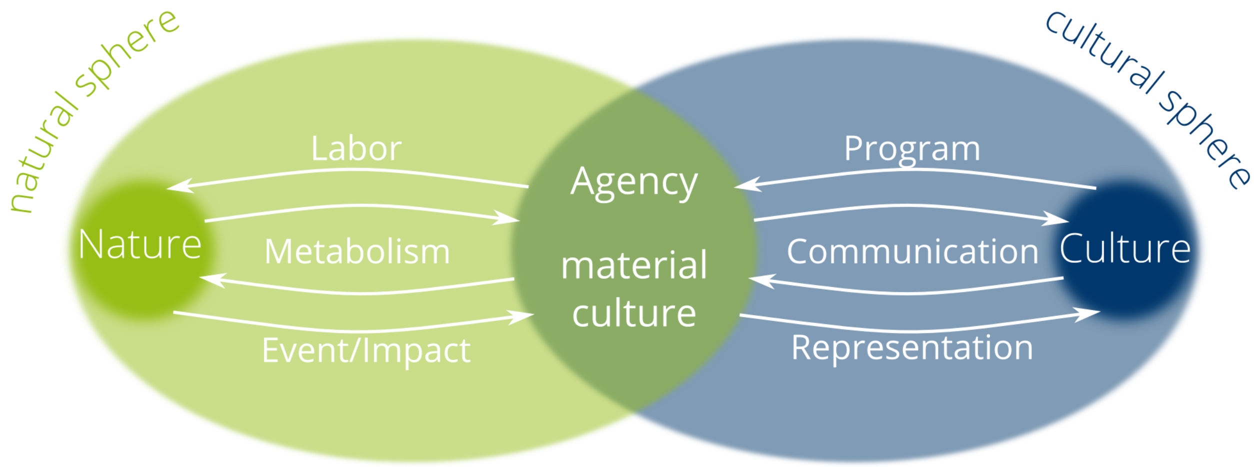
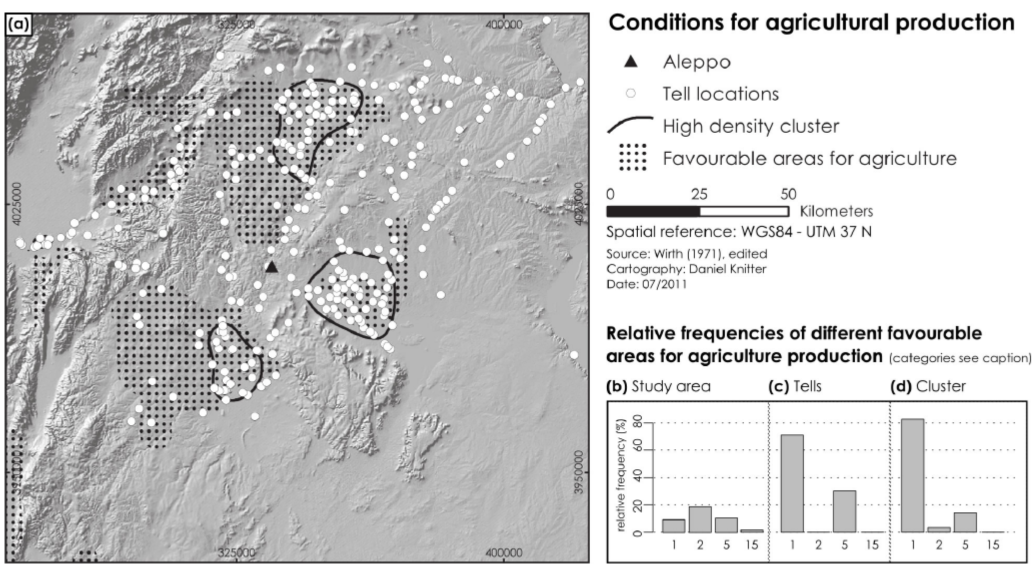
V/S Modellieren in der Landschaftsarchäologie

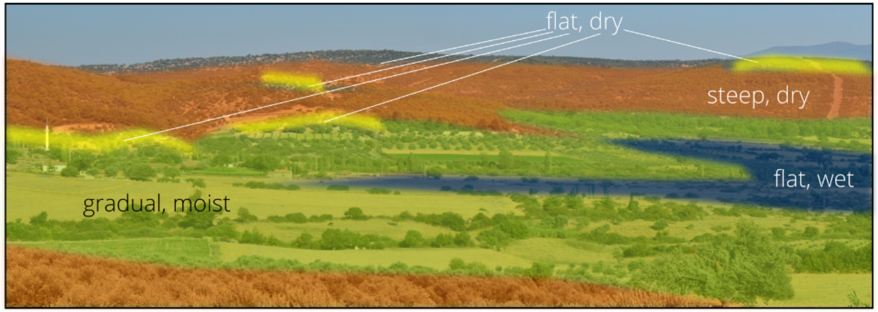
Freie Universität Berlin
M.Sc. Landschaftsarchäologie

Dr. Daniel Knitter

About me







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Terminliches

03.12.2015 10-14
10.12.2015 10-14
17.12.2015 10-14
~~07.01.2016 10-14~~
14.01.2016 10-14
~~21.01.2016~~
~~28.01.2016~~
04.02.2016 10-14
11.02.2016 10-14

Blocktermin als Ersatz…wann?

Aus der Studienordnung

Qualifikationsziele:
Die Studentinnen und Studenten können zwischen Black-Box-, Grey-Box- und White-Box-Modellen differenzieren und deren Vor- und Nachteile benennen. Sie sind in der Lage Modelle unter Berücksichtigung der vorhandenen Datenlage und Fragestellung auszuwählen und anzuwenden.

Inhalte:
In der Landschaftsarchäologie gibt es unterschiedlichste Fragestellungen, für deren Beantwortung sich eine Modellbildung bzw. Modellierung anbietet: Wasserhaushaltsmodellierungen, Predictive Modelling, Least-Cost-Path-Analysis, Erstellung von Modellen zur Landschaftsentwicklung. Ausgewählte Modellansätze werden in der Vorlesung zunächst vorgestellt und im Rahmen des Seminars anschließend erprobt.

http://www.fu-berlin.de/service/zuvdocs/amtsblatt/2012/ab742012.pdf

Aus der Prüfungsordnung

Modul 302: Modellieren in der Landschaftsarchäologie		
Zugangsvoraussetzungen: Keine		
Lehr- und Lernformen	**Modulprüfung**	**Pflicht zu regelmäßiger Teilnahme**
Vorlesung	Hausarbeit (ca. 2 000 Wörter)	~~Teilnahme wird empfohlen~~
Übung		Ja
Leistungspunkte: 5		

Abgabe eines ausformulierten R-Skripts, welches ein selbst gewähltes Modellierungsproblem untersucht
(inkl. Problemstellung/State of the art/Literatur/...)

+ Lesen von Texten, Hausaufgaben

Modellierung...?

Modell – lat. modulus = Gebäude in verkleinertem Maßstab

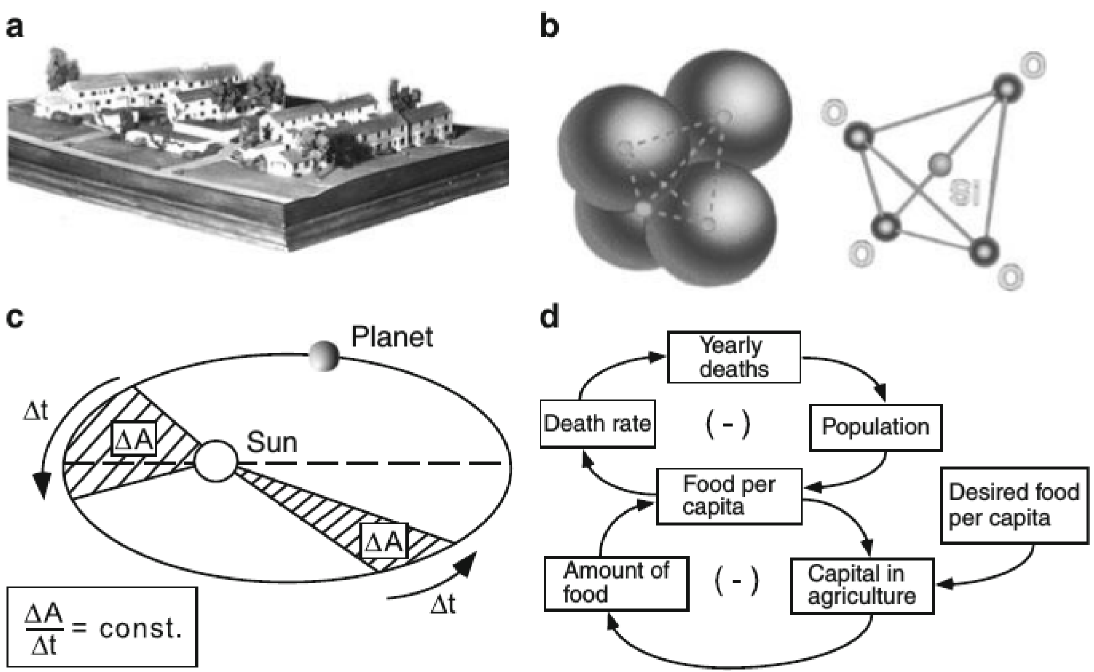


Fig. 1.2: *Examples of models: (**a**) Architectural model: Scaled-down execution of a planned or existing building. (**b**) Physical model: Model of chemical molecules. (**c**) Mathematical model: Kepler's second law of planetary motion. (**d**) Conceptional model: Excerpt from the World model by Forrester and Meadows (see Meadows et al. 1972)*

Modellierung...?

“Ein Modell ist ein Konzept zur vereinfachten Darstellung eines komplexen Systems. Es dient dazu, die wichtigen Eigenschaften eines Systems darzustellen und die nebensächlichen Eigenschaften außer Acht zu lassen”

(Imboden & Koch 2003, 9).

Hausaufgabe 1 zum nächsten Mal

Nakoinz, Oliver, and Martin Hinz. 2015. “Modelle in der Archäologie.” In Wissenschaft und Kunst der Modellierung - Kieler Zugang zur Definition, Nutzung und Zukunft, edited by Bernhard Thalheim and Ivor Nissen. Berlin, Boston: De Gruyter.

→ gibt es per Mail von mir [oder als E-Ressource bei der Stabi]

11 Modelle in der Archäologie

Oliver Nakoinz und Martin Hinz

11.1 Einleitung und Forschungsgeschichte

In den letzten Jahren haben Modelle und hat Modellierung in der Archäologie erheblich an Popularität gewonnen. Dennoch ist es eine eher kleine Gruppe, die aktiv und bewusst Modellierung betreibt und den Modellbegriff gezielt einsetzt. Neben dieser überschaubaren expliziten Nutzung von Modellen spielt jedoch die implizite Modellnutzung in der Archäologie, wie in allen anderen Disziplinen, eine große Rolle. Diese steht im Vordergrund des vorliegenden Beitrages. Es wird versucht die wichtigsten latenten Modelle zu identifizieren und in ihrem forschungsgeschichtlichen Kontext darzustellen. Anschließend werden beispielhaft einige explizite Modelle von Raumstrukturen vorgestellt.

11.1.1 Archäologie zwischen Geistes- und Naturwissenschaften

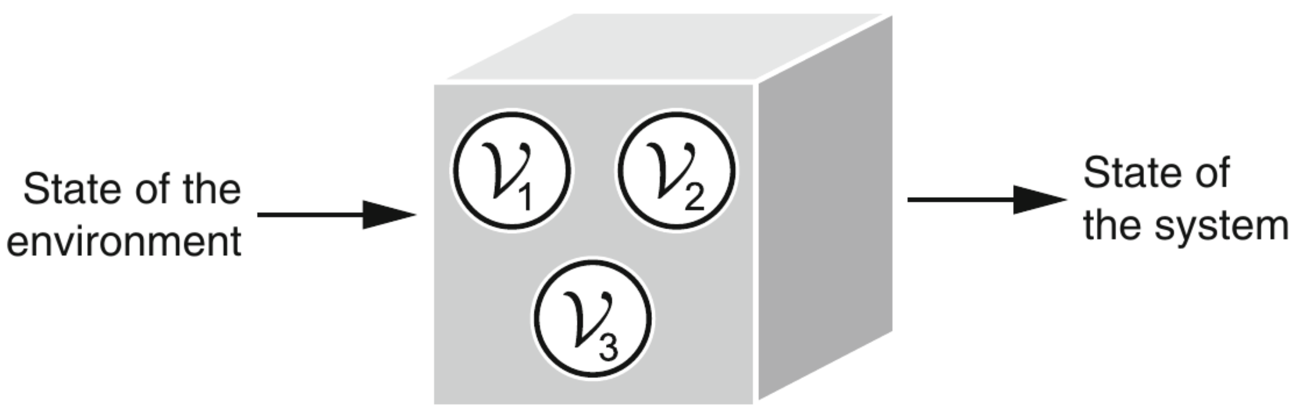
Ebenso wie die Geographie und einige andere Fächer nimmt die Archäologie eine besondere Stellung zwischen Geistes- und Naturwissenschaften ein. Die Archäologie versteht sich einerseits als historische Wissenschaft, die historische Fragestellungen zu klären hat. Die Besonderheit der archäologischen Quellen führen zu einem spezifischen Schwerpunkt der Fragestellungen. Während Ereignisgeschichte anhand archäologischer Quellen meist nur sehr schwer zu schreiben ist, so ist die Strukturgeschichte ein natürliches Anwendungsfeld der Archäologe. Die archäologischen Quellen unterscheiden sich andererseits sehr deutlich von den historischen Quellen und machen die Archäologie zu einem nativen Mitglied der Naturwissenschaften. Archäologische Funde und Befunde sind zunächst nicht mit Bedeutung ausgestattet, wie es historische Quellen sind. Das hermeneutische Ausdeuten archäologischer Quellen und deren Interpretation erscheint demnach oft eher als wilde Spekulation denn als Wissenschaft. *Per se* sind archäologische Quellen dieser geisteswissenschaftlichen Herangehensweise nicht zugänglich. Sie erlauben jedoch die Anwendung naturwissenschaftlicher Konzepte. Während die Geisteswissenschaften im Wesentlichen auf dem Deuten und Aushandeln prädefinierter Bedeutungen gegebener Gegenstände beruhen, setzt die Naturwissenschaft mit einer Strukturanalyse zunächst bedeutungsloser Gegenstände ein und stattet diese im Laufe des Forschungsprozesses mit Bedeutung aus. Anders

Black-, Grey-, White-box Models

?

Black-, Grey-, White-box Models

Ziel: einfachste Struktur der Black Box finden, die den vermuteten Zustand der Umwelt und dem Systemzustand reproduziert



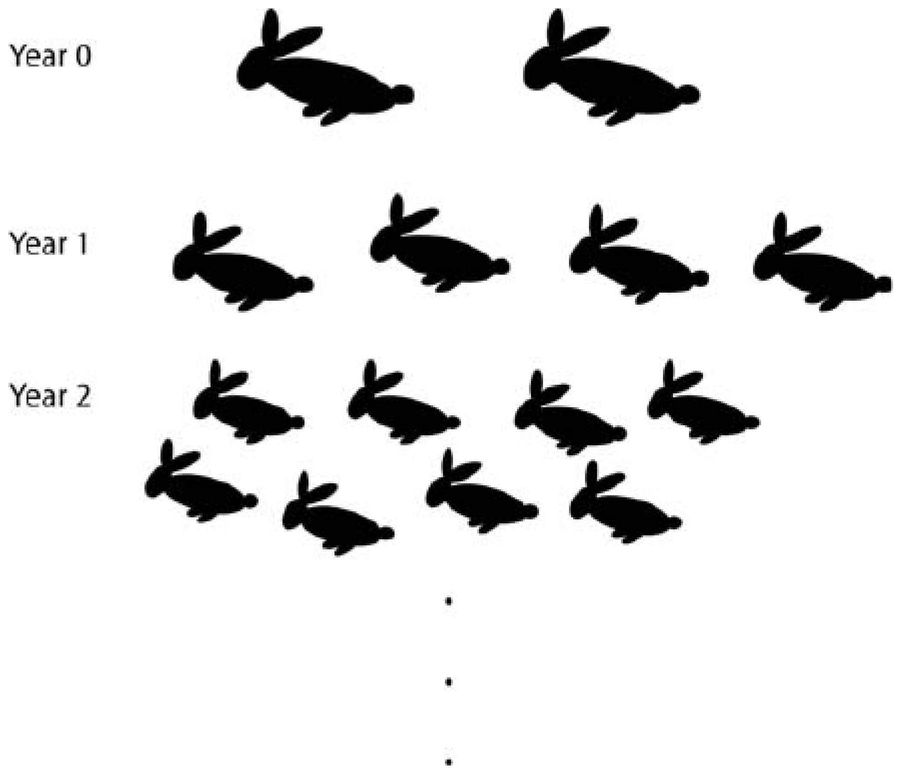
(Imboden & Pfenninger 2013)

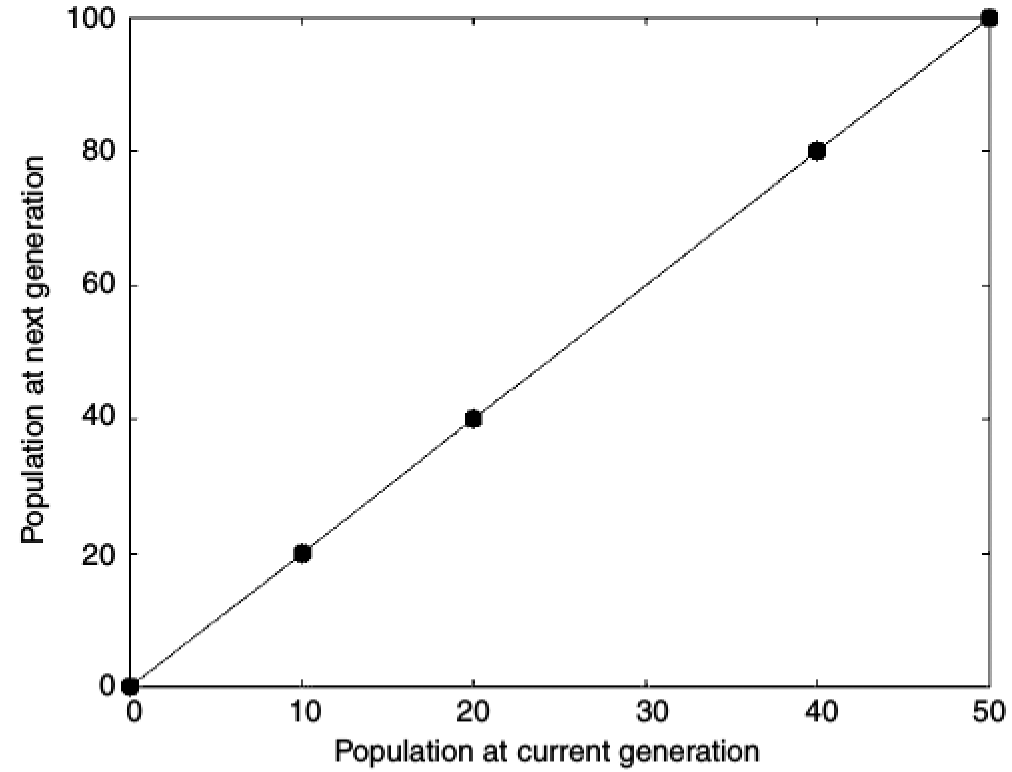
Black-, Grey-, White-box Models

Black-box models are completely nonmechanistic. We cannot investigate interactions of subsystems of such a non-transparent model. A white-box model of complex dynamic systems has ‘transparent walls’ and directly shows underlying mechanisms – all events at micro-, meso- and macro-levels of a modeled dynamic system are directly visible at all stages. Logical deterministic cellular automata is the only known approach, which allows to create white-box models of complex dynamic systems (*3*). A micro-level is modeled by a lattice site (cellular automata cell). A meso-level of local interactions of micro-objects is modeled by a cellular automata neighbourhood. A macro-level is modeled by the entire cellular automata lattice. Unfortunately, this simple approach is commonly used in the overloaded form, what makes it less transparent. This is achieved by adding differential equations and stochasticity. Grey-box models are intermediate and combine black-box and white-box approaches. Basic ecological models are of black-box type, e.g. Malthusian, Verhulst, Lotka-Volterra models. These models are not individual-based and cannot show features of local interactions of individuals of competing species. That is why they principally cannot provide a mechanistic insight into interspecific competition.

(Kalmykov 2015, 2-3)

Black-, Grey-, White-box Models





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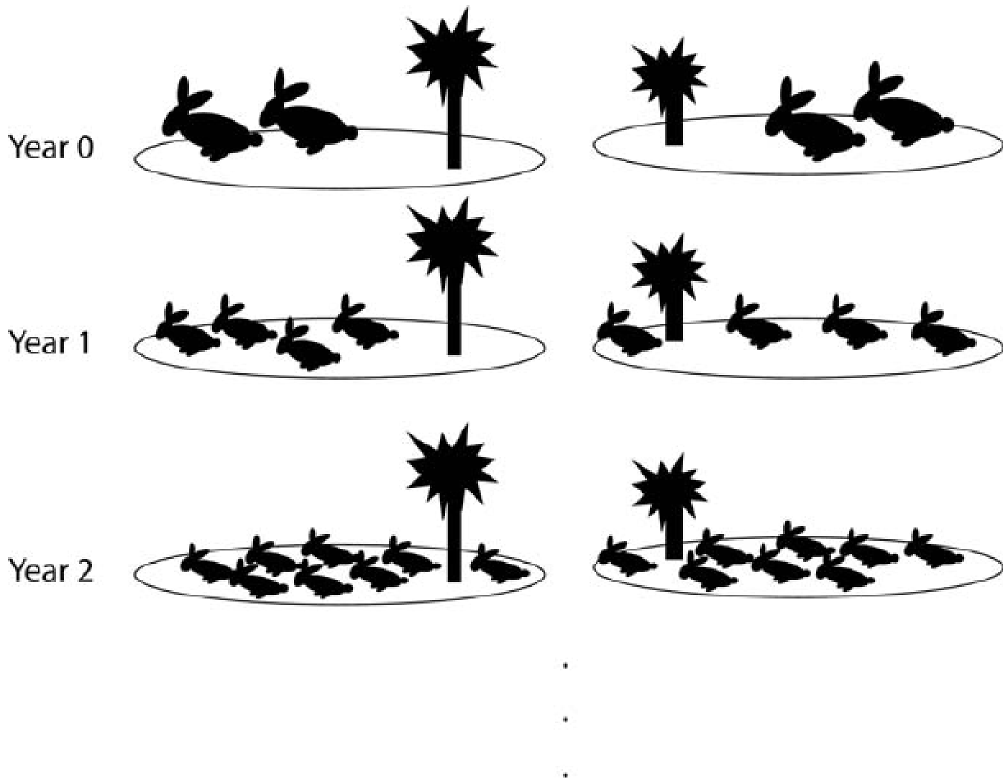
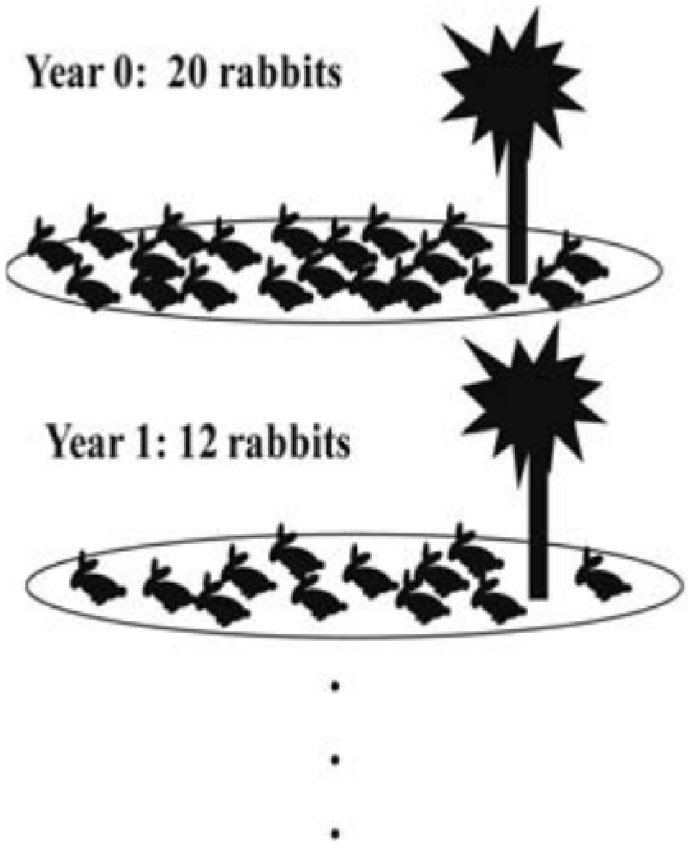
(Mitchell 2009)

Black-, Grey-, White-box Models





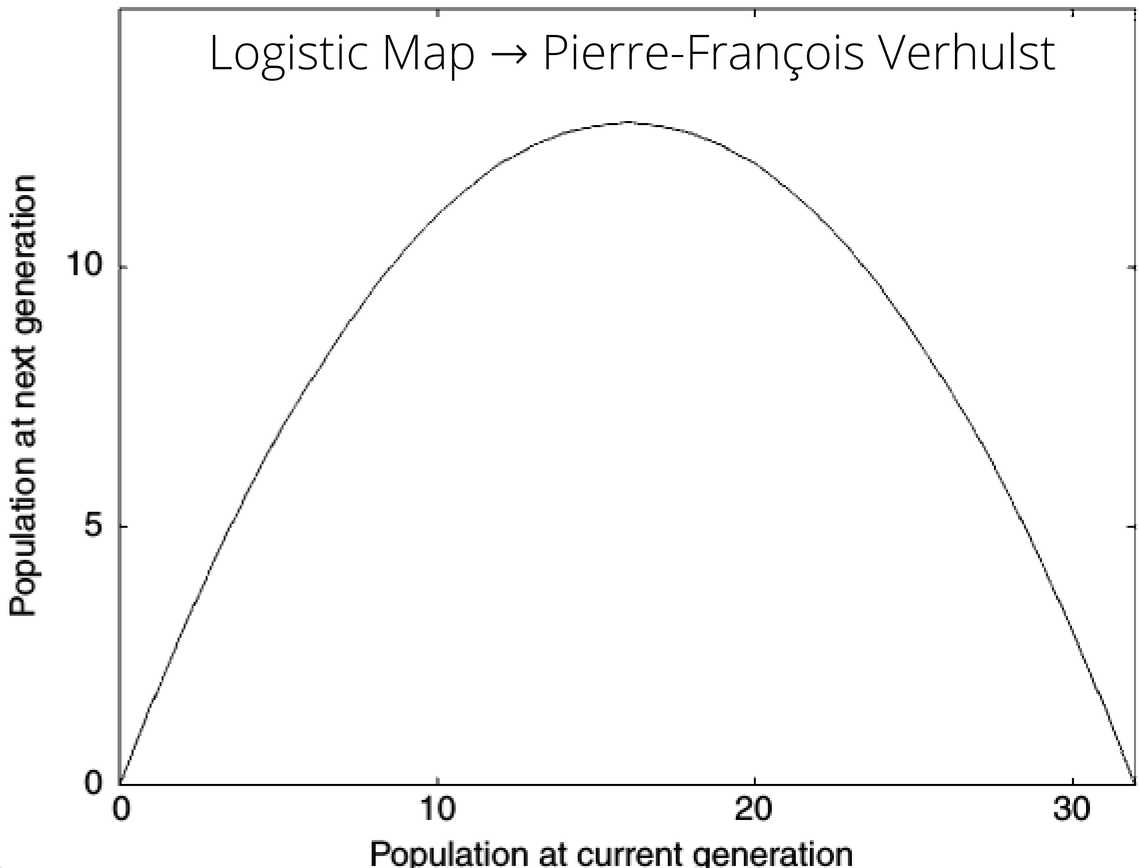
(Mitchell 2009)

Black-, Grey-, White-box Models

$$\frac{dP}{dt} = P \cdot r$$

$$x_{t+1} = R\, x_t (1 - x_t)$$

Birth rate/death rate
+ carrying capacity



(Mitchell 2009)

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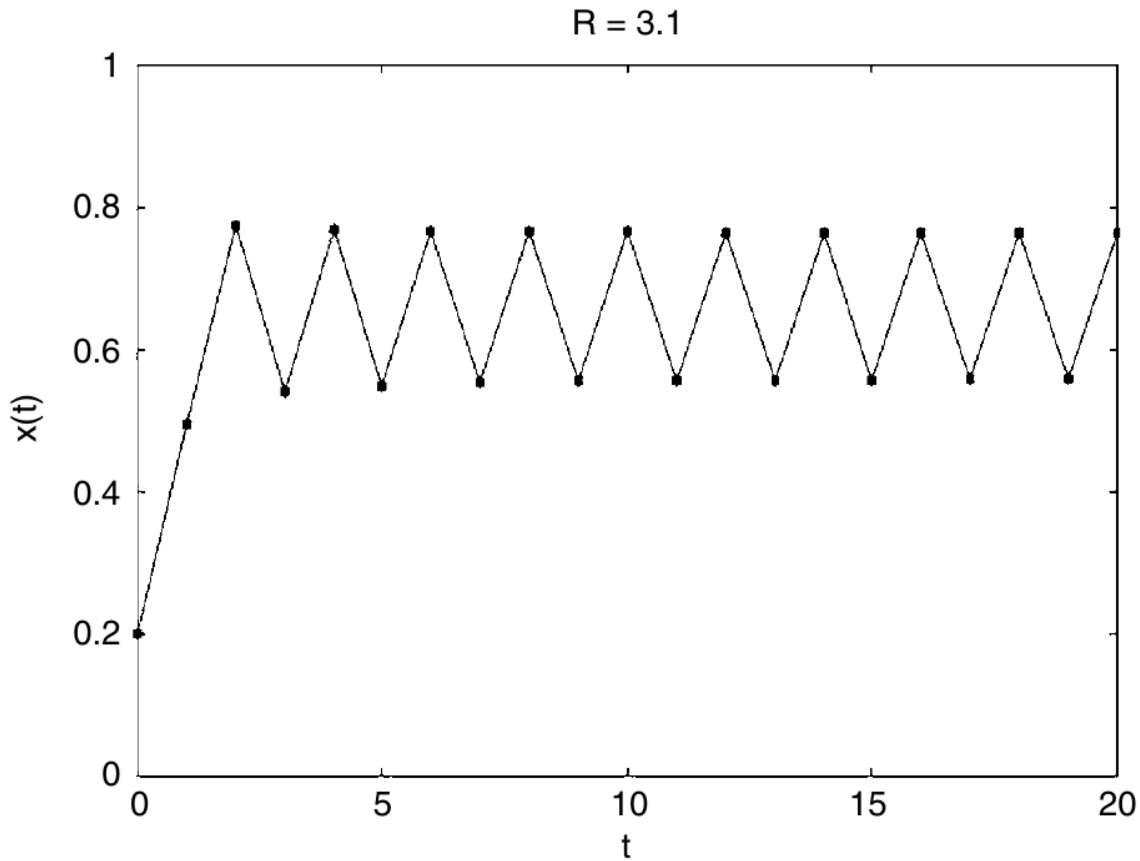

(Mitchell 2009)

Black-, Grey-, White-box Models

$$\frac{dP}{dt} = P \cdot r$$

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"deterministic chaos"

→ Sensitivity to initial conditions

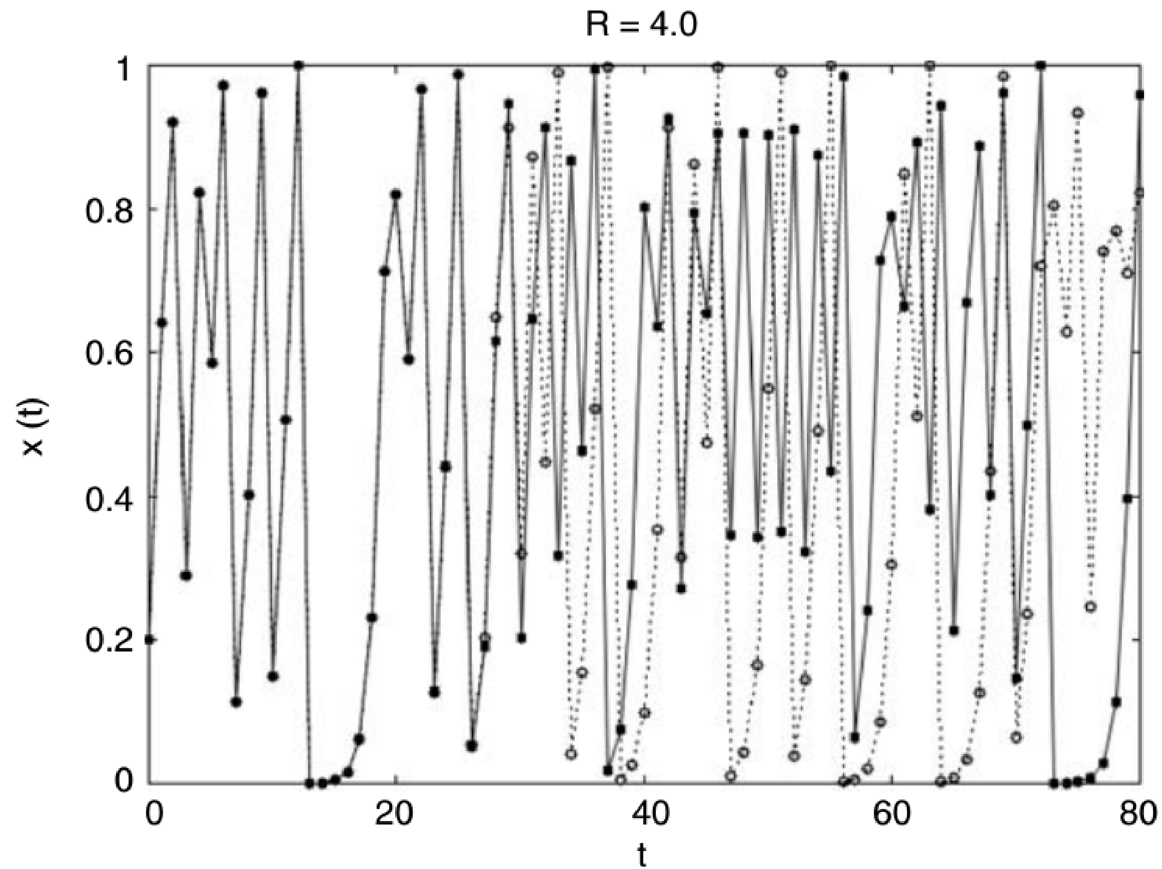


FIGURE 2.10. Two trajectories of the logistic map for $R = 4.0 : x_0 = 0.2$ and $x_0 = 0.2000000001$.

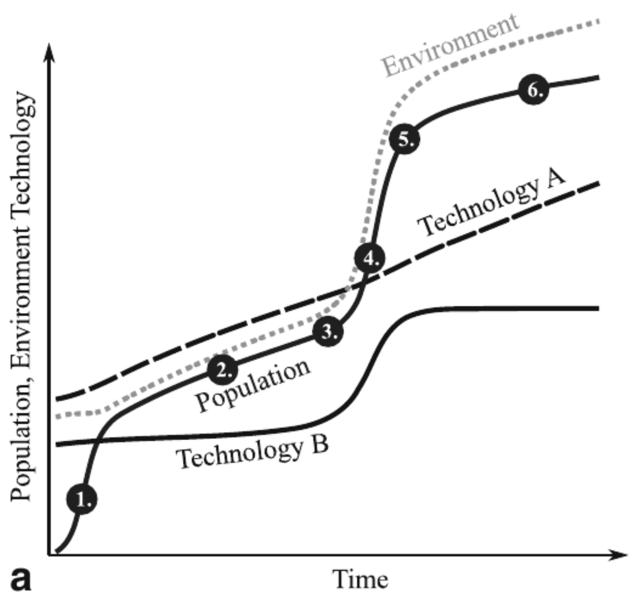
(Mitchell 2009)

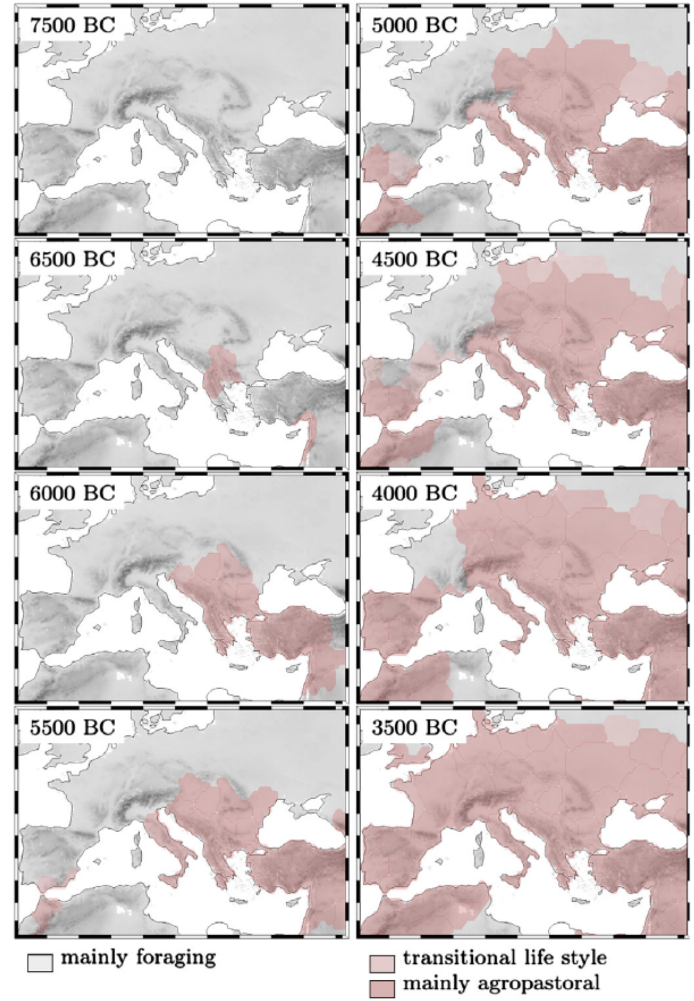
Black-, Grey-, White-box Models

$$\frac{dP}{dt} = P \cdot r$$

$$r = \mu \cdot (1 - \omega T_A) \cdot \left(1 - \gamma \sqrt{T_A} P\right) \cdot SI - \rho \cdot T_A^{-1} \cdot P$$

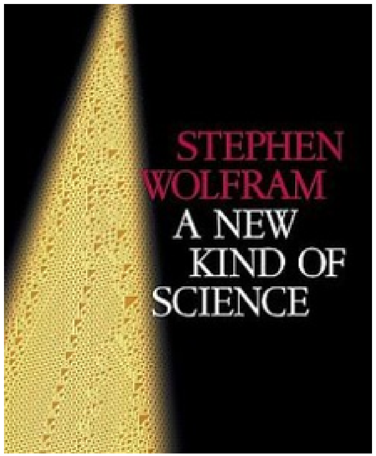
PET trajectories

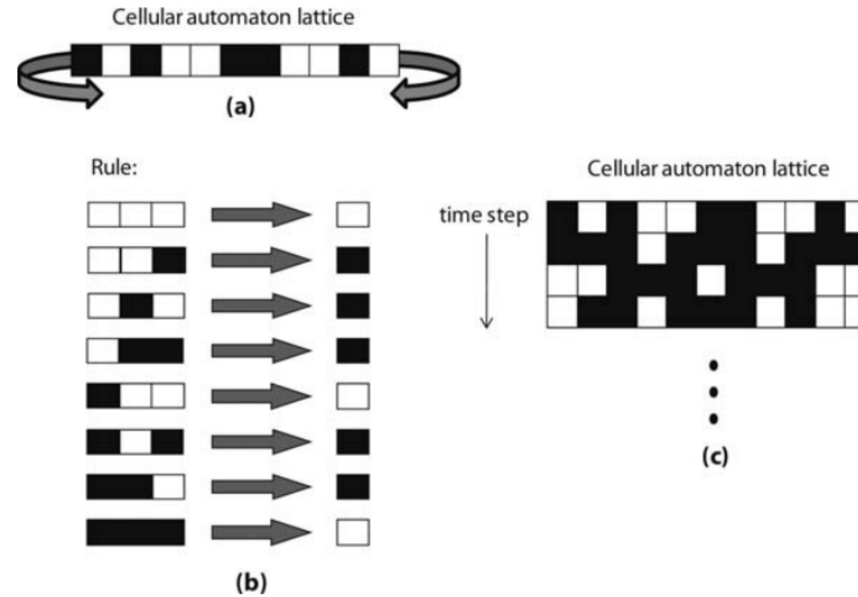


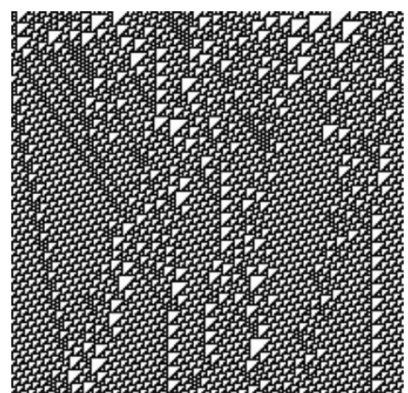


(Lemmen 2011, 2014)

Black-, Grey-, White-box Models







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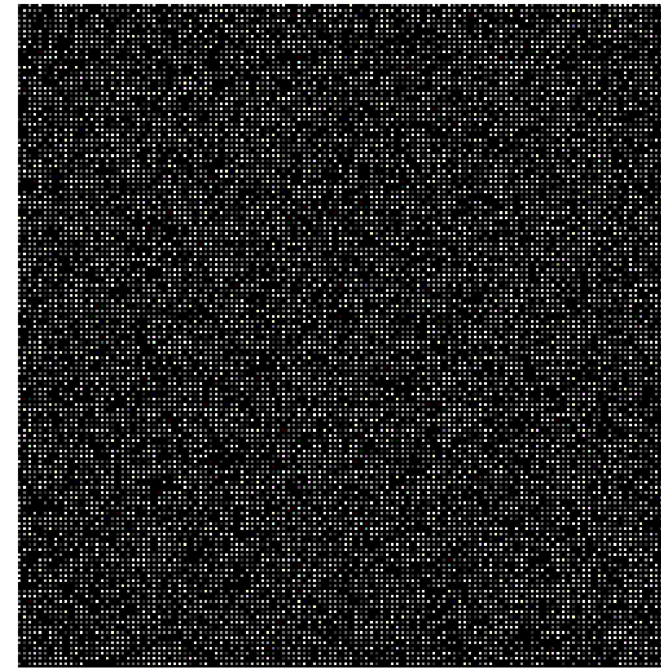
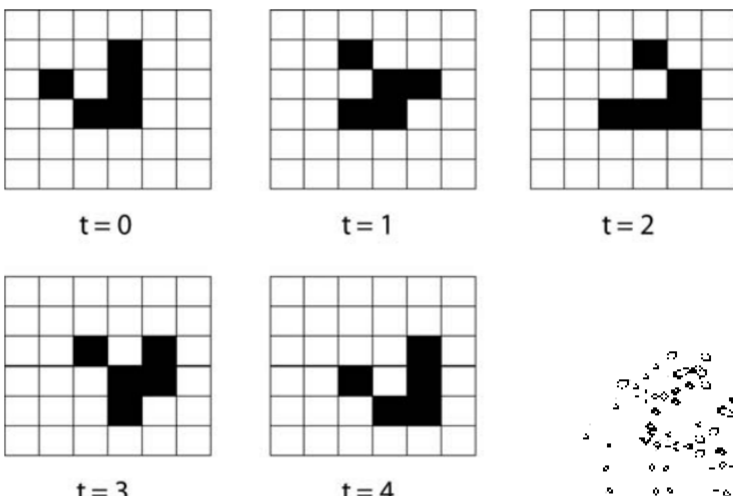
(Kalmykov 2014; Mitchell 2009)

Black-, Grey-, White-box Models



Conway's Game of life

- Any live cell with fewer than two live neighbours dies (loneliness)
- Any live cell with two or three live neighbours lives on to the next generation.
- Any live cell with more than three live neighbours dies (too crowded)
- Any dead cell with exactly three live neighbours becomes a live cell, as if by reproduction.



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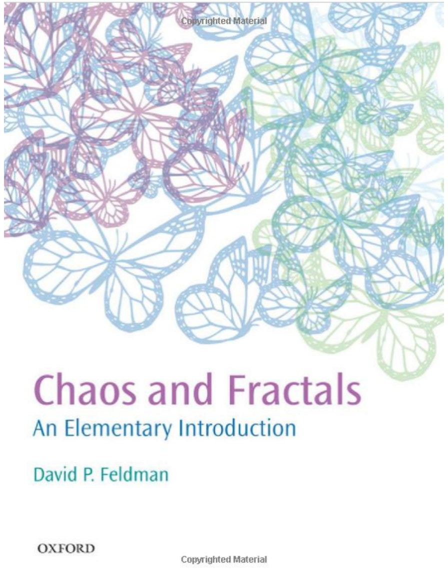
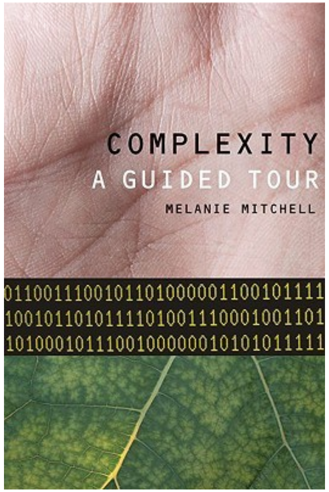
(Mitchell 2009, http://gjgreenberg.bol.ucla.edu/images/game.gif; https://upload.wikimedia.org/wikipedia/commons/e/e6/Conways_game_of_life_breeder_animation.gif)

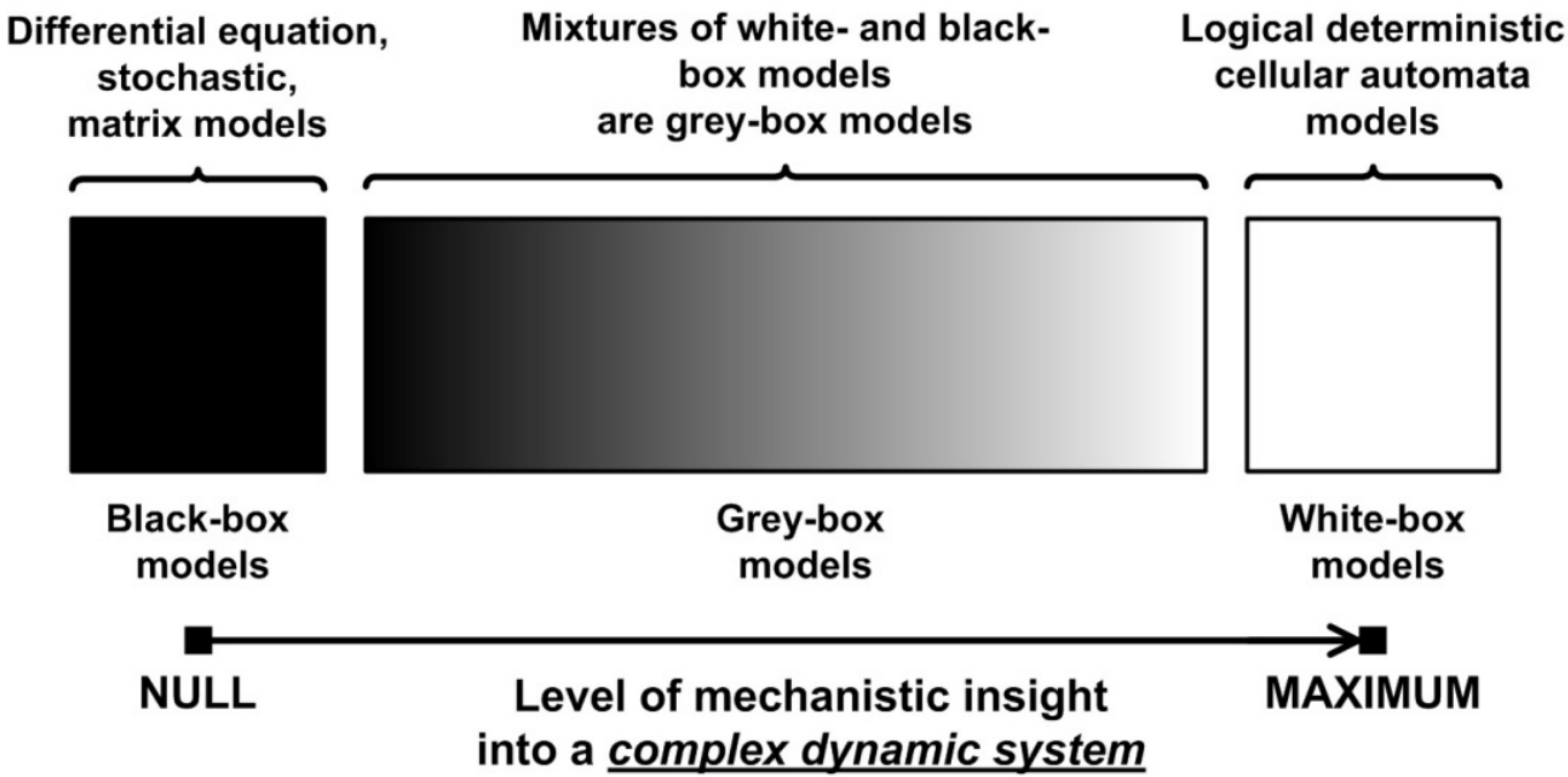
Black-, Grey-, White-box Models





https://www.complexityexplorer.org/

Black-, Grey-, White-box Models



(Kalmykov 2015)

Where to start?

Aus der Studienordnung

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http://www.fu-berlin.de/service/zuvdocs/amtsblatt/2012/ab742012.pdf

Spatial data are special

Pitfalls of spatial data:

→ spatial autocorrelation
→ modifiable areal unit problem
→ scale
→ ecological fallacy
→ non-uniformity of space
→ edge effects

Spatial autocorrelation

The Earth is not an isotropic plate

Spatial data is not random

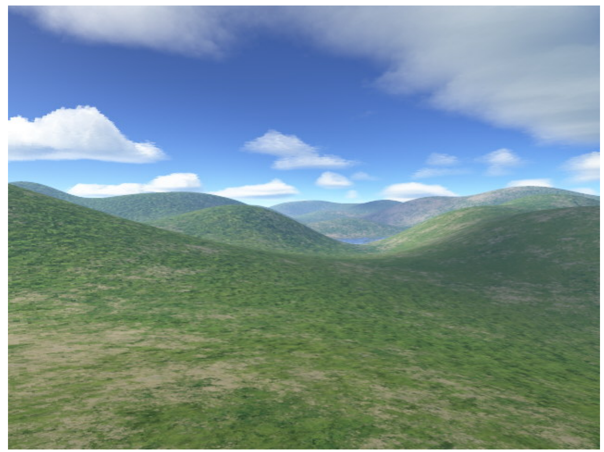
Data from locations near to each other are usually more similar than data far away from each other

Space and location are important because of Spatial autocorrelation.

Without spatial autocorrelation, spatial analyses would be pointless

Spatial autocorrelation

Low



High

Maximum

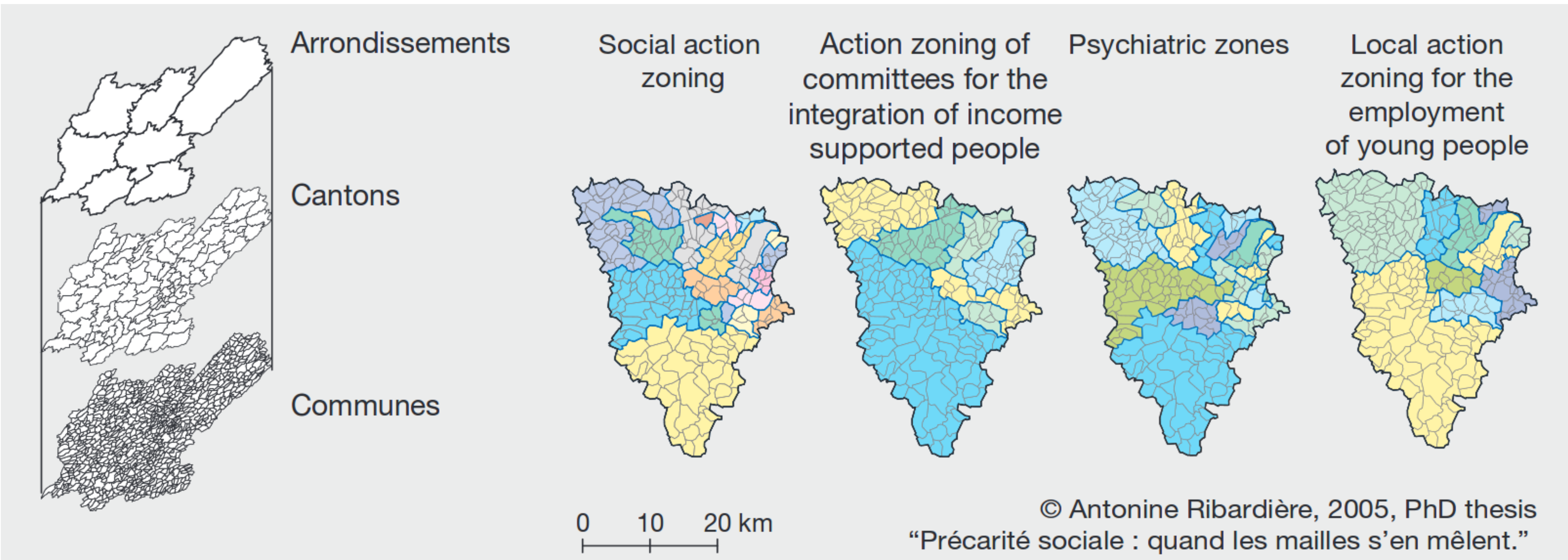
www.geog.ucsb.edu/~kclarke/G176B/Lecture12.ppt

Modifiable Areal Unit Problem (MAUP)

- aggregation units used are arbitrary with respect to the phenomena under investigation
- If spatial units are specified differently, one might get very different patterns

→ Openshaw, Stan (1984): The modifiable areal unit problem

Modifiable Areal Unit Problem (MAUP)



http://www.bbsr.bund.de/BBSR/DE/Veroeffentlichungen/IzR/2009/10_11/Inhalt/DL_Madelin_ua.pdf?__blob=publicationFile&v=2

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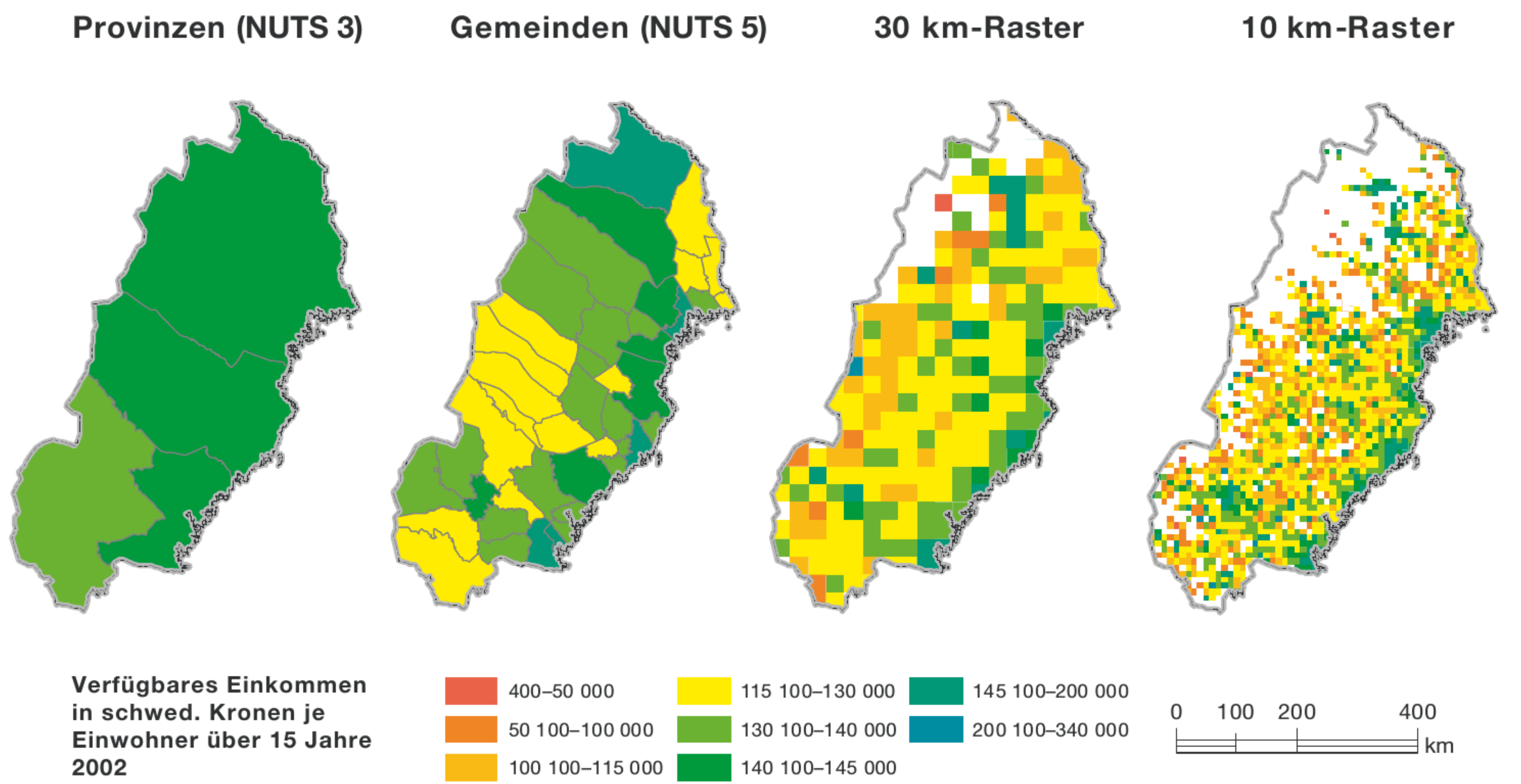

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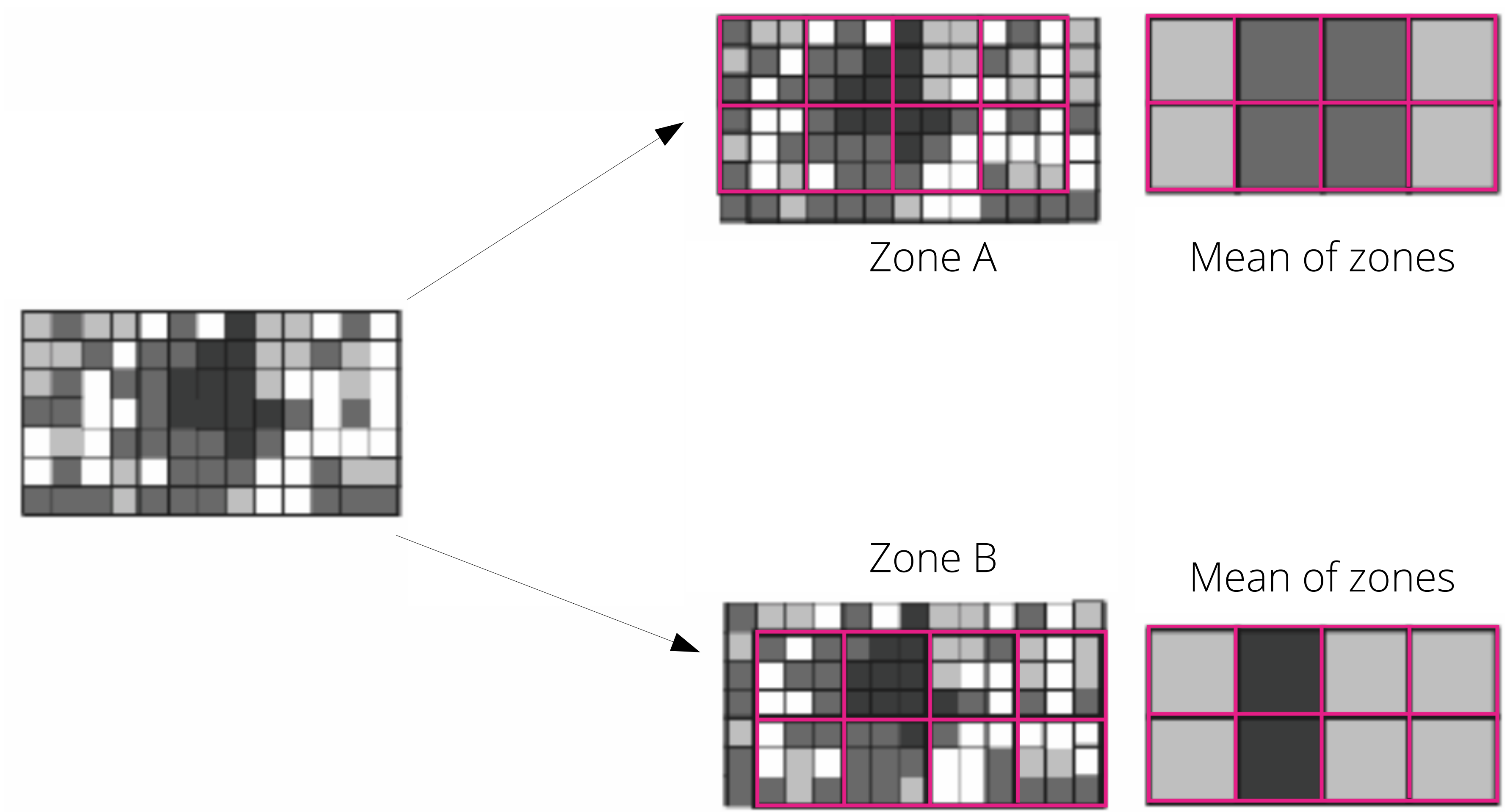

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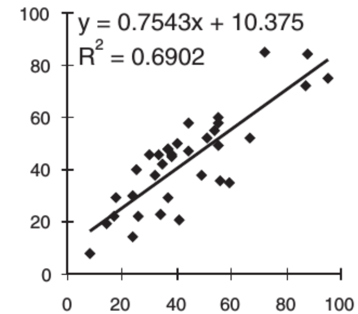
Modifiable Areal Unit Problem (MAUP)

Independent variable

87	95	72	37	44	24
40	55	55	38	88	34
41	30	26	35	38	24
14	56	37	34	8	18
49	44	51	67	17	37
55	25	33	32	59	54

Dependent variable

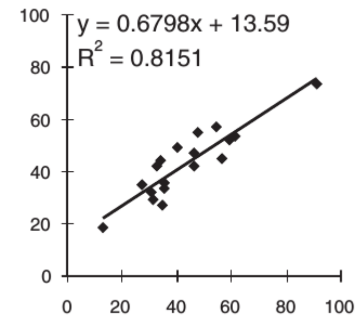
72	75	85	29	58	30
50	60	49	46	84	23
21	46	22	42	45	14
19	36	48	23	8	29
38	47	52	52	22	48
58	40	46	38	35	55



Aggregation scheme 1

91	54.5	34
47.5	46.5	61
35.5	30.5	31
35	35.5	13
46.5	59	27
40	32.5	56.5

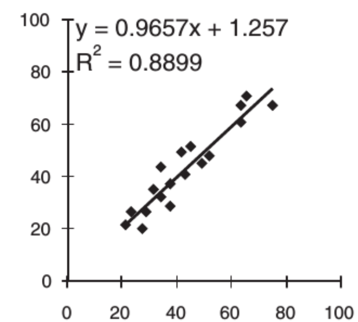
73.5	57	44
55	47.5	53.5
33.5	32	29.5
27.5	35.5	18.5
42.5	52	35
49	42	45



Aggregation scheme 2

63.5	75	63.5	37.5	66	29
27.5	43	31.5	34.5	23	21
52	34.5	42	49.5	38	45.5

61	67.5	67	37.5	71	26.5
20	41	35	32.5	26.5	21.5
48	43.5	49	45	28.5	51.5



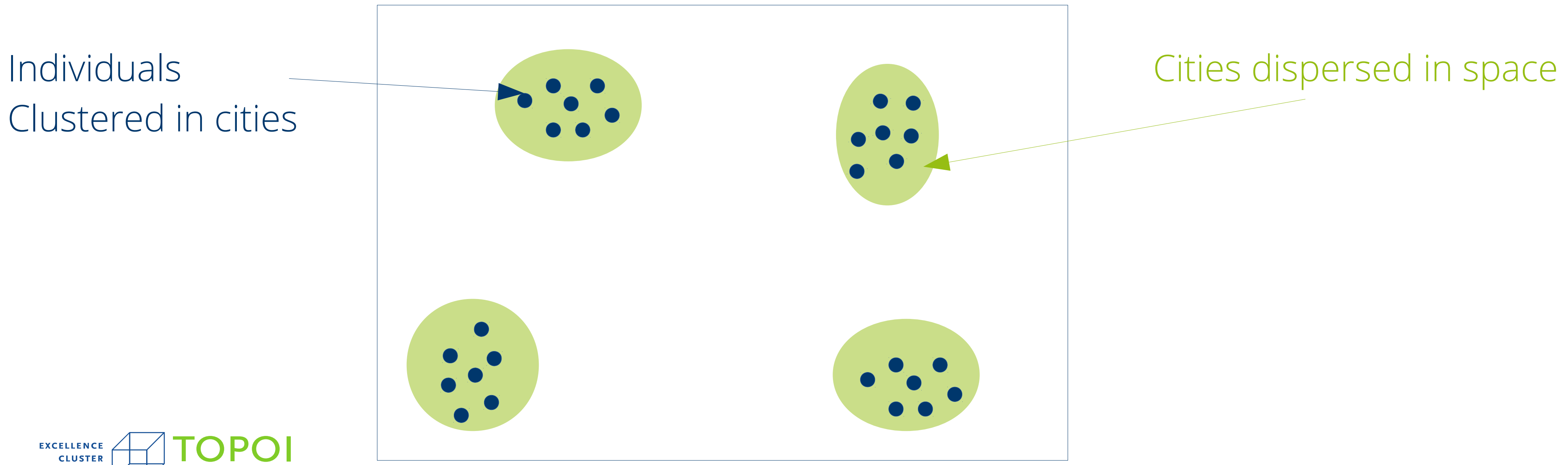
(O'Sullivan & Unwin, 2010)

Scale effects

- Scale affects results and representativity of data

- e.g. cities may be represented as points or polygons

- results depend on the scale of analysis, e.g. province or county → MAUP



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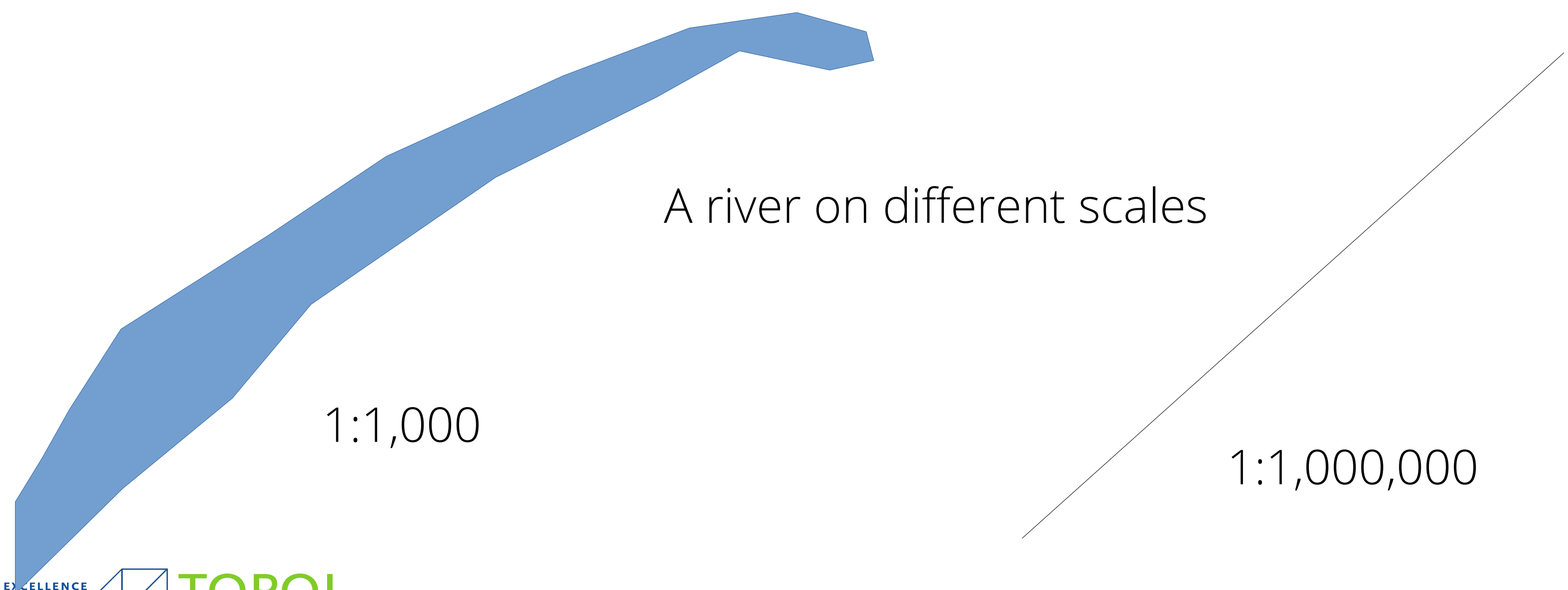


A river on different scales

Ecological fallacy

Arises when:
- Statistical relationship at one level of aggregation...
- ...is assumed to hold true because it holds at a more detailed level

For example, we might observe a strong relationship between income and crime at the county level, with lower-income counties being associated with higher crime rates. If from this we conclude that lower-income individuals are more likely to commit a crime, then we are falling for the ecological fallacy. In fact, it is only valid to say exactly what the data say: that lower-income counties tend to experience higher crime rates. What causes the observed effect may be something entirely different

(O'Sullivan & Unwin, 2010)

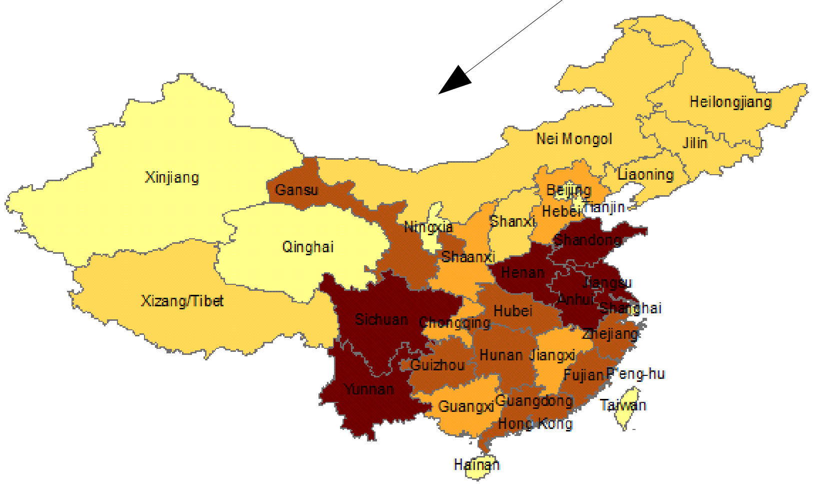
Non-uniformity of space

Bank robberies are clustered
→ because banks are clustered

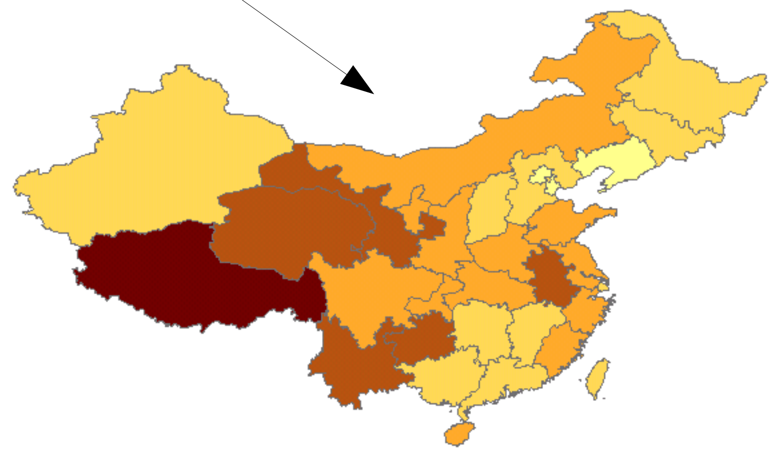
Diseases due to bad air are clustered
→ because factories are clustered

Illiteracy in China

absolute



as ratio of population



Edge effects

- unless you study the entire world: Every study region has a boundary

- You do not have data for outside your study region

- But: the “outside” data may/do affect the data of your study region (if there is spatial autocorrelation...)

Spatial data are special

Pitfalls of spatial data:

→ spatial autocorrelation
→ modifiable areal unit problem
→ scale
→ ecological fallacy
→ non-uniformity of space
→ edge effects

Potentials of spatial data:

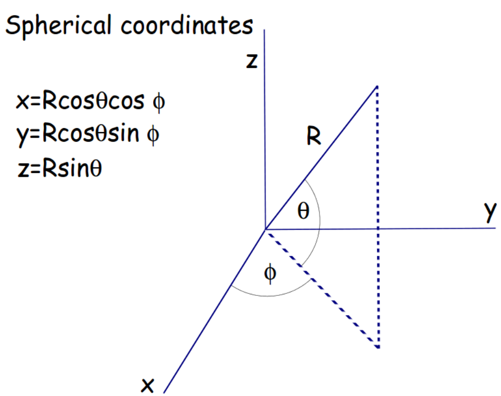
→ distance
→ adjacency
→ interaction
→ neighborhood

Distance

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$$

Euclidean distance as calculated using *Pythagoras'* formula

→ for *projected* data on the local/regional scale



R = radius of earth, ca. 6378 km

Spherical distance via spherical coordinates and a 3D version of *Pythagoras'* formula

$$d^2 = (x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2$$

→ for *unprojected* data on a global scale

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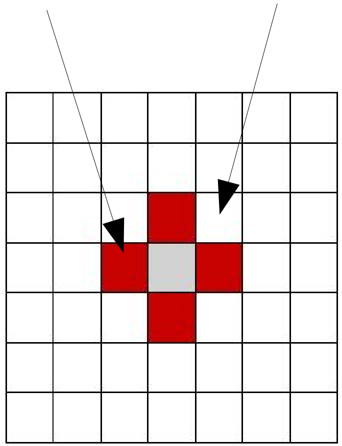
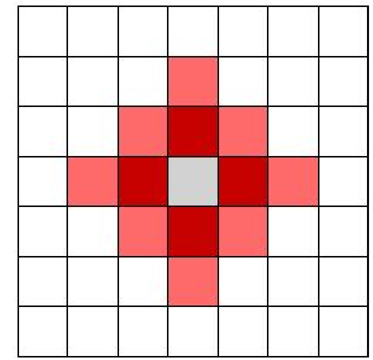
https://www.math.ksu.edu/~dbski/writings/haversine.pdf

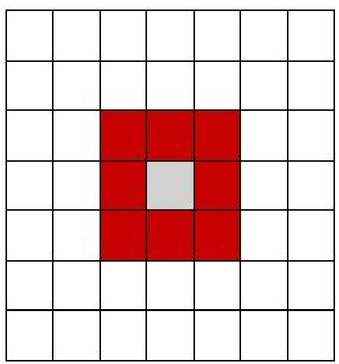
Adjacency

Binary
→ things are adjacent or not

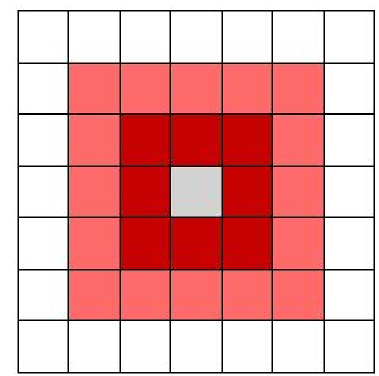


Rook case
→ sharing a boundary





Queen case
→ sharing a boundary or point



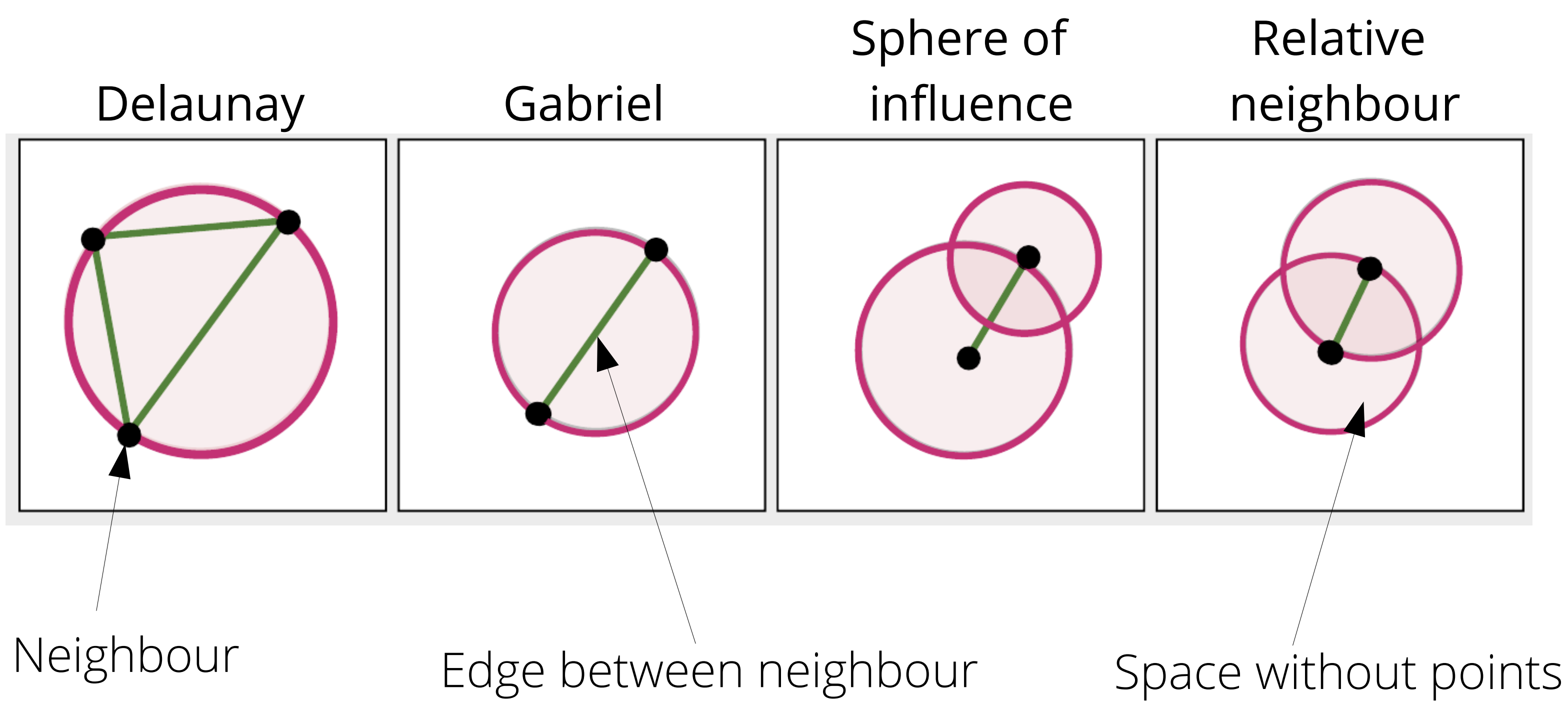
1st order neighbor

2nd order neighbor

and also...distance based neighbors...

Adjacency

...or graph based neighbors.



Interaction

- A combination of distance and adjacency
- related to Tobler's first law of geography:

"(...) everything is related to everything else,
but near things are more related
than distant things" (Tobler 1970, 236)

rate of decline

interaction *weight*
between *I* and *j*

$$w_{ij} \propto \frac{1}{d^k}$$

distance between *I* and *j*

...strength of interaction between I and j is proportional to their inverse distance

Neighborhood

Neighborhood of X is:
- the set of adjacent cells/areas
- the set of points/cells/areas within a certain distance
- the set of points/cells/areas that share some specific attribute or that are alike

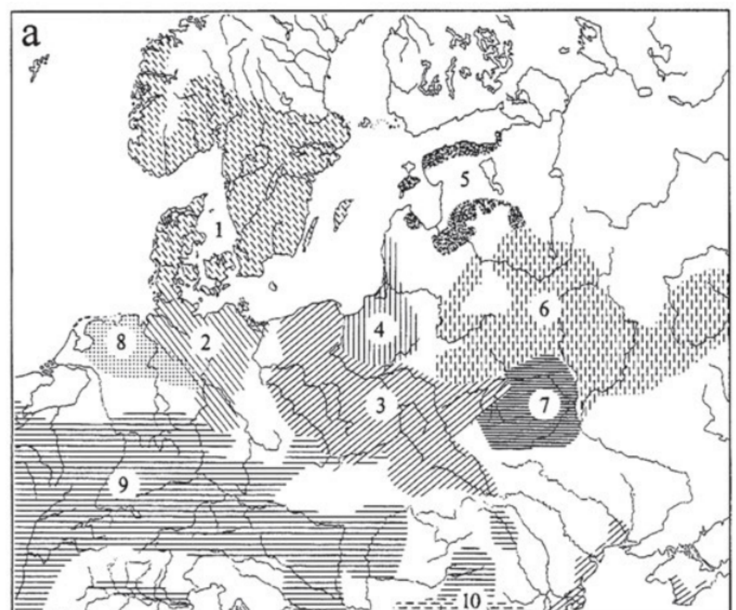
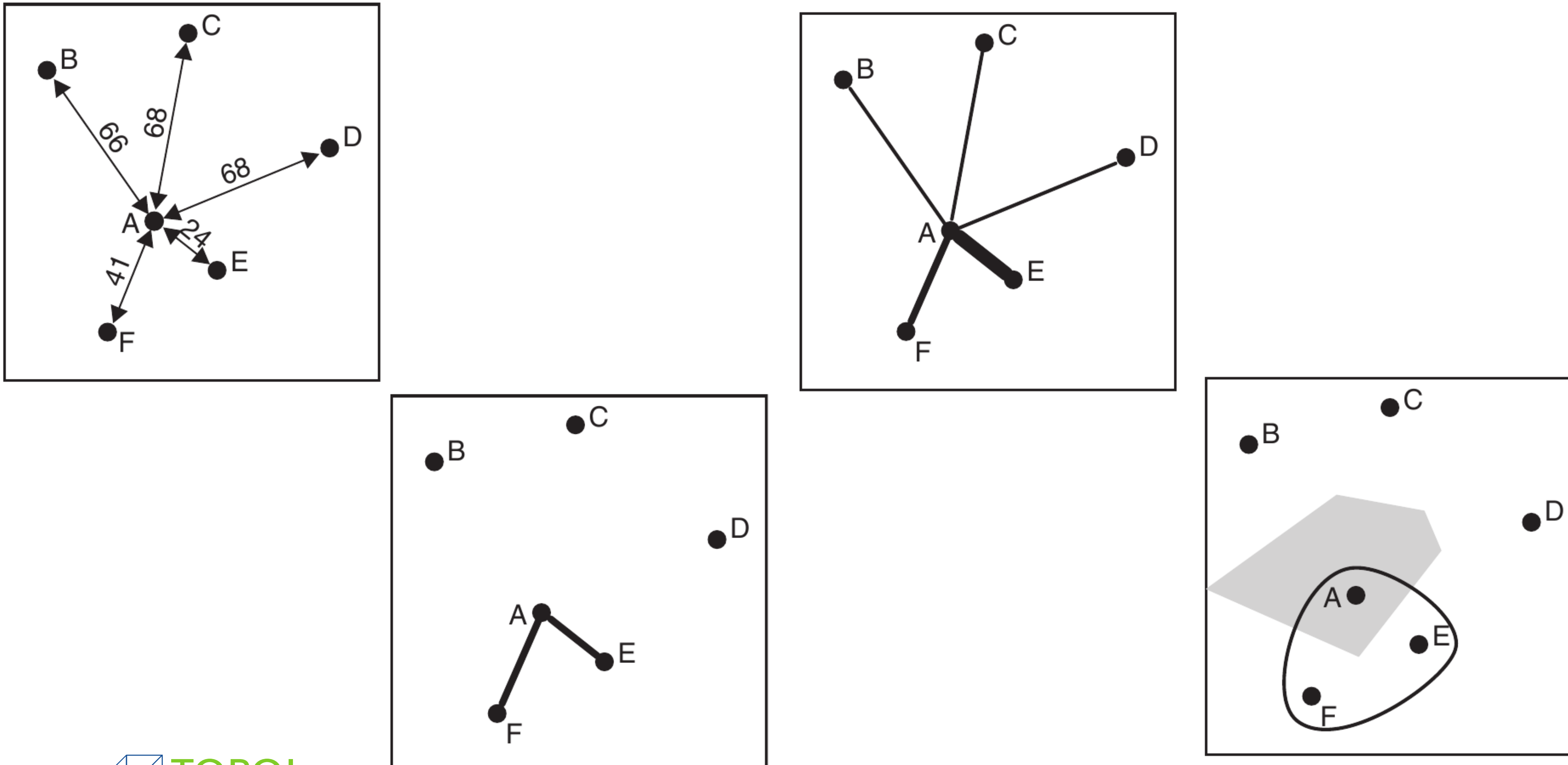


Abb. 11.4. Karte ältereisenzeitlicher Kulturen (Mey10, Abb. 1), die Nummern verweisen auf einzelne eisenzeitliche Kulturen, die mit unterschiedlichen Signaturen angezeigt sind.

Distance – Adjacency – Interaction - Neighborhood



(O'Sullivan & Unwin, 2010)

Distance – Adjacency – Interaction - Neighborhood

$$\mathbf{D} = \begin{bmatrix} 0 & 66 & 68 & 68 & 24 & 41 \\ 66 & 0 & 51 & 110 & 99 & 101 \\ 68 & 51 & 0 & 67 & 91 & 116 \\ 68 & 110 & 67 & 0 & 60 & 108 \\ 24 & 99 & 91 & 60 & 0 & 45 \\ 41 & 101 & 116 & 108 & 45 & 0 \end{bmatrix}$$

(O'Sullivan & Unwin, 2010)

Distance – Adjacency – Interaction - Neighborhood

$$\mathbf{A}_{k=3} = \begin{bmatrix} * & 1 & 0 & 0 & 1 & 1 \\ 1 & * & 1 & 0 & 1 & 0 \\ 1 & 1 & * & 1 & 0 & 0 \\ 1 & 0 & 1 & * & 1 & 0 \\ 1 & 0 & 0 & 1 & * & 1 \\ 1 & 1 & 0 & 0 & 1 & * \end{bmatrix}$$

$$\mathbf{A}_{d \leq 50} = \begin{bmatrix} * & 0 & 0 & 0 & 1 & 1 \\ 0 & * & 0 & 0 & 0 & 0 \\ 0 & 0 & * & 0 & 0 & 0 \\ 0 & 0 & 0 & * & 0 & 0 \\ 1 & 0 & 0 & 0 & * & 1 \\ 1 & 0 & 0 & 0 & 1 & * \end{bmatrix}$$

(O'Sullivan & Unwin, 2010)

Distance – Adjacency – Interaction - Neighborhood

$$\mathbf{W} = \begin{bmatrix} \infty & 0.0152 & 0.0147 & 0.0147 & 0.0417 & 0.0244 \\ 0.0152 & \infty & 0.0196 & 0.0091 & 0.0101 & 0.0099 \\ 0.0147 & 0.0196 & \infty & 0.0149 & 0.0110 & 0.0086 \\ 0.0147 & 0.0091 & 0.0149 & \infty & 0.0167 & 0.0093 \\ 0.0417 & 0.0101 & 0.0110 & 0.0167 & \infty & 0.0222 \\ 0.0244 & 0.0099 & 0.0086 & 0.0093 & 0.0222 & \infty \end{bmatrix} \quad \begin{array}{c} \text{row totals:} \\ 0.1106 \\ 0.0639 \\ 0.0688 \\ 0.0646 \\ 0.1016 \\ 0.0744 \end{array}$$

W[1,2] = W[1,] / sum(W[1,])

...

$$\mathbf{W} = \begin{bmatrix} \infty & 0.1370 & 0.1329 & 0.1329 & 0.3767 & 0.2205 \\ 0.2373 & \infty & 0.3071 & 0.1424 & 0.1582 & 0.1551 \\ 0.2136 & 0.2848 & \infty & 0.2168 & 0.1596 & 0.1252 \\ 0.2275 & 0.1406 & 0.2309 & \infty & 0.2578 & 0.1432 \\ 0.4099 & 0.0994 & 0.1081 & 0.1640 & \infty & 0.2186 \\ 0.3279 & 0.1331 & 0.1159 & 0.1245 & 0.2987 & \infty \end{bmatrix}$$

$$\begin{array}{ccccccc} \text{column totals:} & 1.4161 & 0.7949 & 0.8949 & 0.7805 & 1.2510 & 0.8626 \end{array}$$

Influence of element A on all other elements

(O'Sullivan & Unwin, 2010)

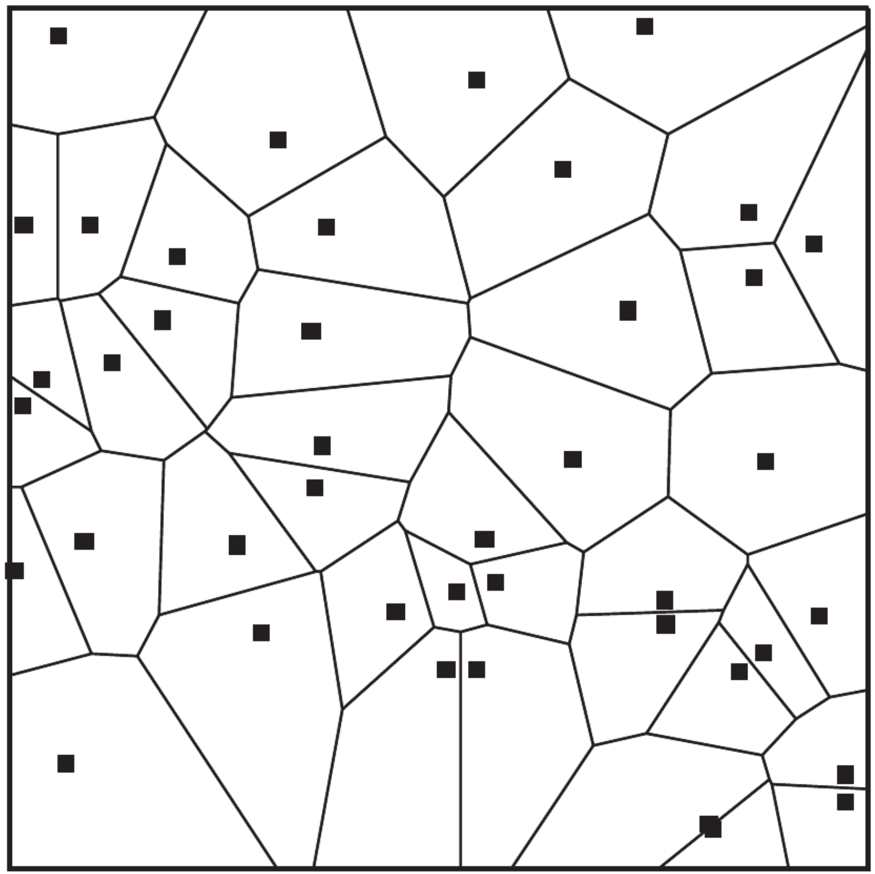
Voronoi/Thiessen polygons

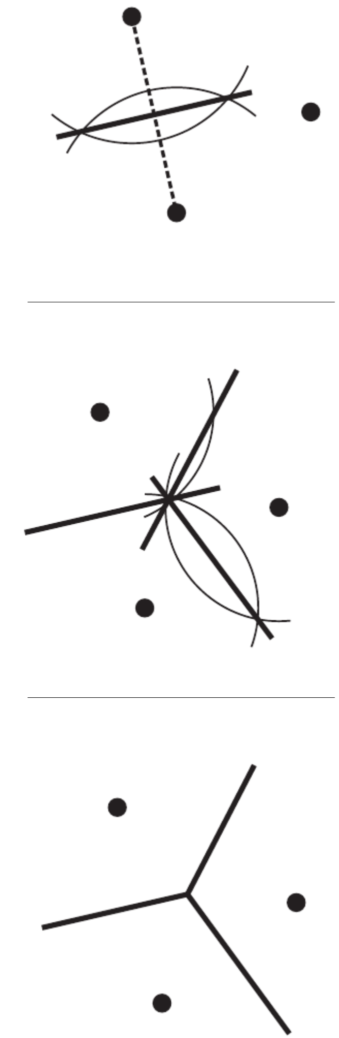
Adjacency

Interaction

Distance

Neighborhood





(O'Sullivan & Unwin, 2010)

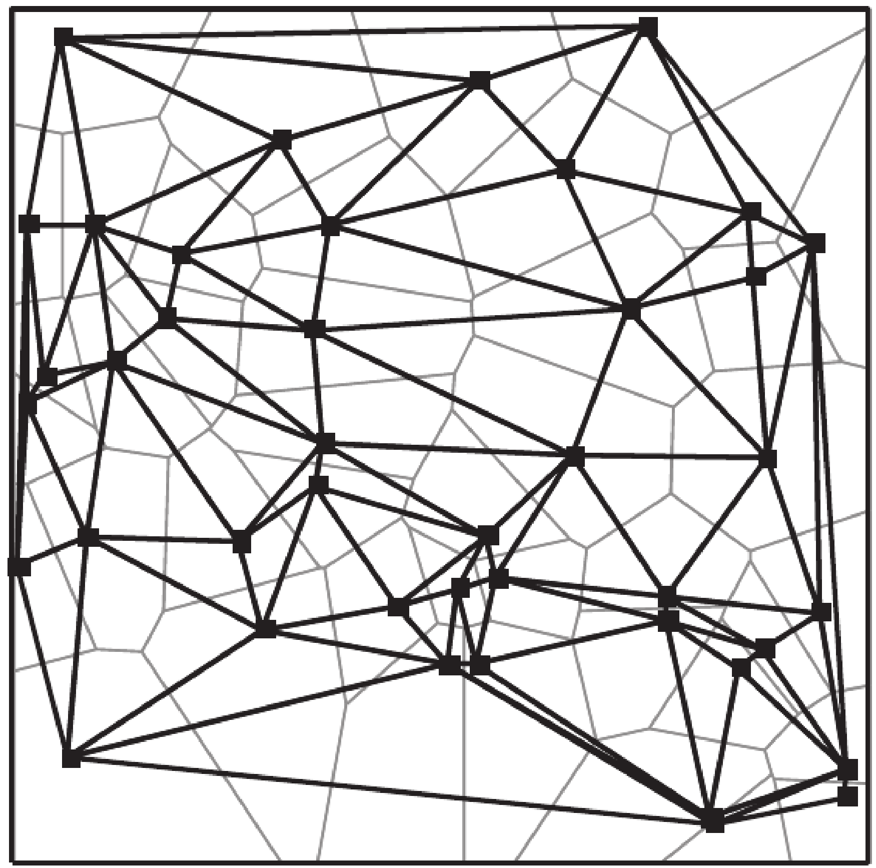
Voronoi/Thiessen polygons

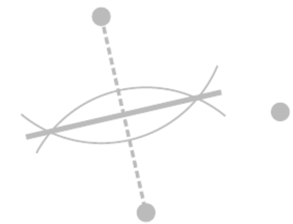
Adjacency

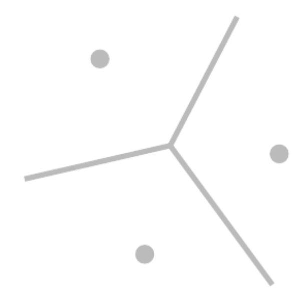
Interaction

Distance

Neighborhood







Proximity polygon sharing an edge….Delaunay triangulation

(O'Sullivan & Unwin, 2010)

Spatial data are special

Pitfalls of spatial data:

→ spatial autocorrelation
→ modifiable areal unit problem
→ scale
→ ecological fallacy
→ non-uniformity of space
→ edge effects

Potentials of spatial data:

→ distance
→ adjacency
→ interaction
→ neighborhood

...it's all about processes

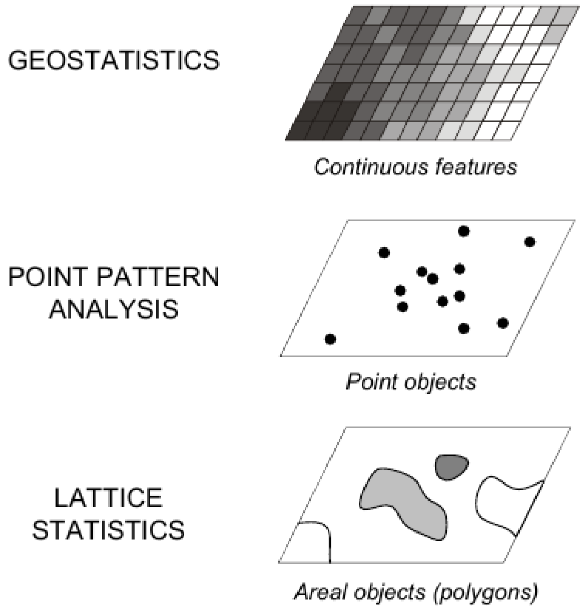


Fig. 1.2: Spatial statistics and its three major subfields after Cressie (1993).

However you call it and focus on...

Everything is about processes...

Because they are the cause of spatial patterning, Autocorrelation, ...

(Hengl, 2009)

https://userpage.fu-berlin.de/~dare211/VS_Modellierung/Intro_R.html