

A state-space representation to assess urban change

Alex Hagen-Zanker

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Research context

- Understanding urban processes by analysis of urban form
- Urban systems are far-from-equilibrium
 - Drivers (e.g. population & economy) change faster than urban form
- Therefore analysis of *changes*, rather than states

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- Cellular automata
- Agent based models
- Spatial interaction

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Explanatory models of **dynamics**

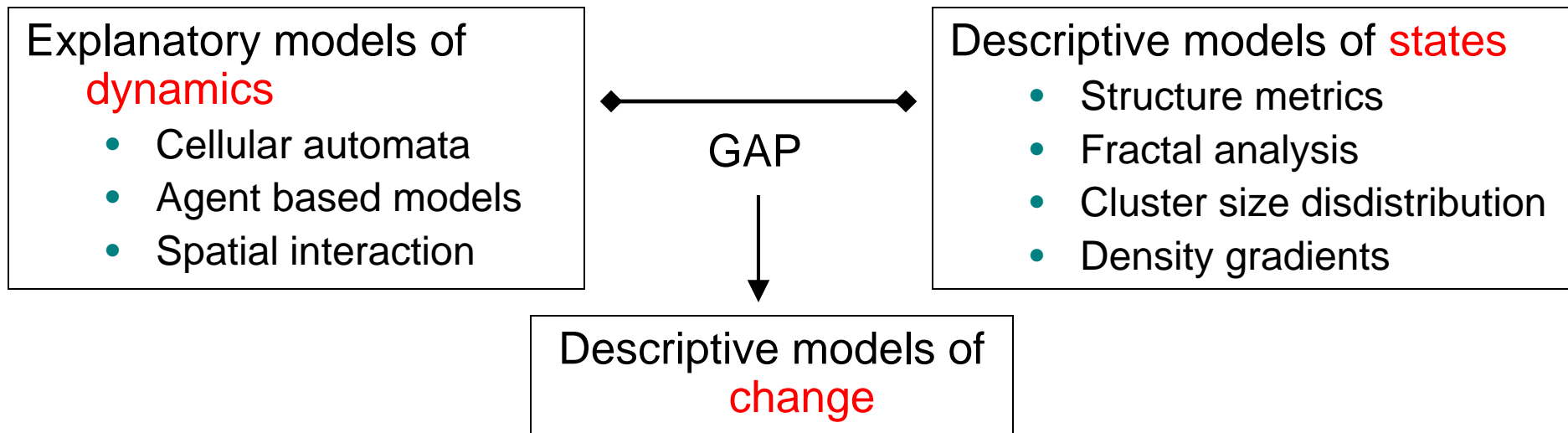
- Cellular automata
- Agent based models
- Spatial interaction

Descriptive models of **states**

- Structure metrics
- Fractal analysis
- Cluster size disdistribution
- Density gradients

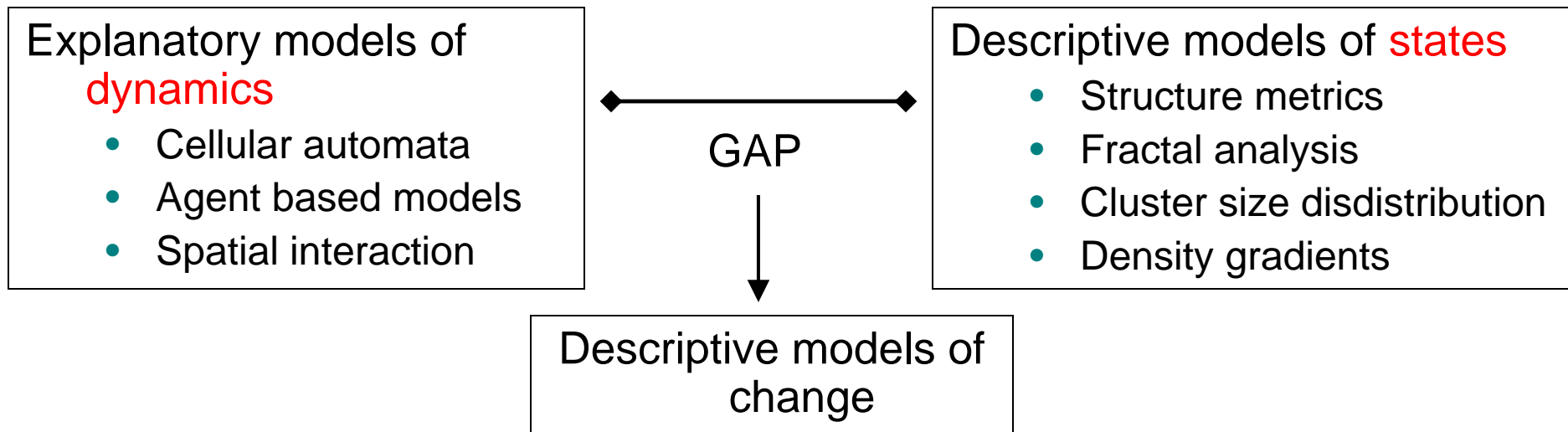
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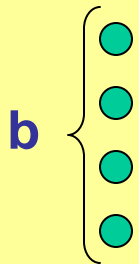
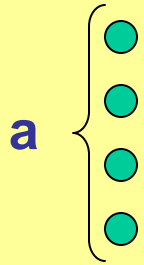
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Richer information by delaying the aggregation

NOT LIKE THIS

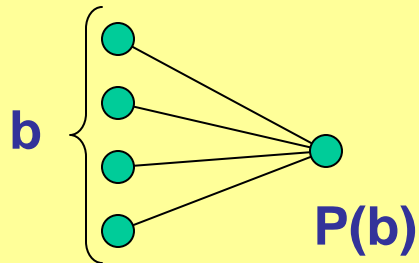
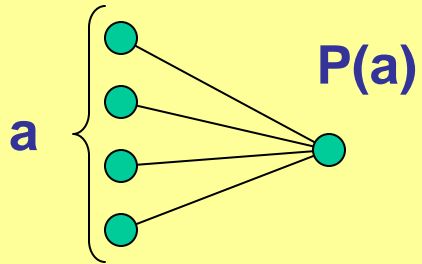
Change [Pattern (a), Pattern (b)]



Richer information by delaying the aggregation

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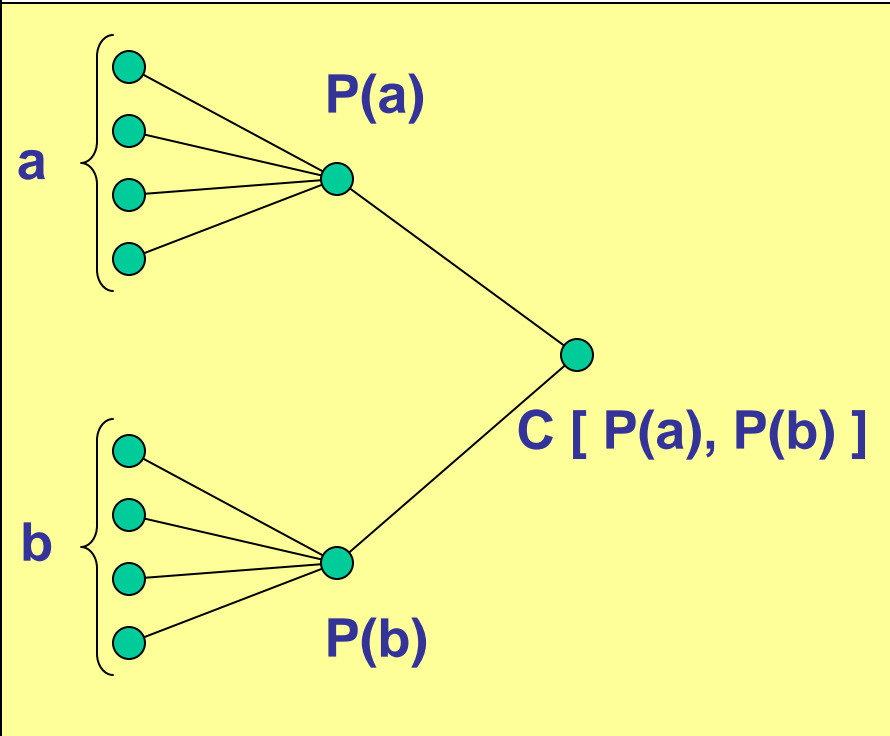
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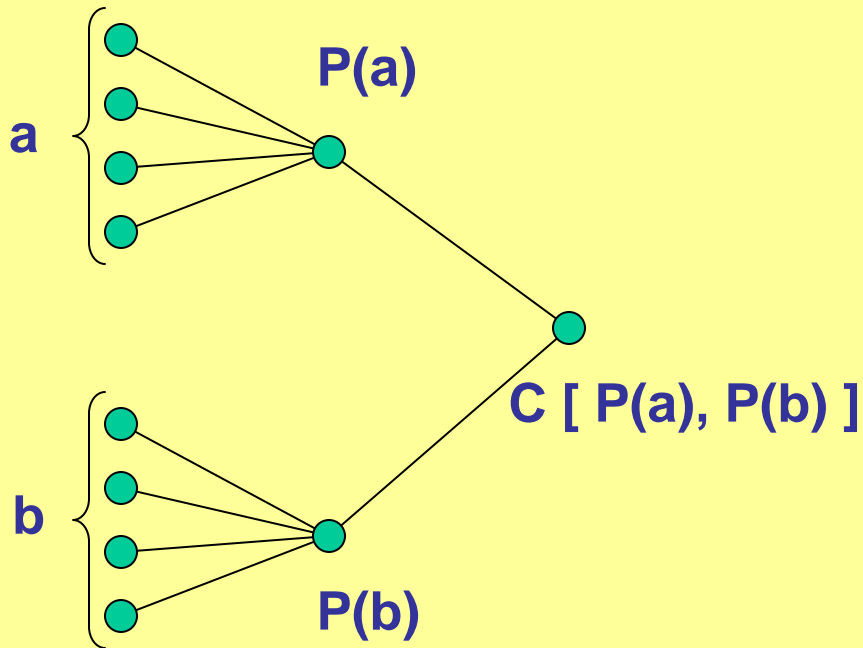
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Richer information by delaying the aggregation

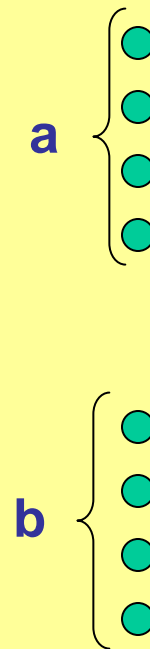
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BUT LIKE THIS

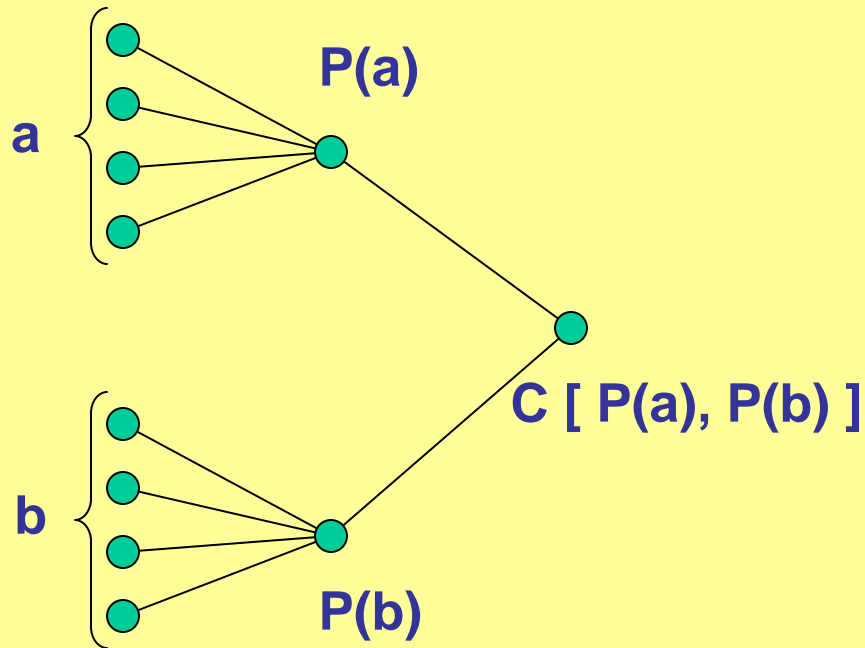
Pattern (Change [a , b])



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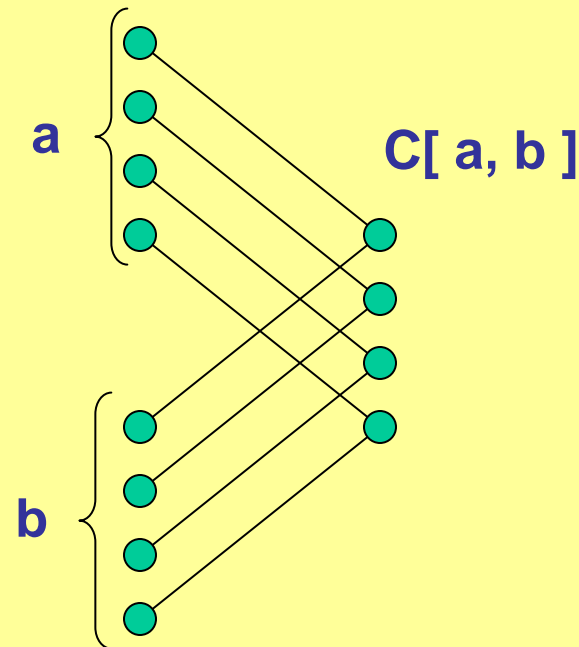
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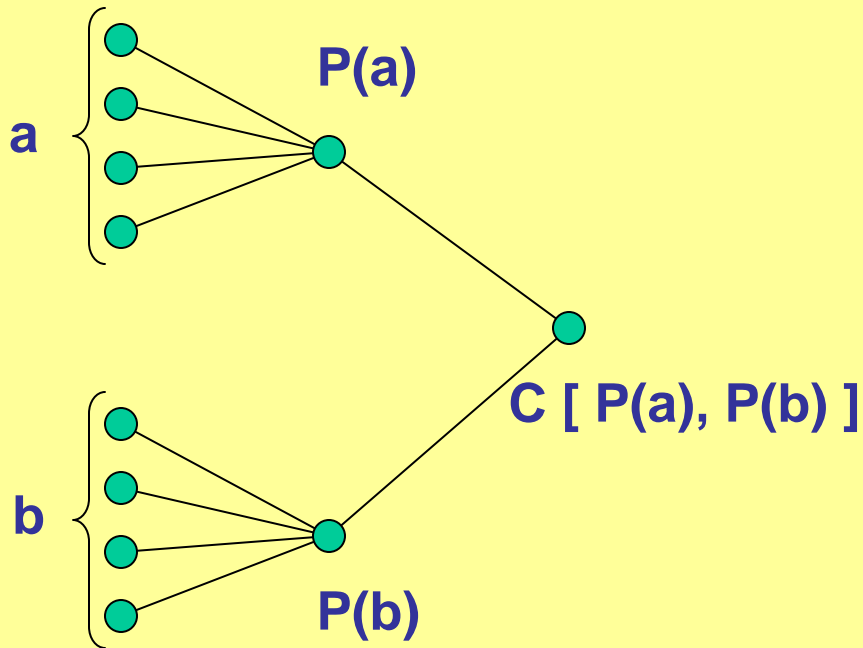
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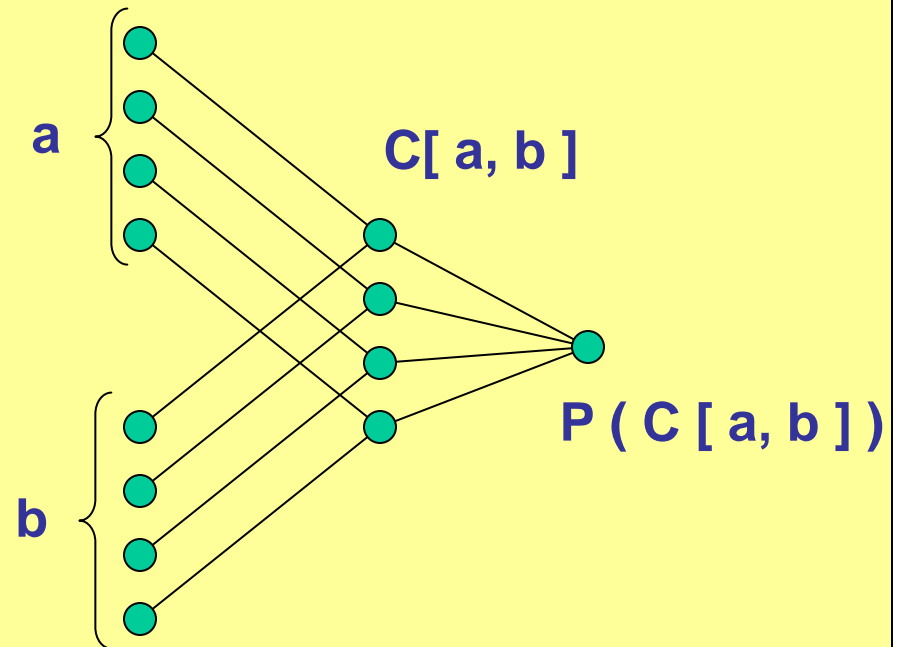
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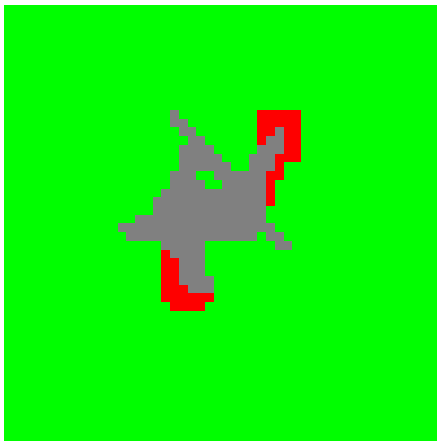
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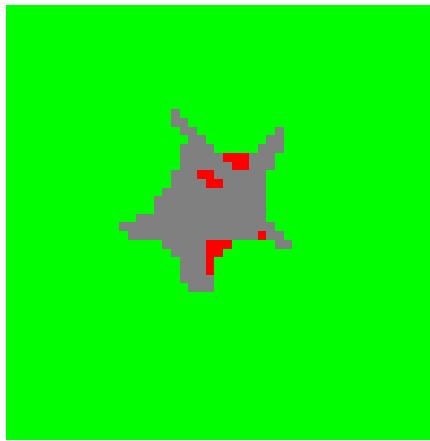


Some earlier work

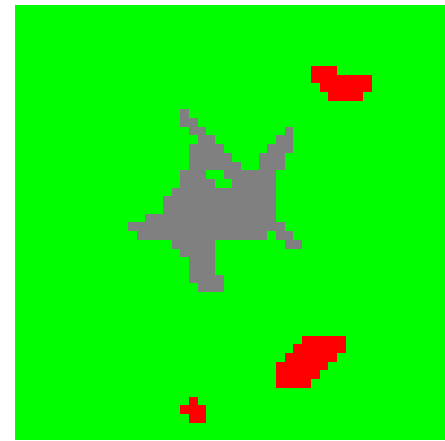
- Classification of change forms
 - Wilson et al. 2003, Remote Sensing of Environment
 - Xu et al. 2007, Landscape Ecology
- Three main classes of urban growth (Wilson et al. have 2 more)



Edge

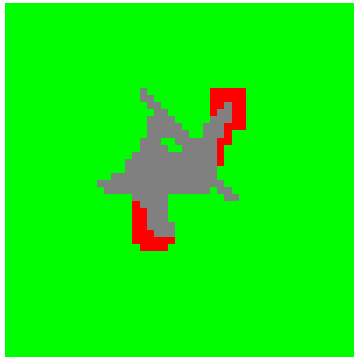


Infill

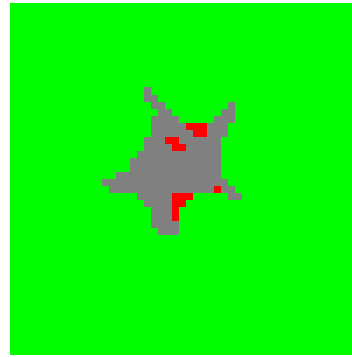


Spontaneous

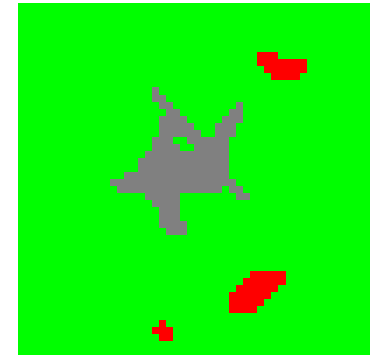
Intuitive classification, but many border cases



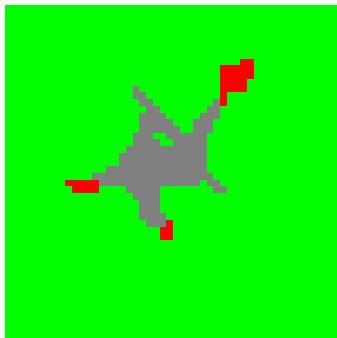
Edge



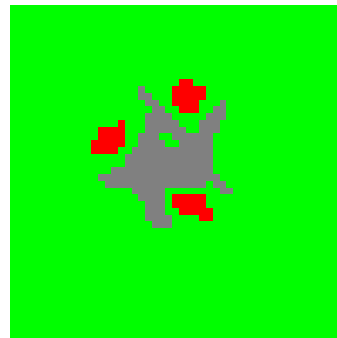
Infill



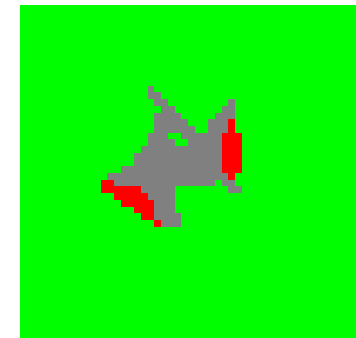
Spontaneous



Edge / Spont.



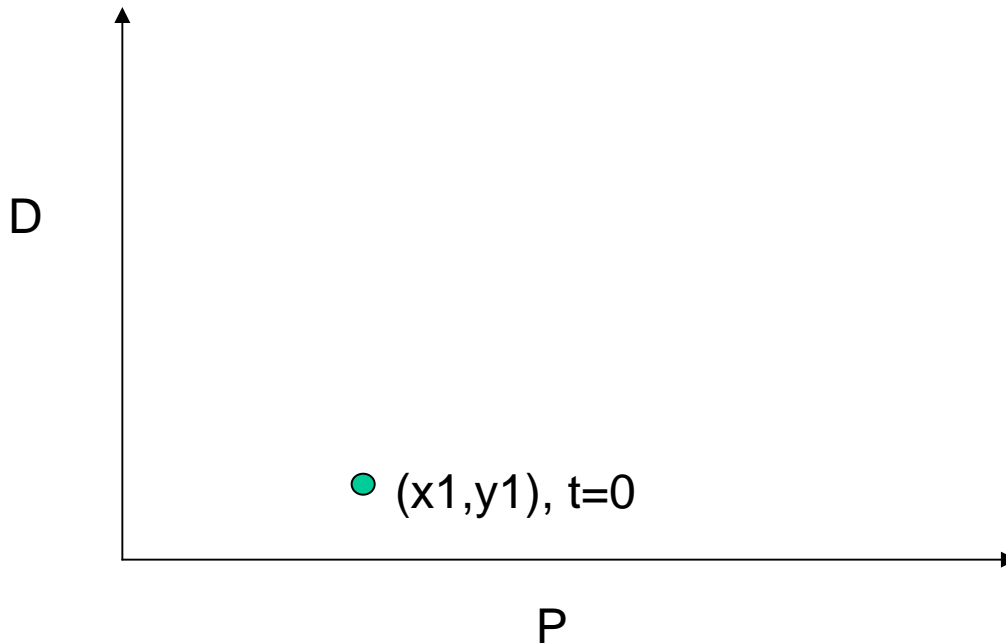
Infill / Spont.



Edge / Infill

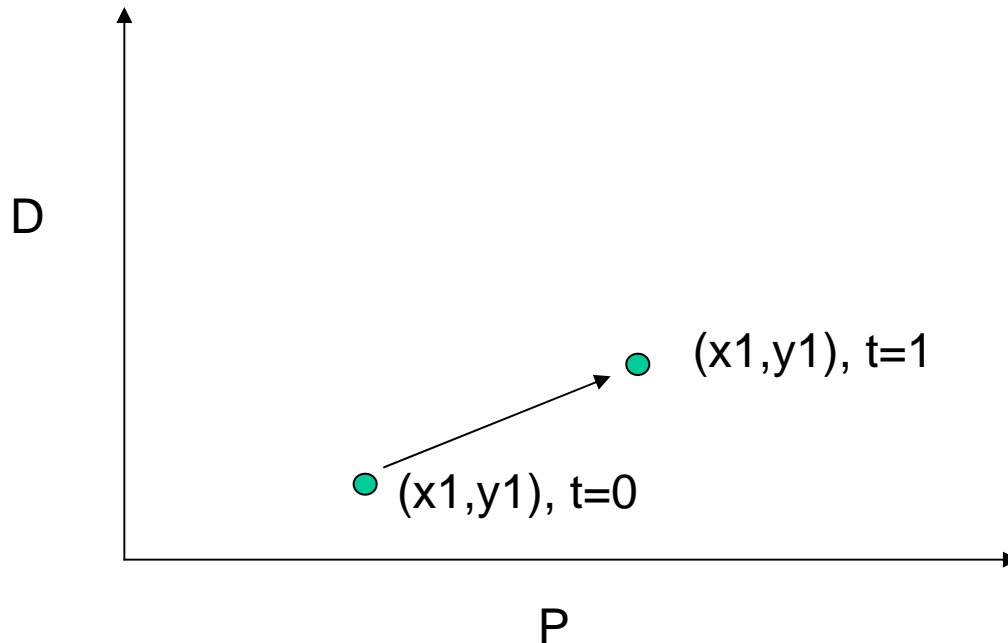
Methodology(1): State space

- N-dimensional state-space, e.g.:
 - Population (P) within 2500 m
 - Distance (D) to nature



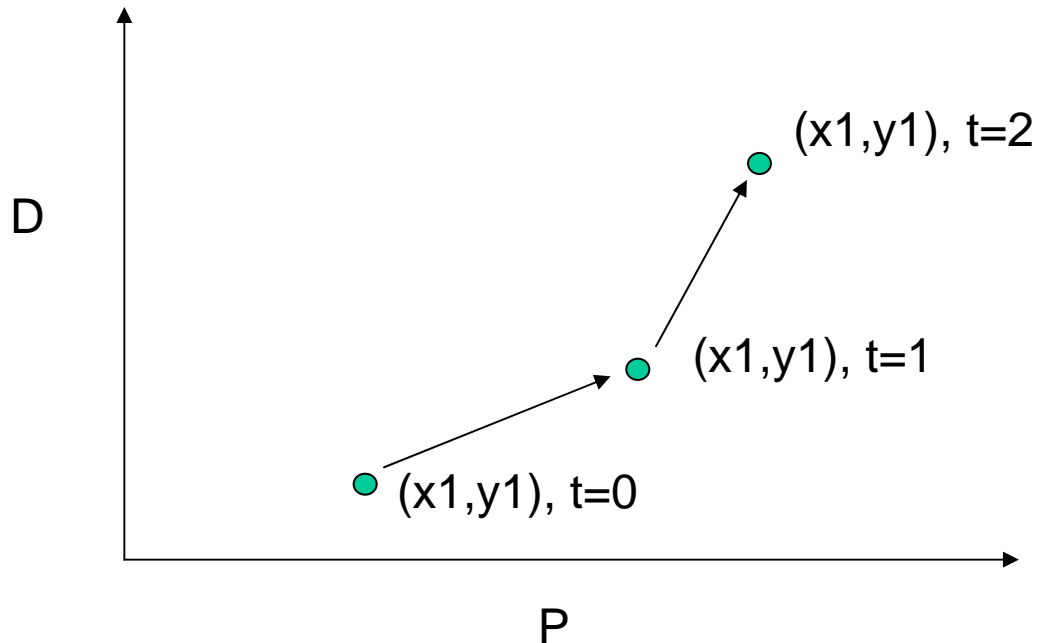
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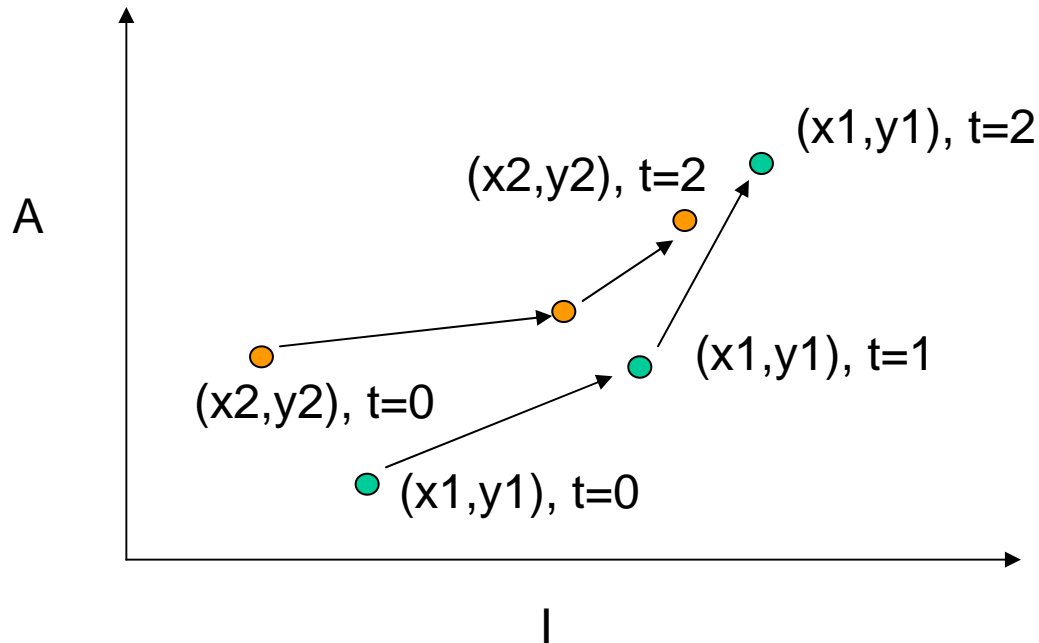
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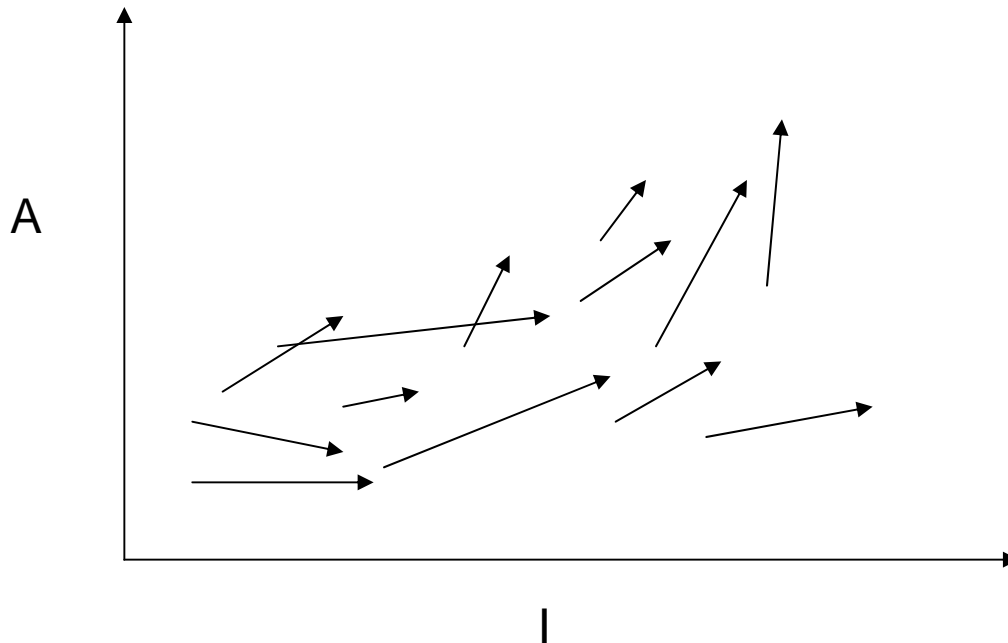
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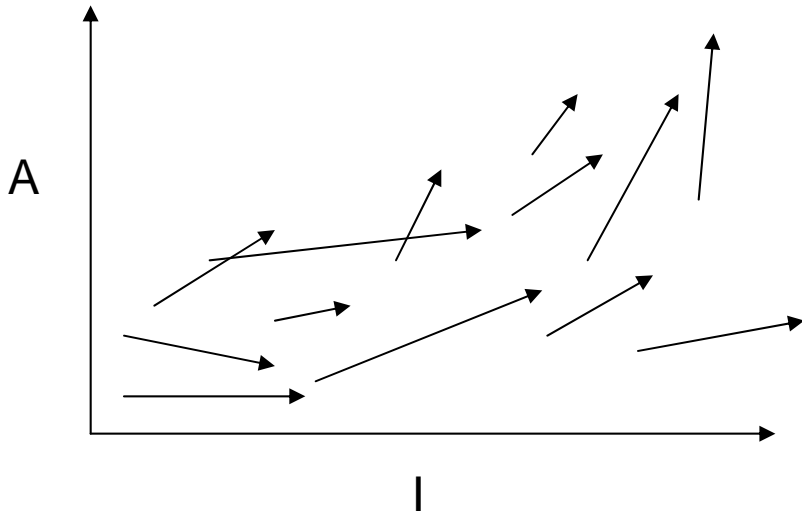


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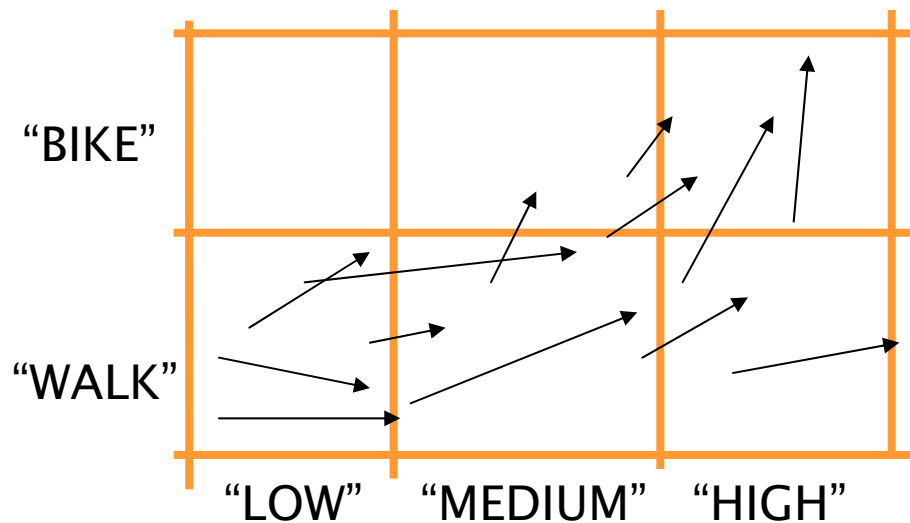
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Methodology (2): Transition matrix

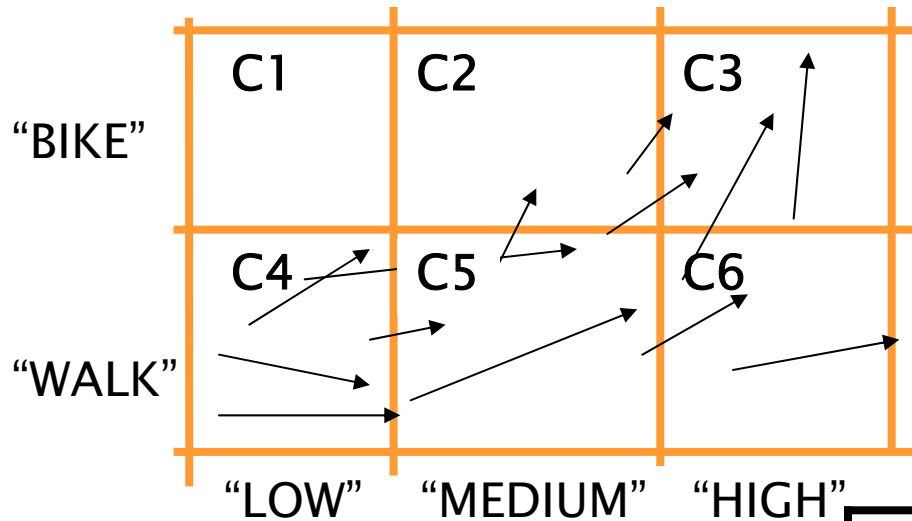


Methodology (2): Transition matrix



- Clusters in state-space
- Here simple bins
 - Alternatives are further work

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Transition matrix

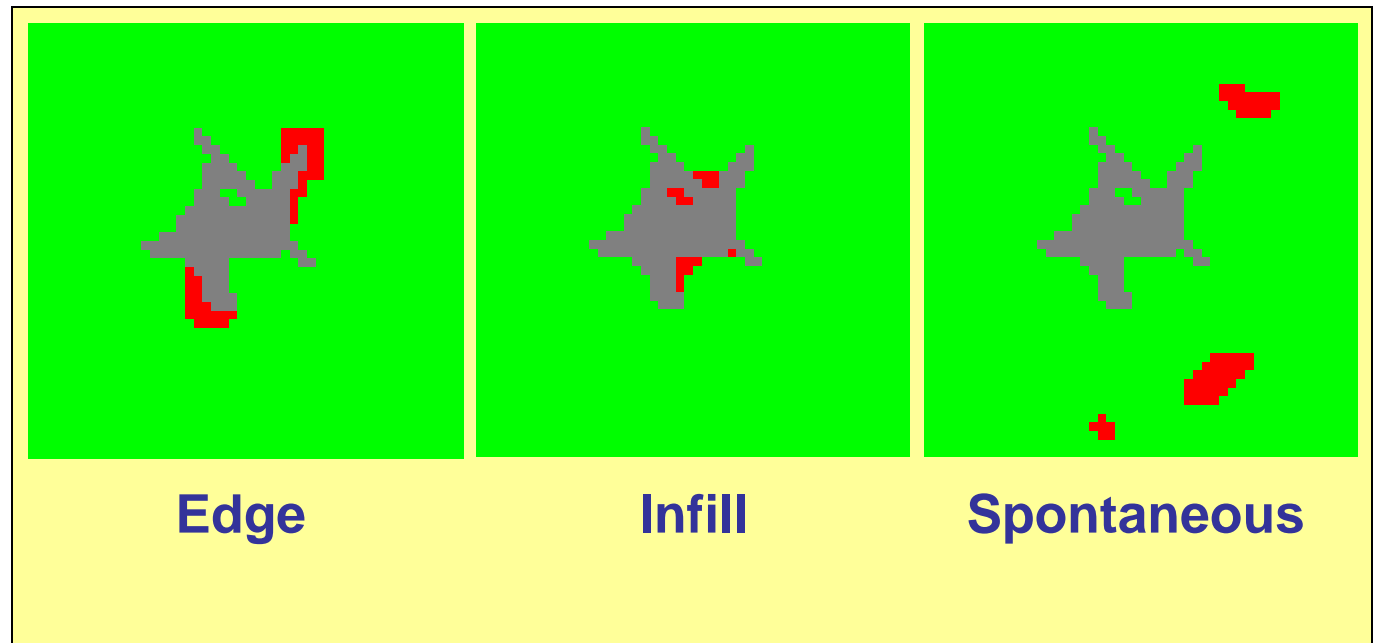
		T+1					
		C1	C2	C3	C4	C5	C6
T	C1	T(1,1)	T(2,1)	etc.			
	C2	T(1,2)	T(2,2)				
	C3	etc.					
	C4						
	C5						
	C6						

Transition matrix is input for further analysis

- Application 1: Validation of spatial dynamic model by comparing modelled and real dynamics
- Application 2: Cluster analysis to find regions of similar urban dynamics in the Netherlands (see proceedings)
- **Application 3: Indicator of compactness of urban change**

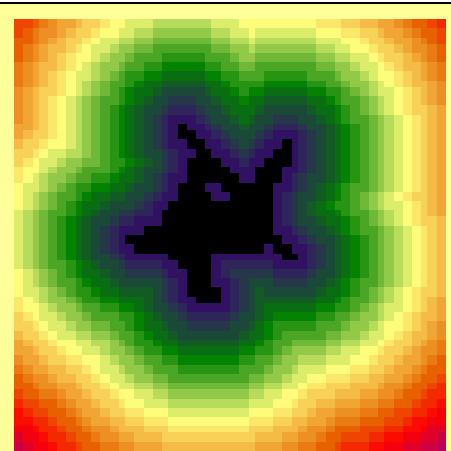
Compactness of urban change: Attribute maps

- State-space based on single attribute: Distance to artificial areas

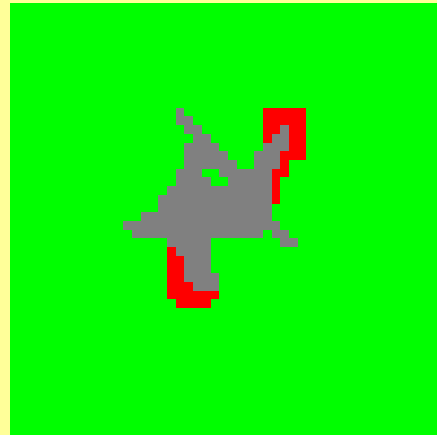


Compactness of urban change: Attribute maps

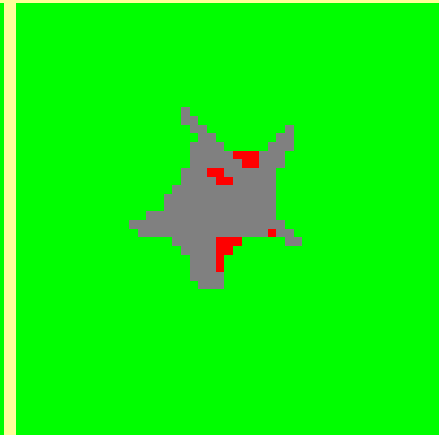
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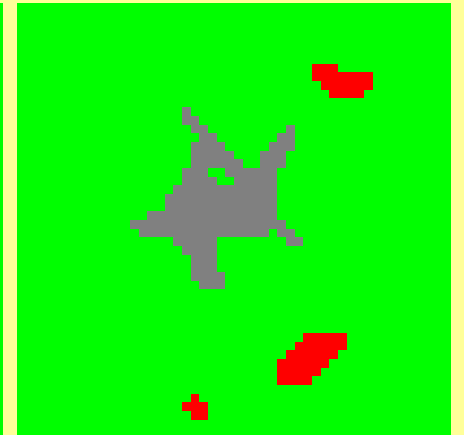
BEFORE



Edge



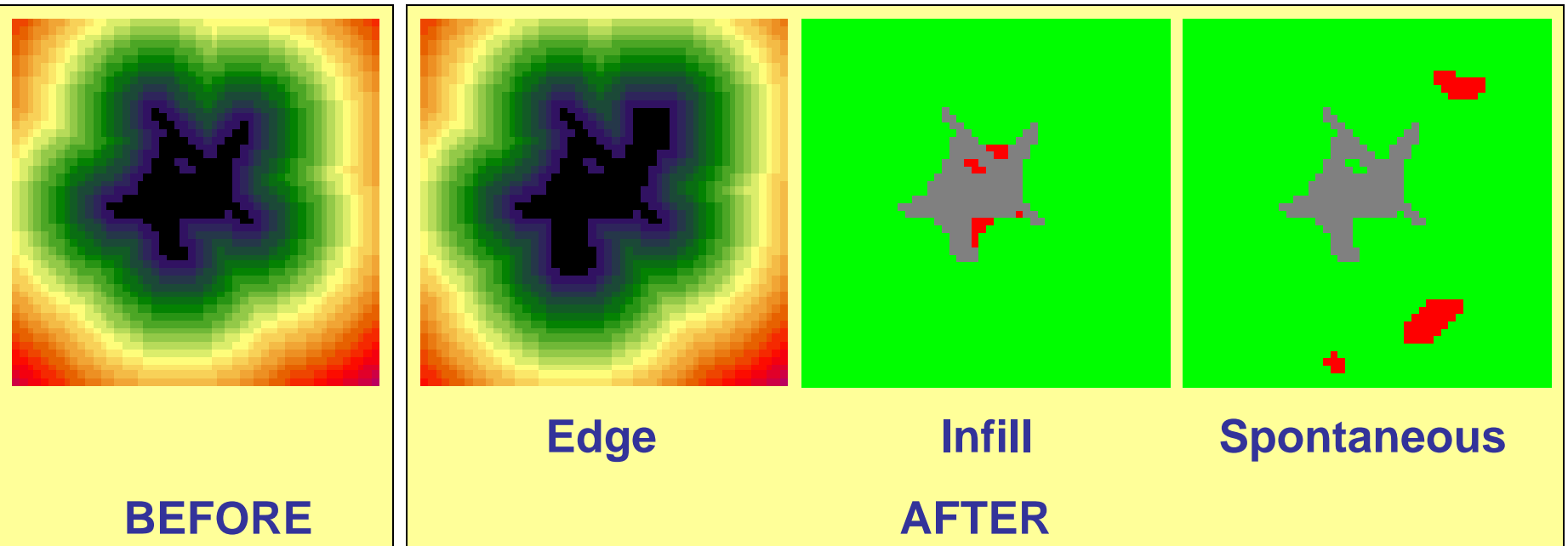
Infill



Spontaneous

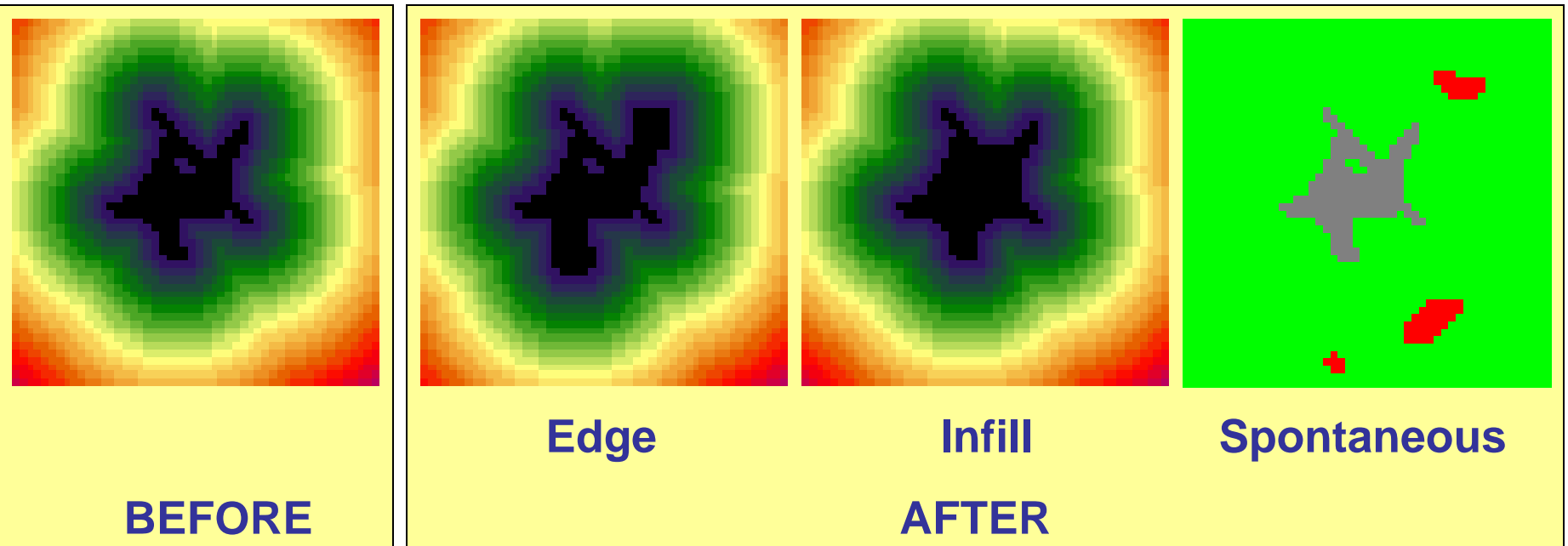
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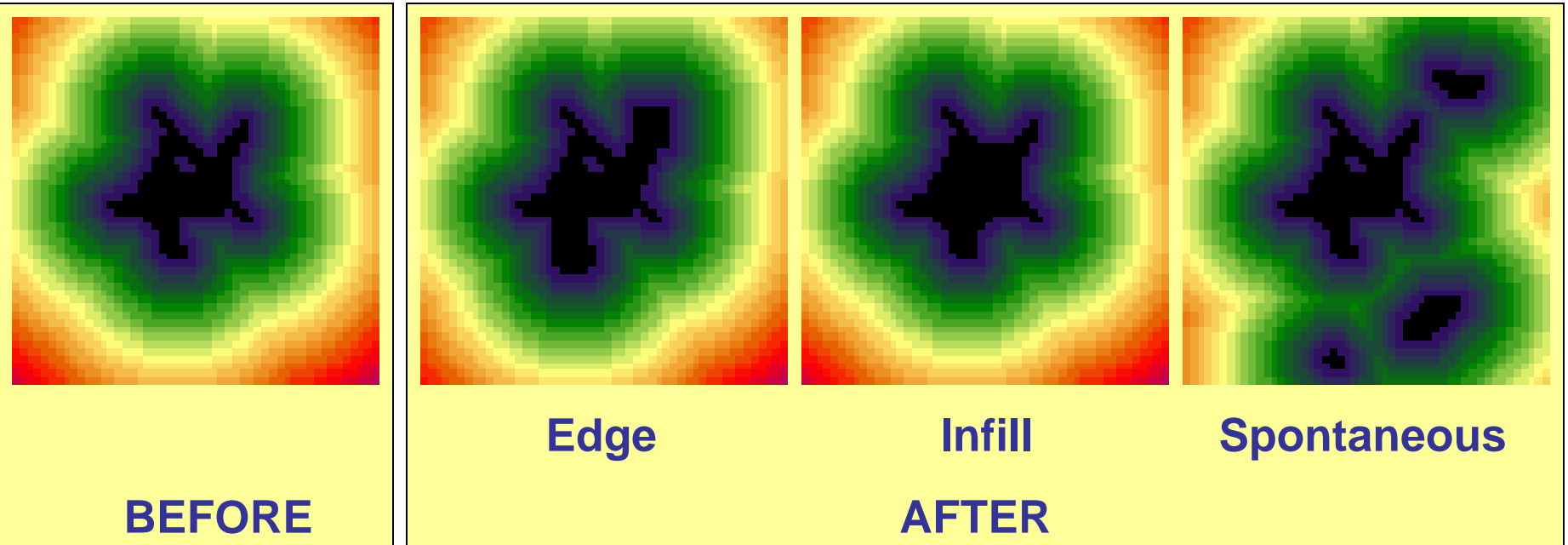
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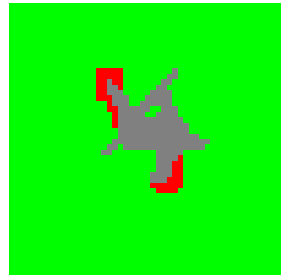
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Compactness of urban change: Transition matrices

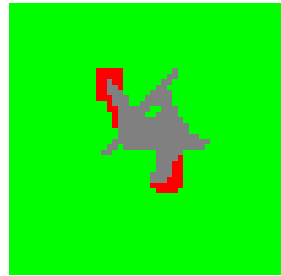
	FROM	TO
C1	0	1
C2	1	1.4
C3	1.4	2
C4	2	2.8
C5	2.8	4
C6	4	5.9
C7	5.9	8
C8	8	11.3
C9	11.3	16
C10	16	22.6
C11	22.6	32



50

Compactness of urban change: Transition matrices

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C11	22.6	32



50

EDGE	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	164	0	0	0	0	0	0	0	0	0	0
C2	20	56	0	0	0	0	0	0	0	0	0
C3	8	3	25	0	0	0	0	0	0	0	0
C4	16	8	2	53	0	0	0	0	0	0	0
C5	4	23	3	11	77	0	0	0	0	0	0
C6	0	0	4	29	44	140	0	0	0	0	0
C7	0	0	0	0	7	79	133	0	0	0	0
C8	0	0	0	0	0	14	99	324	0	0	0
C9	0	0	0	0	0	0	0	141	465	0	0
C10	0	0	0	0	0	0	0	0	134	345	0
C11	0	0	0	0	0	0	0	0	0	21	48

SPONT.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	164	0	0	0	0	0	0	0	0	0	0
C2	0	76	0	0	0	0	0	0	0	0	0
C3	0	0	36	0	0	0	0	0	0	0	0
C4	0	0	0	79	0	0	0	0	0	0	0
C5	0	0	0	0	118	0	0	0	0	0	0
C6	0	3	3	5	5	201	0	0	0	0	0
C7	9	4	0	4	6	34	162	0	0	0	0
C8	13	18	8	26	38	56	31	247	0	0	0
C9	36	21	11	27	41	77	61	66	266	0	0
C10	0	2	4	10	21	52	70	120	79	121	0
C11	0	0	0	0	0	0	1	12	37	19	0

INFILL	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	164	0	0	0	0	0	0	0	0	0	0
C2	15	61	0	0	0	0	0	0	0	0	0
C3	1	4	31	0	0	0	0	0	0	0	0
C4	1	3	1	74	0	0	0	0	0	0	0
C5	0	0	1	2	115	0	0	0	0	0	0
C6	0	0	0	0	1	216	0	0	0	0	0
C7	0	0	0	0	0	0	219	0	0	0	0
C8	0	0	0	0	0	0	0	437	0	0	0
C9	0	0	0	0	0	0	0	0	606	0	0
C10	0	0	0	0	0	0	0	0	0	479	0
C11	0	0	0	0	0	0	0	0	0	0	69

Compactness of urban change: Summary statistic

IMPACT	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1		-0.4	-0.5	-0.7	-1.0	-1.2	-1.4	-1.6	-1.7	-1.7	-1.8
C2	0.4		-0.1	-0.4	-0.7	-1.0	-1.2	-1.4	-1.6	-1.6	-1.6
C3	0.5	0.1		-0.3	-0.5	-0.9	-1.1	-1.3	-1.5	-1.6	-1.6
C4	0.7	0.4	0.3		-0.3	-0.6	-0.9	-1.2	-1.4	-1.5	-1.5
C5	1.0	0.7	0.5	0.3		-0.4	-0.6	-1.0	-1.2	-1.3	-1.4
C6	1.2	1.0	0.9	0.6	0.4		-0.3	-0.6	-1.0	-1.1	-1.1
C7	1.4	1.2	1.1	0.9	0.6	0.3		-0.4	-0.7	-0.9	-0.9
C8	1.6	1.4	1.3	1.2	1.0	0.6	0.4		-0.4	-0.6	-0.6
C9	1.7	1.6	1.5	1.4	1.2	1.0	0.7	0.4		-0.2	-0.2
C10	1.7	1.6	1.6	1.5	1.3	1.1	0.9	0.6	0.2		0.0
C11	1.8	1.6	1.6	1.5	1.4	1.1	0.9	0.6	0.2	0.0	

Impact = Relative drop in
cumulative distribution

Compactness of urban change: Summary statistic

EDGE	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
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C2	20	56									
C3	8	3	25								
C4	16	8	2	53							
C5	4	23	3	11	77						
C6			4	29	44	140					
C7					7	79	133				
C8						14	99	324			
C9								141	465		
C10									134	345	
C11										21	48

EDGE	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1											
C2	7.52										
C3	4.07	0.42									
C4	11.8	3.09	0.5								
C5	3.88	15	1.58	3.14							
C6			5.4	18.6	16.4						
C7					4.42	21.6					
C8						9.02	38.4				
C9								51.8			
C10									29.3		
C11										0.59	
Mean:	0.098					Normalized	0.334				

IMPACT	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1		-0.4	-0.5	-0.7	-1.0	-1.2	-1.4	-1.6	-1.7	-1.7	-1.8
C2	0.4		-0.1	-0.4	-0.7	-1.0	-1.2	-1.4	-1.6	-1.6	-1.6
C3	0.5	0.1		-0.3	-0.5	-0.9	-1.1	-1.3	-1.5	-1.6	-1.6
C4	0.7	0.4	0.3		-0.3	-0.8	-0.9	-1.2	-1.4	-1.5	-1.5
C5	1.0	0.7	0.5	0.3		-0.4	-0.6	-1.0	-1.2	-1.3	-1.4
C6	1.2	1.0	0.9	0.6	0.4		-0.3	-0.6	-1.0	-1.1	-1.1
C7	1.4	1.2	1.1	0.9	0.6	0.3		-0.4	-0.7	-0.9	-0.9
C8	1.6	1.4	1.3	1.2	1.0	0.6	0.4		-0.4	-0.6	-0.6
C9	1.7	1.6	1.5	1.4	1.2	1.0	0.7	0.4		-0.2	-0.2
C10	1.7	1.6	1.6	1.5	1.3	1.1	0.9	0.6	0.2		0.0
C11	1.8	1.6	1.6	1.5	1.4	1.1	0.9	0.6	0.2	0.0	

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C2	0.4		-0.1	-0.4	-0.7	-1.0	-1.2	-1.4	-1.6	-1.6	-1.6
C3	0.5	0.1		-0.3	-0.5	-0.9	-1.1	-1.3	-1.5	-1.6	-1.6
C4	0.7	0.4	0.3		-0.3	-0.8	-0.9	-1.2	-1.4	-1.5	-1.5
C5	1.0	0.7	0.5	0.3		-0.4	-0.6	-1.0	-1.2	-1.3	-1.4
C6	1.2	1.0	0.9	0.6	0.4		-0.3	-0.6	-1.0	-1.1	-1.1
C7	1.4	1.2	1.1	0.9	0.6	0.3		-0.4	-0.7	-0.9	-0.9
C8	1.6	1.4	1.3	1.2	1.0	0.6	0.4		-0.4	-0.6	-0.6
C9	1.7	1.6	1.5	1.4	1.2	1.0	0.7	0.4		-0.2	-0.2
C10	1.7	1.6	1.6	1.5	1.3	1.1	0.9	0.6	0.2		0.0
C11	1.8	1.6	1.6	1.5	1.4	1.1	0.9	0.6	0.2	0.0	

Impact = Relative drop in cumulative distribution

Compactness of urban change: Summary statistic

EDGE	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	164										
C2	20	56									
C3	8	3	25								
C4	16	8	2	53							
C5	4	23	3	11	77						
C6			4	29	44	140					
C7					7	79	133				
C8						14	99	324			
C9								141	465		
C10									134	345	
C11										21	48

EDGE	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1											
C2	7.52										
C3	4.07	0.42									
C4	11.8	3.09	0.5								
C5	3.88	15	1.58	3.14							
C6			5.4	18.6	16.4						
C7					4.42	21.6					
C8						9.02	38.4				
C9								51.8			
C10									29.3		
C11										29.3	0.59
Mean:	0.098										
Normalized											0.334

IMPACT	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1		-0.4	-0.5	-0.7	-1.0	-1.2	-1.4	-1.6	-1.7	-1.7	-1.8
C2	0.4		-0.1	-0.4	-0.7	-1.0	-1.2	-1.4	-1.6	-1.6	-1.6
C3	0.5	0.1		-0.3	-0.5	-0.9	-1.1	-1.3	-1.5	-1.6	-1.6
C4	0.7	0.4	0.3		-0.3	-0.6	-0.9	-1.2	-1.4	-1.5	-1.5
C5	1.0	0.7	0.5	0.3		-0.4	-0.6	-1.0	-1.2	-1.3	-1.4
C6	1.2	1.0	0.9	0.6	0.4		-0.3	-0.6	-1.0	-1.1	-1.1
C7	1.4	1.2	1.1	0.9	0.6	0.3		-0.4	-0.7	-0.9	-0.9
C8	1.6	1.4	1.3	1.2	1.0	0.6	0.4		-0.4	-0.6	-0.6
C9	1.7	1.6	1.5	1.4	1.2	1.0	0.7	0.4		-0.2	-0.2
C10	1.7	1.6	1.6	1.5	1.3	1.1	0.9	0.6	0.2		0.0
C11	1.8	1.6	1.6	1.5	1.4	1.1	0.9	0.6	0.2	0.0	

Normalized to area growth

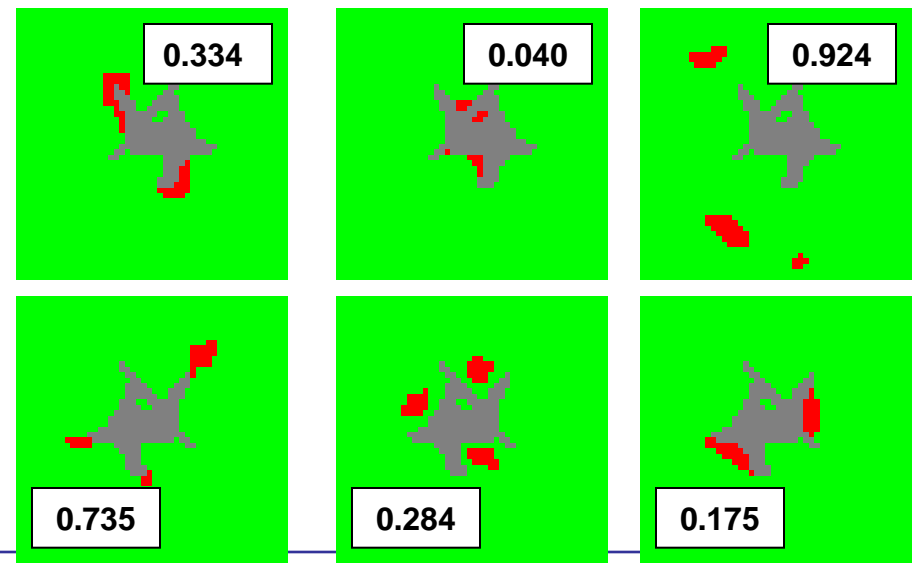
Impact = Relative drop in cumulative distribution

Compactness of urban change: Summary statistic

EDGE	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	164										
C2	20	56									
C3	8	3	25								
C4	16	8	2	53							
C5	4	23	3	11	77						
C6			4	29	44	140					
C7					7	79	133				
C8						14	99	324			
C9								141	465		
C10									134	345	
C11										21	48

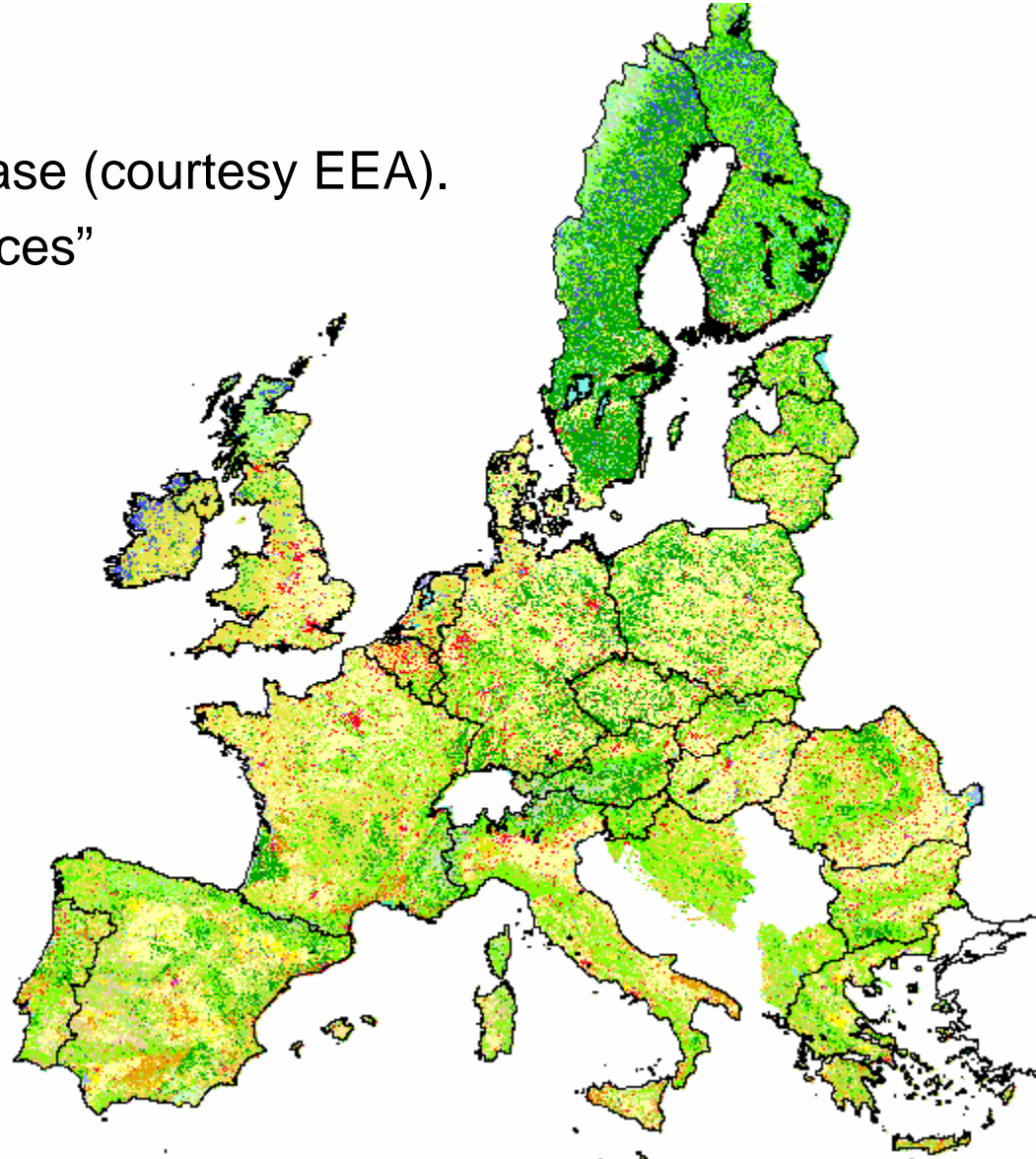
EDGE	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1											
C2	7.52										
C3	4.07	0.42									
C4	11.8	3.09	0.5								
C5	3.88	15	1.58	3.14							
C6			5.4	18.6	16.4						
C7					4.42	21.6					
C8						9.02	38.4				
C9								51.8			
C10									29.3		
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Mean:	0.098					Normalized					0.334

IMPACT	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1		-0.4	-0.5	-0.7	-1.0	-1.2	-1.4	-1.6	-1.7	-1.7	-1.8
C2	0.4		-0.1	-0.4	-0.7	-1.0	-1.2	-1.4	-1.6	-1.6	-1.6
C3	0.5	0.1		-0.3	-0.5	-0.9	-1.1	-1.3	-1.5	-1.6	-1.6
C4	0.7	0.4	0.3		-0.3	-0.6	-0.9	-1.2	-1.4	-1.5	-1.5
C5	1.0	0.7	0.5	0.3		-0.4	-0.6	-1.0	-1.2	-1.3	-1.4
C6	1.2	1.0	0.9	0.6	0.4		-0.3	-0.6	-1.0	-1.1	-1.1
C7	1.4	1.2	1.1	0.9	0.6	0.3		-0.4	-0.7	-0.9	-0.9
C8	1.6	1.4	1.3	1.2	1.0	0.6	0.4		-0.4	-0.6	-0.6
C9	1.7	1.6	1.5	1.4	1.2	1.0	0.7	0.4		-0.2	-0.2
C10	1.7	1.6	1.6	1.5	1.3	1.1	0.9	0.6	0.2		0.0
C11	1.8	1.6	1.6	1.5	1.4	1.1	0.9	0.6	0.2	0.0	

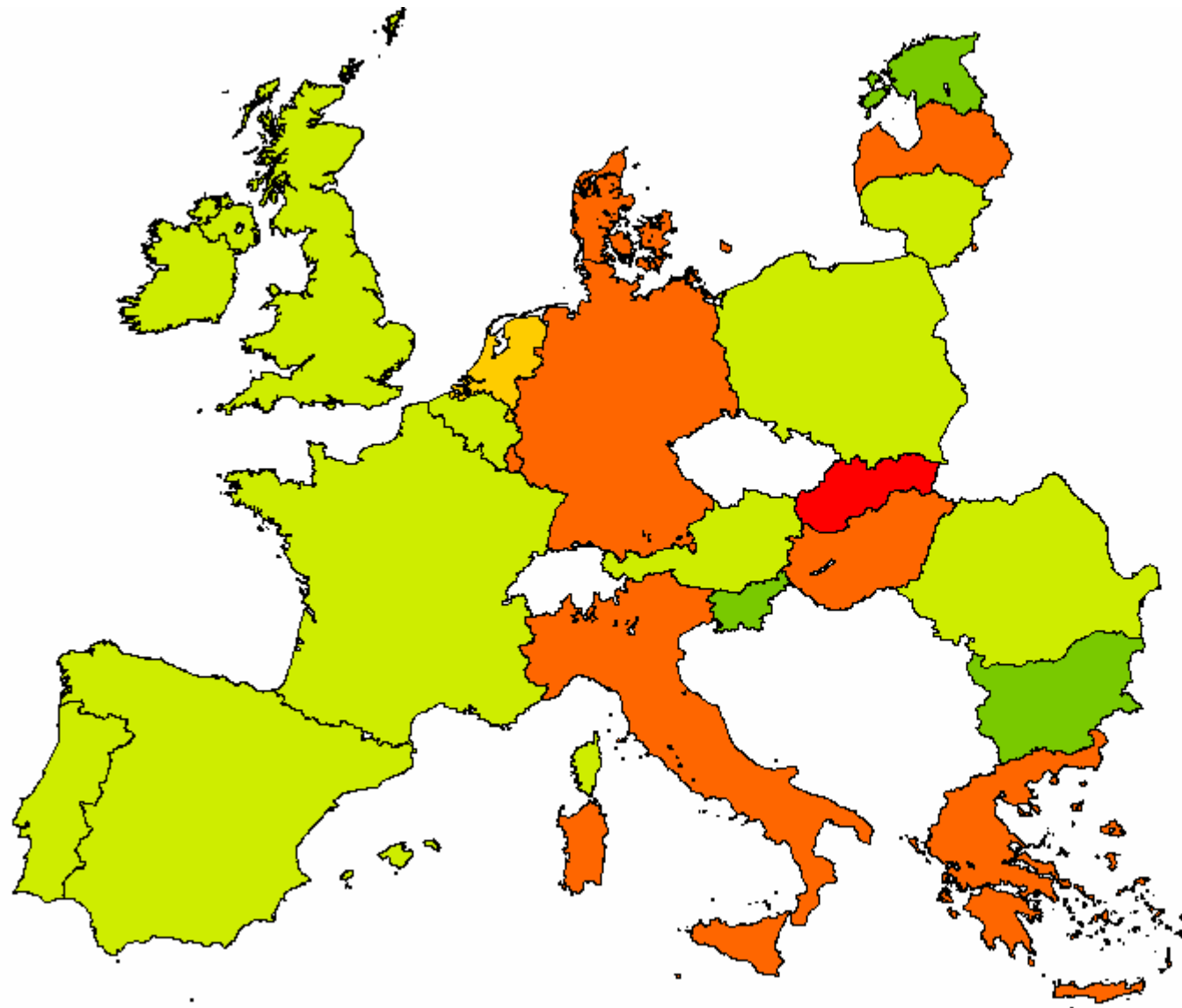


Comparing European countries +/- 1990-2000

- CORINE land cover database (courtesy EEA).
- Distance to “Artificial Surfaces”
- 22 Countries



Results – Compactness of urban change



	0.04	INFILL
Estonia	0.12	
Slovenia	0.13	
Bulgaria	0.16	
	0.18	INFILL - EDGE
Romania	0.18	
Lithuania	0.18	
Austria	0.21	
United Kingdom	0.21	
Portugal	0.22	
Spain	0.23	
Poland	0.23	
Belgium	0.24	
France	0.27	
Ireland	0.28	
	0.28	INFILL - SPONT.
The Netherlands	0.32	
	0.33	EDGE
Greece	0.35	
Luxembourg	0.35	
Hungary	0.41	
Denmark	0.41	
Italy	0.44	
Germany	0.46	
Latvia	0.72	
	0.74	EDGE - SPONT.
	0.92	SPONT.
Slovakia	3.71	

Further work

- Impact of errors in data
- Sensitivity to initial situation
- Applications at different scales: Region & Municipality
- Determinants of compact change
- Alternative (combinations of) attributes

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- Impact of errors in data
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	Urban	Non-urban
Urban		
Non-urban		

Further work

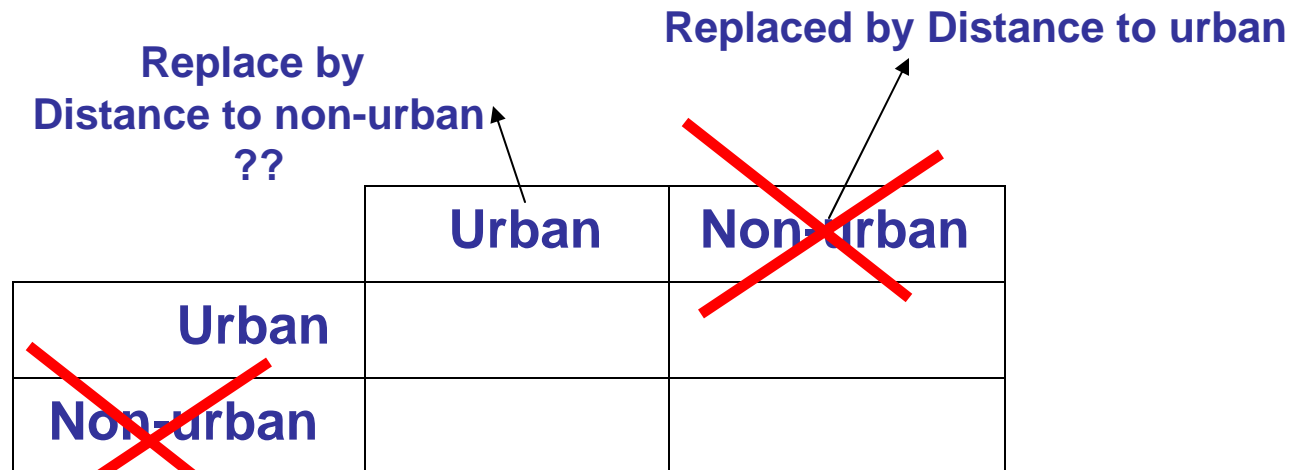
- Impact of errors in data
- Sensitivity to initial situation
- Applications at different scales: Region & Municipality
- Determinants of compact change
- Alternative (combinations of) attributes

Replaced by Distance to urban

	Urban	Non-urban
Urban		
Non-urban		

Further work

- Impact of errors in data
- Sensitivity to initial situation
- Applications at different scales: Region & Municipality
- Determinants of compact change
- Alternative (combinations of) attributes



Conclusion

- Classification of the compactness of patterns of urban change
 - Controlled for initial situation
 - Controlled for total area of change
- Supplements other indicators of urban sprawl
 - Density
 - Area
 - Concentration
- Scope for further analysis of urban transitions in urban form

Questions?

UrbanPulse - Instruments for monitoring and analysis of urban change

www.riks.nl/projects/urbanpulse

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