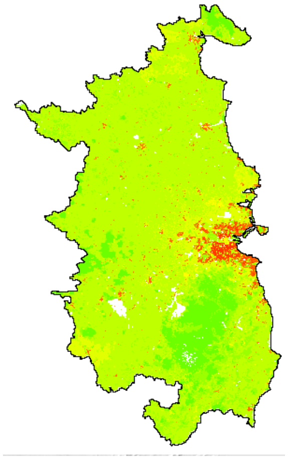
+

Individual differences



(calculations for every cell on the map)

Population Density



+

Neighbourhood effect

$$N_{ki} = \sum_{k} \sum_{j} w_{lkji} A_{kj}$$

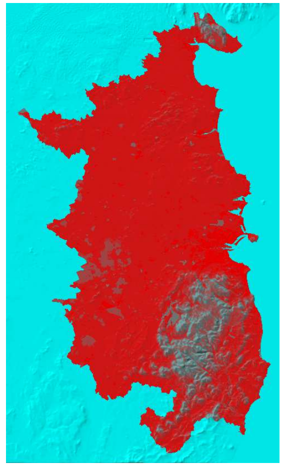
Negative externalities

$$D_{Ki} = \frac{1}{\max\left(K_K, \left(1 + V_{i,pop} - V_{crit}\right)\right)^{\lambda_K}}$$

$$with: \quad V_{crit} = \varepsilon < V_{init} >$$

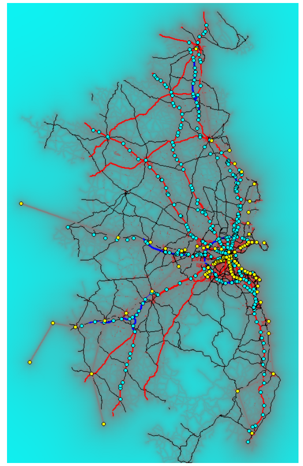
+

Suitability



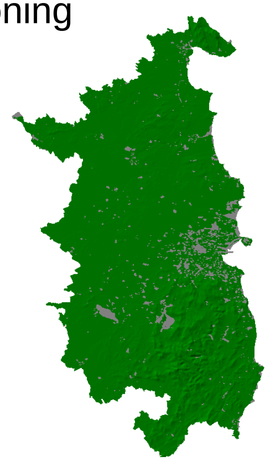
+

Accessibility



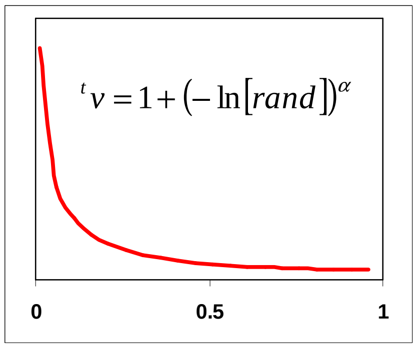
+

Zoning



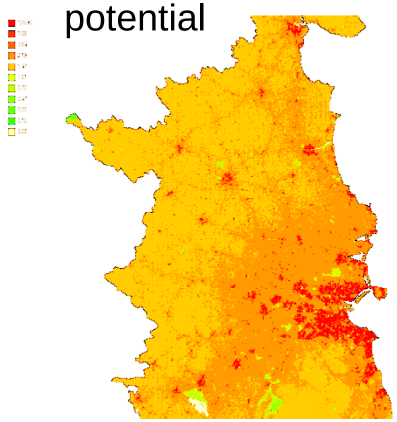
+

Individual differences

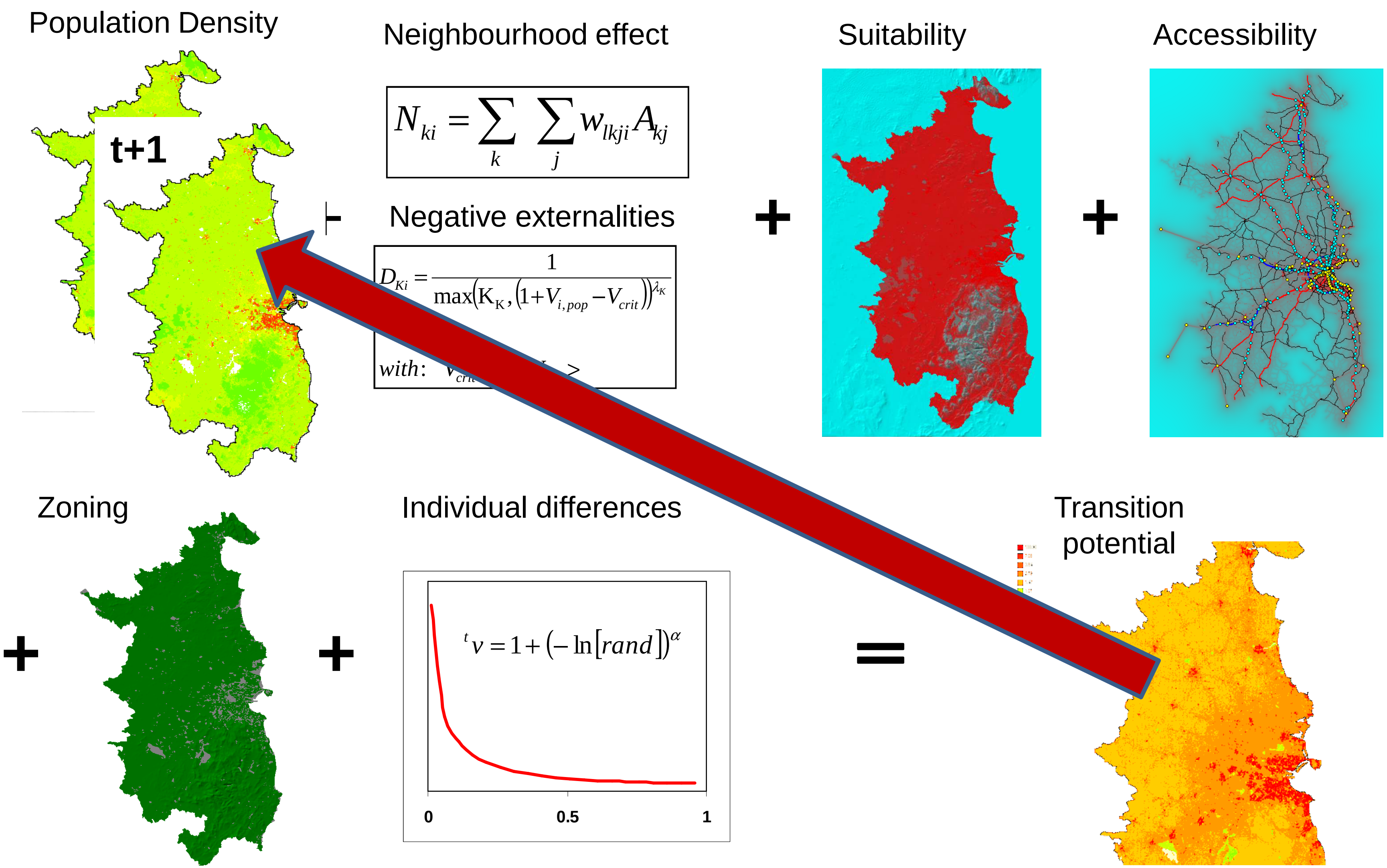


=

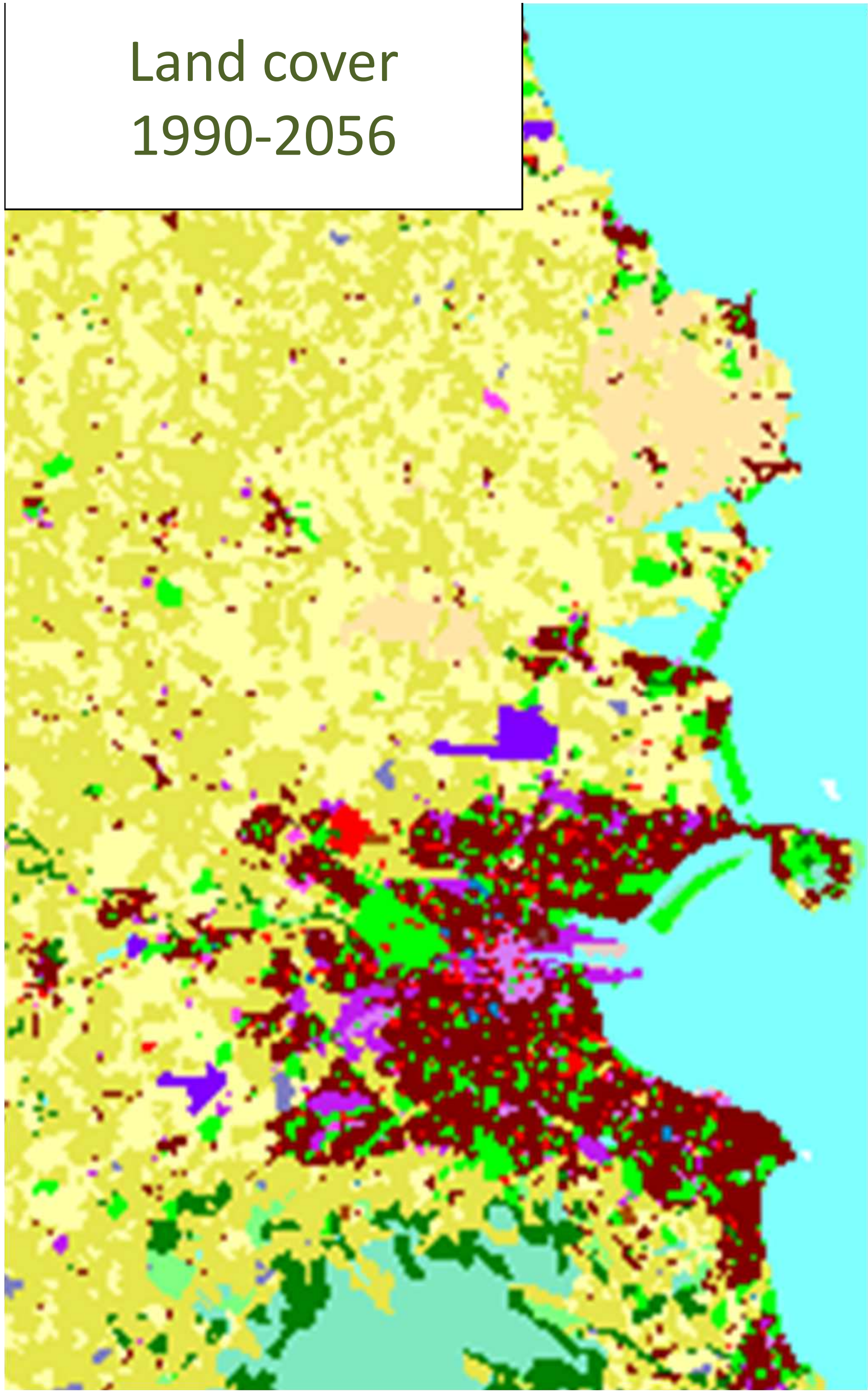
Transition potential

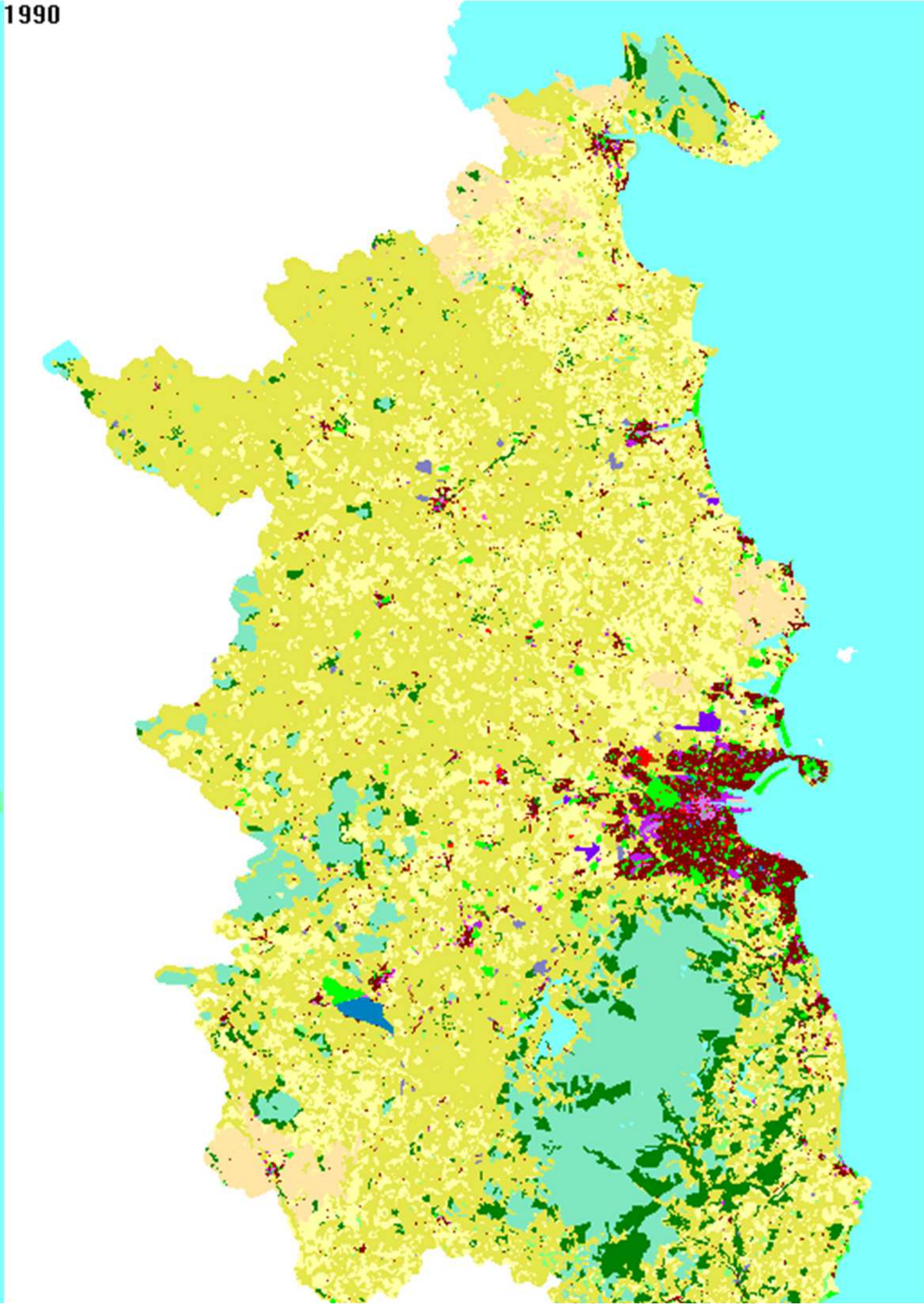


(calculations for every cell on the map)



Land cover 1990-2056





Complexity

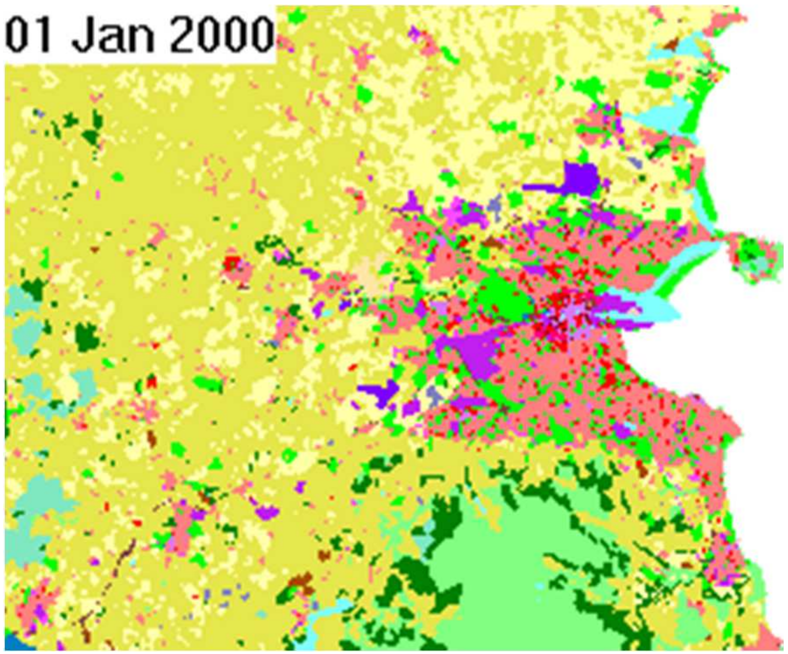
The relatively simple rules of the model generate complex, changing patterns.

Two signatures of complexity are present–

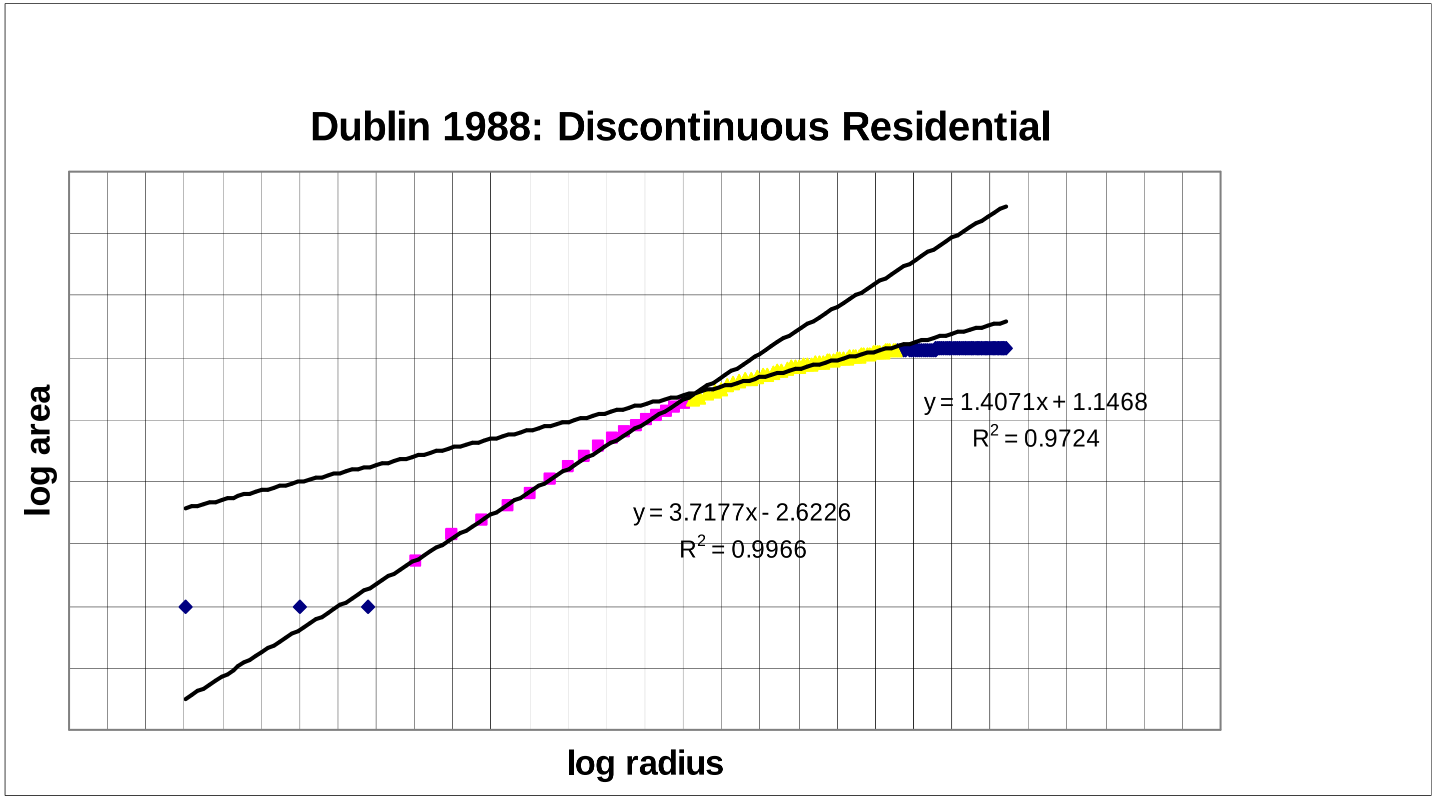
The patterns are

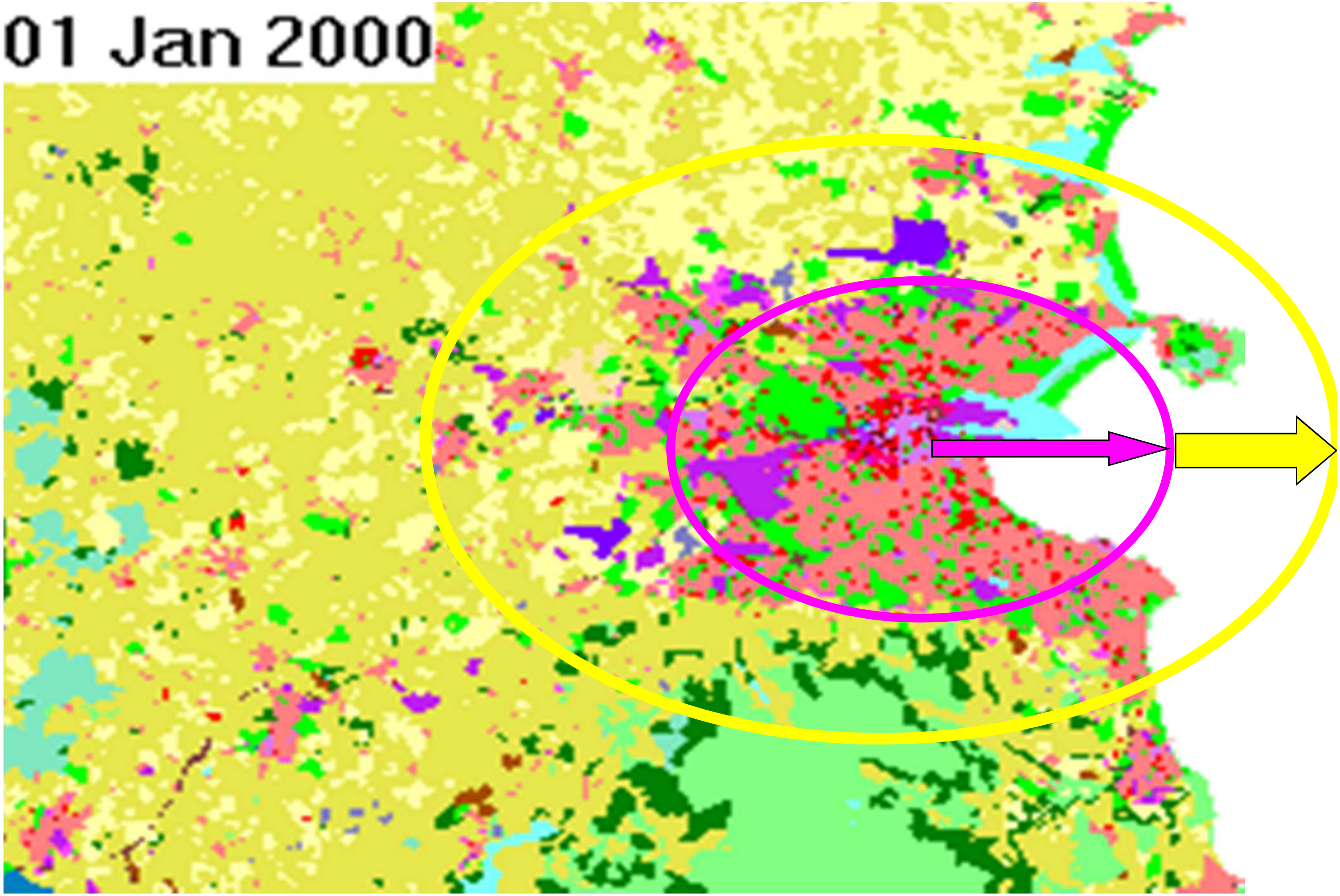
(1) fractal

(2) non-deterministic



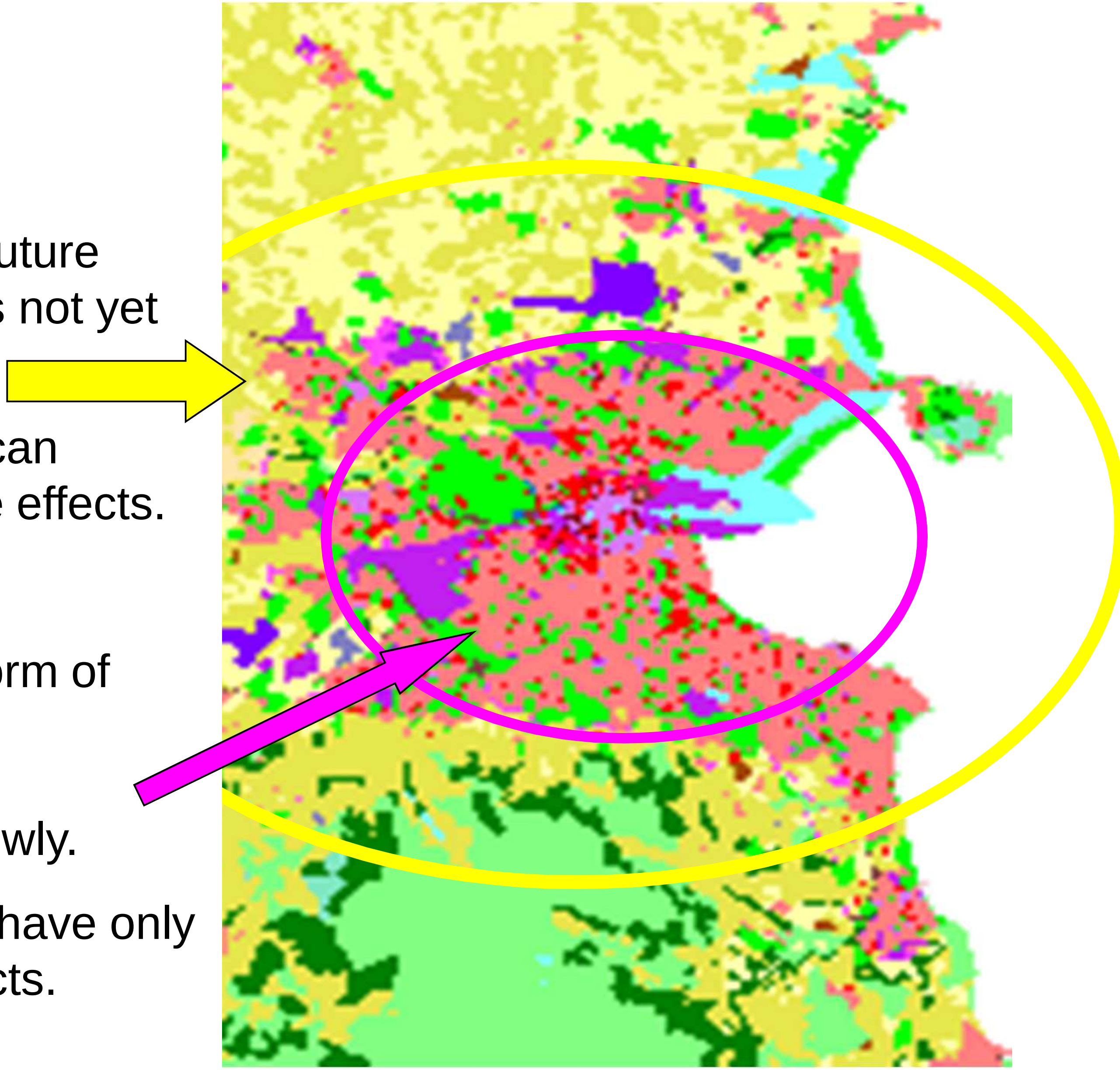
Radial dimension of sparse residential land use: Dublin




01 Jan 2000

- In the outer zone, the future form of the city is not yet determined.

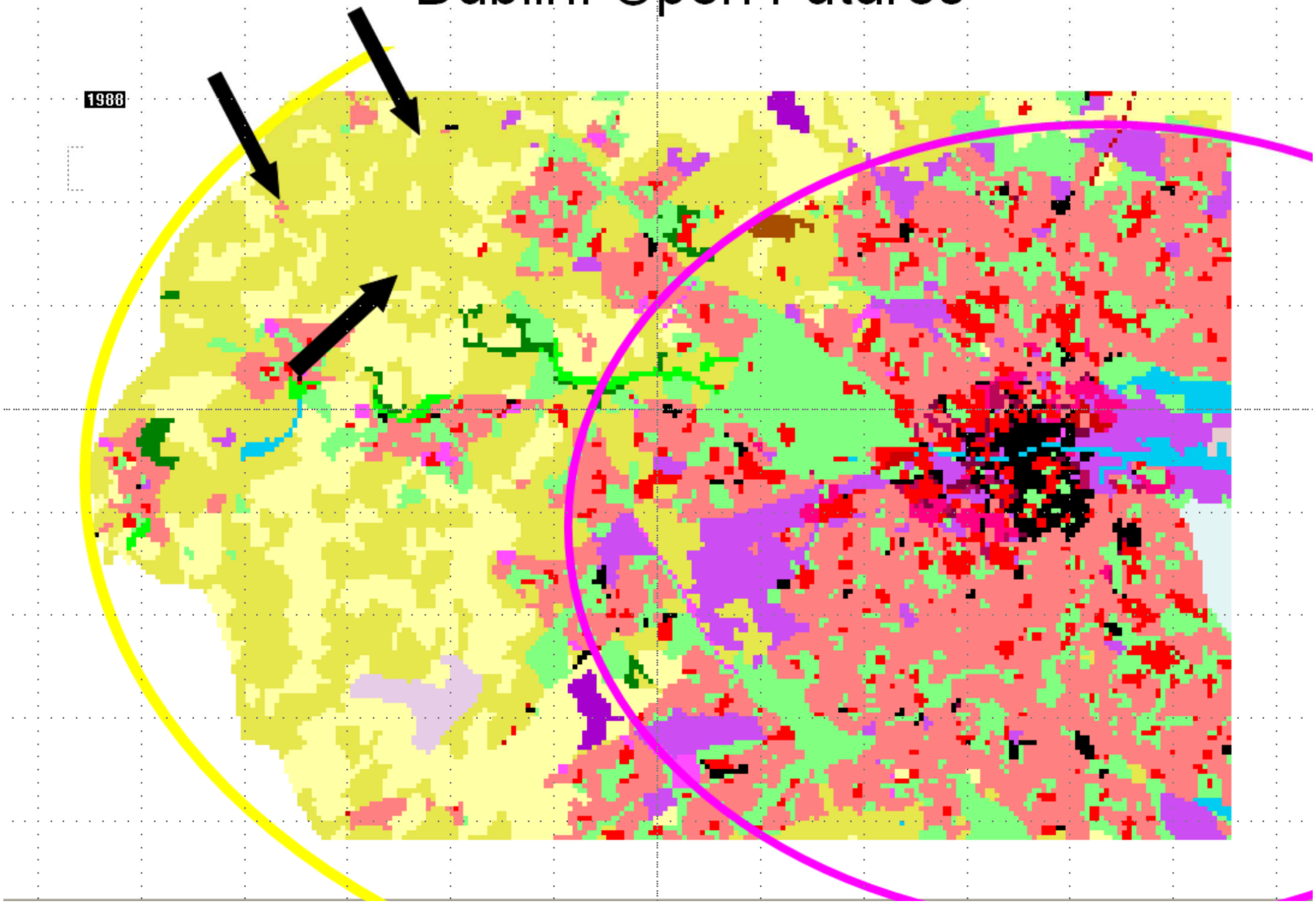
  Small interventions can have large future effects.



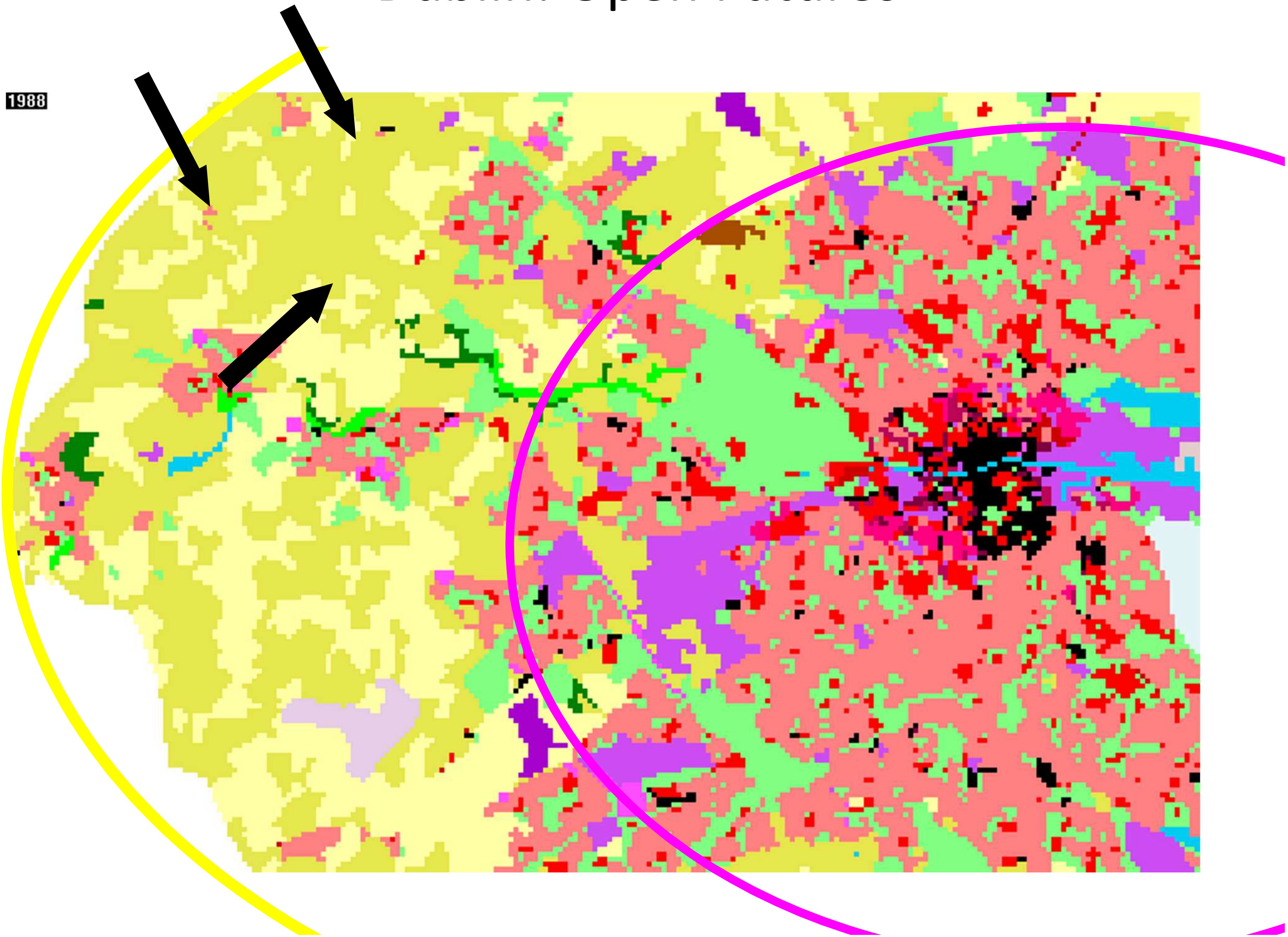
- In the inner zone the form of the city is largely determined and changes only slowly.

  Small interventions have only small future effects.

Dublin: Open Futures



Dublin: Open Futures



3.

Using the model:

Problems and opportunities

Integrated modelling

The land-use and activity model can be linked dynamically with other models:

- Transportation
- Demographic
- Economic
- Hydrological
- Ecosystem

This allows feedback effects between these phenomena and land use and activity densities.

Policy and planning applications

- Puerto Rico
- The Netherlands
- French railways
- Dublin
- Flanders

Problems for users—and opportunities

- Gaps in data

  Identifying and filling gaps improves results

- Difficulties in reconciling the idea of open futures with planning

  Recognizing open futures opens minds to other possibilities

- Difficulties in developing practices for "working with the system" rather than trying to control it directly.

  Planners can ask what is the least disruptive policy likely to achieve a desired result.

Problems for users – and opportunities

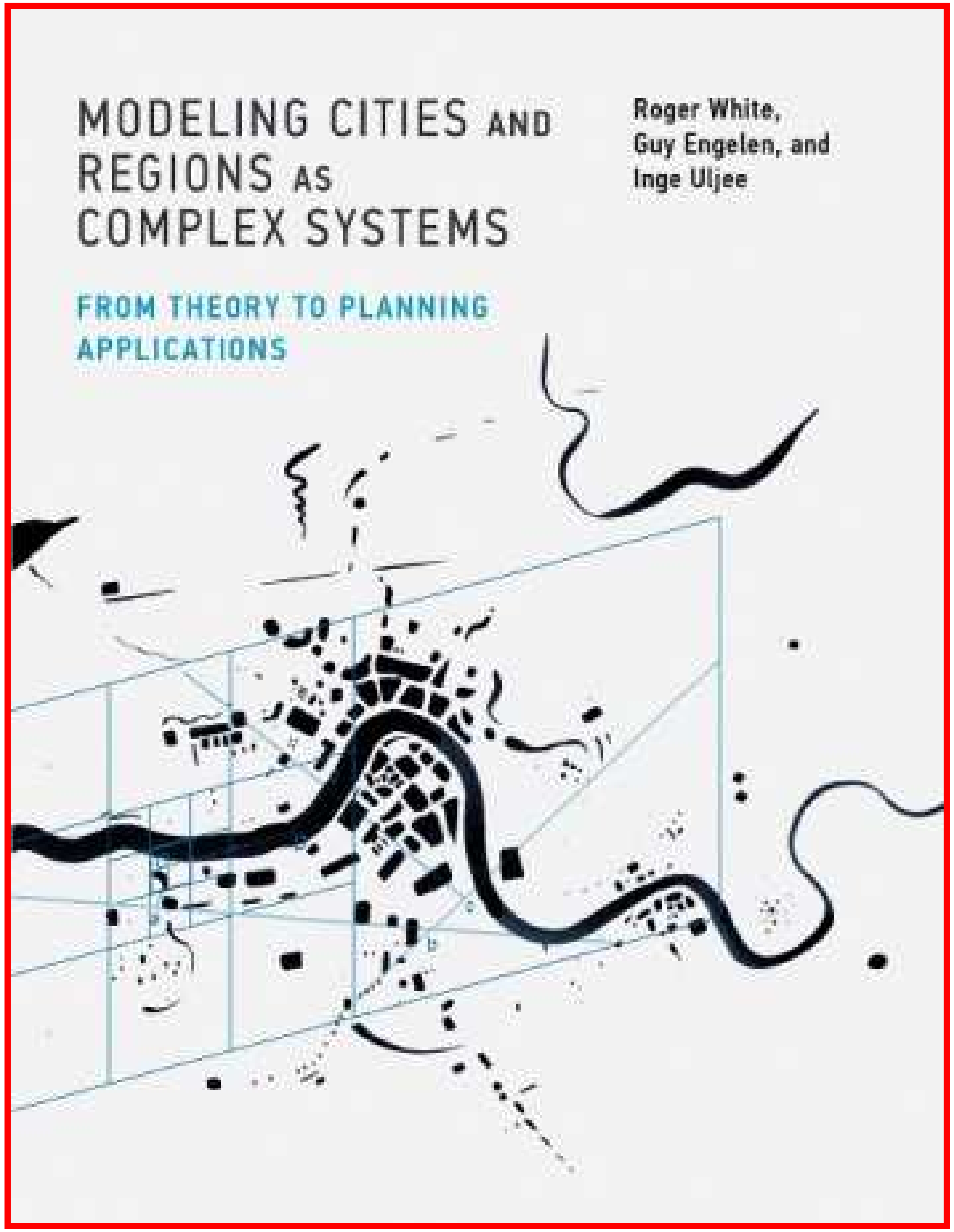
- Using an integrated model can cause stresses within an organization.

  But it can help bring together groups and points of view that normally do not communicate with each other.

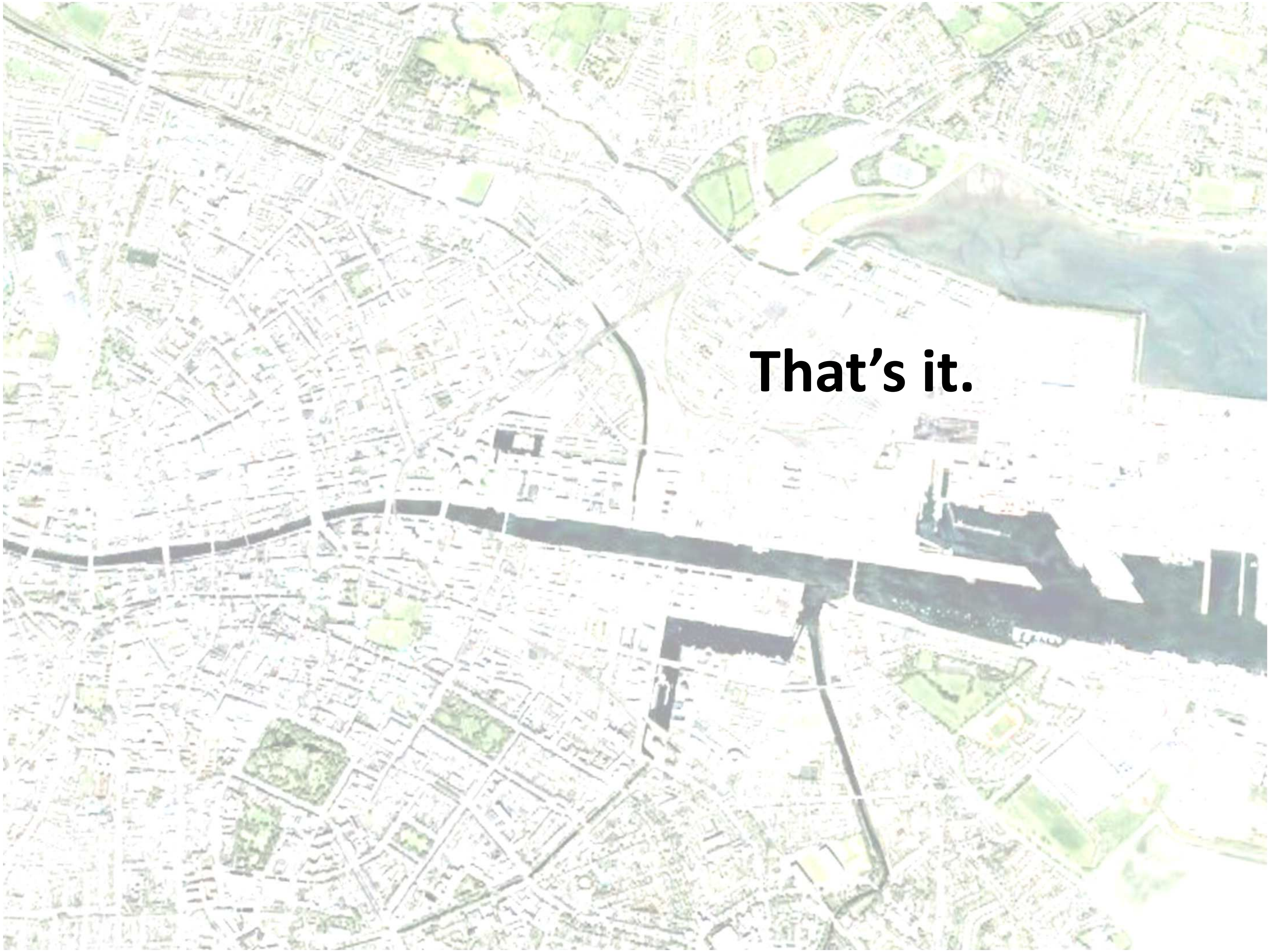
- The approach does not provide a "solution"—it is not an optimising technique.

  It helps planners think about the possibilities and imagine various solutions.

  It can be used as a basis for collaboration with the public.



MIT Press, 2015
344 pp.
17 tables
15 color plates
93 b&w illustrations
ISBN: 9780262331364.


That’s it.