Geoinformation methods for the evaluation of spatial distribution of urban green areas and allotments

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Outline - Foci of Urban Remote Sensing in Urban Ecology

- Theoretical Background
- Scale-dependent analysis of a city and its surroundings
- Land-use / land-cover analysis in urban regions
- Investigation of urban structures and potential changes
- Combined analysis of spatial and socio-demographic data
- Application of geometrically high resolution sensors (VHR)

Urban Remote Sensing and Geomatics

- A city is characterised by its **heterogeneity** – in space and time
- In the field of remote sensing and the applied data there are **different sensors and scales** selected dependent on the goal of the analysis
- **Unmodified and dynamically developing areas** are closely **intertwined** in a city
- In addition, a **dynamic suburban and peri-urban environment** with a manifold of interdependencies with the city exists
- Spatial heterogeneity and spatially limited, temporal dynamics are **challenges for the monitoring and the analyse of remotely sensed data and digital Geoinformation datasets**

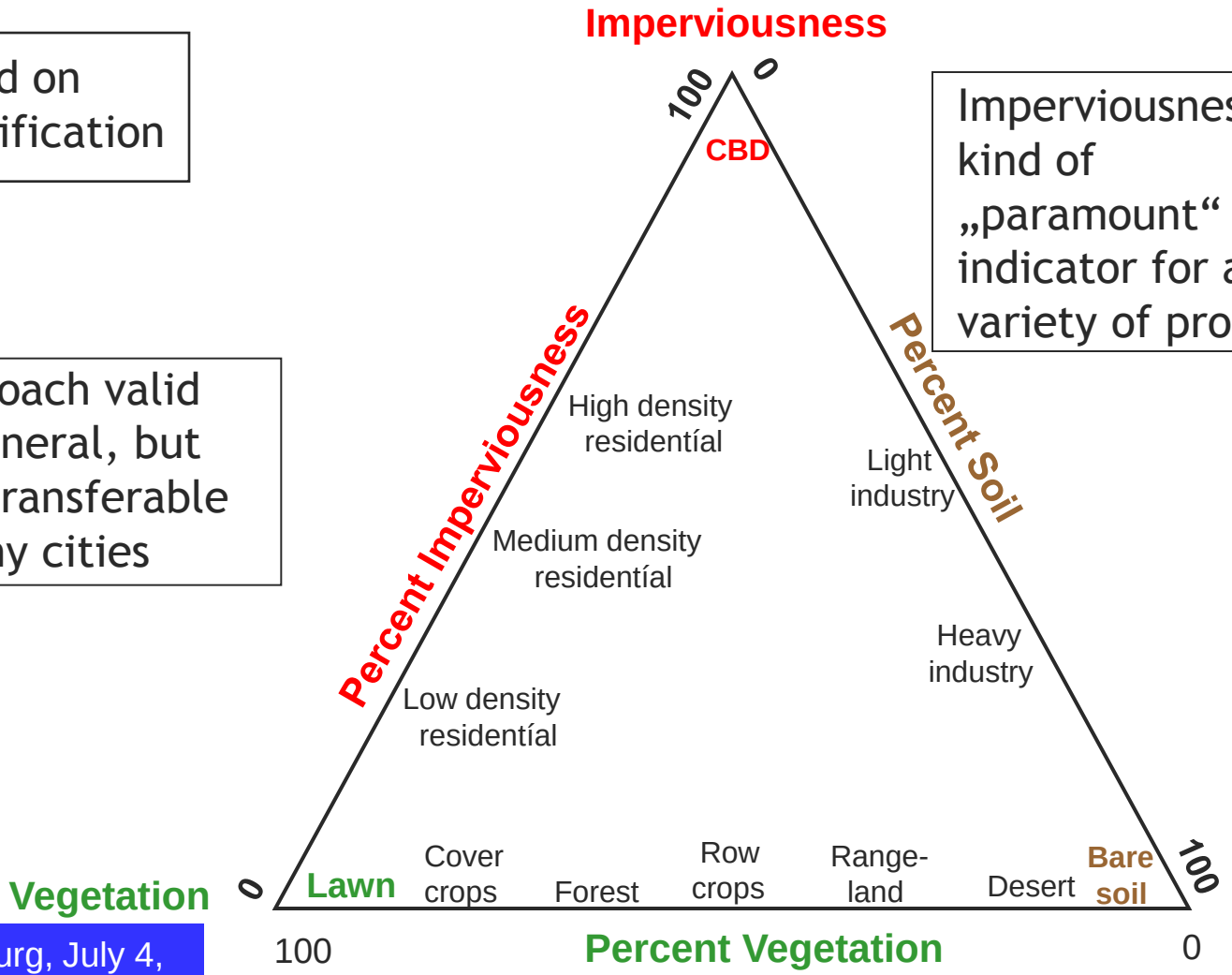
Methodological Background

Vegetation-Imperviousness-Soil (V-I-S) Modell after Ridd (1995)

Based on classification

Approach valid in general, but not transferable to any cities

Imperviousness as a kind of „paramount“ indicator for a variety of processes



Indicators for the urban environment

- Natural Environment:

  Soil / groundwater: degree of imperviousness, risk of contamination

  Climate / air: thermal stress, circulation

  Green spaces: quantity and location, biodiversity, network of green spaces

- Built-up Environment:

  Energy supply: Energy requirements / availability, energy consumption

  Waste disposal: Quantity, collection, compost, recycling

  Water management: needs, water treatment , rain water retention

  Urban built-up structure: land use distribution and composition, densification and urban land use potentials, building structure, state (quality) of buildings, industrial plants

  Mobility structure: motorised, non-motorised people in streets, public transport

- Social Environment:

  Housing: housing supply, demolition, empty housing

  Population: age structure, marital status, ♀/♂ , proportion of foreigners, income

  Socio cultural structure: socio cultural infrastructure, supply with goods and services, green spaces, quality of neighborhood environment

Two ecological approaches to understand and manage the dynamics of urban and urbanizing ecosystems (Zipperer et al., 2000):

- The **ecosystem approach**: fluxes of energy, matter and species.
- The **patch dynamic approach**: creation of the spatial heterogeneity within landscapes and how that influences the flow of energy, matter, etc. across the landscape.
- Spatially focused approach of patch dynamics (Pickett et al. 1997): urban landscape is a **mosaic** of biotic and abiotic **patches** within a **matrix** of infrastructure, social institutions, cycles and order.
- Spatial heterogeneity within an urban landscape has both natural and human sources

Remote Sensing and Landscape Metrics

- Analysed satellite image data is a very useful instrument offering the information needed:
  - continuous land-cover information,
  - quasi-recent to retrospective (back to the 1970's)
  - reasonable price, i.e. for monitoring purposes
- Digital image processing and landscape metrics software can 'sharpen' information contained in the raster-based image structure:
  - texture
  - shape
  - neighbourhood
- Show public decision makers the necessity of regional concerted actions and to be able to regulate the process ('spatial map *aha* effect').

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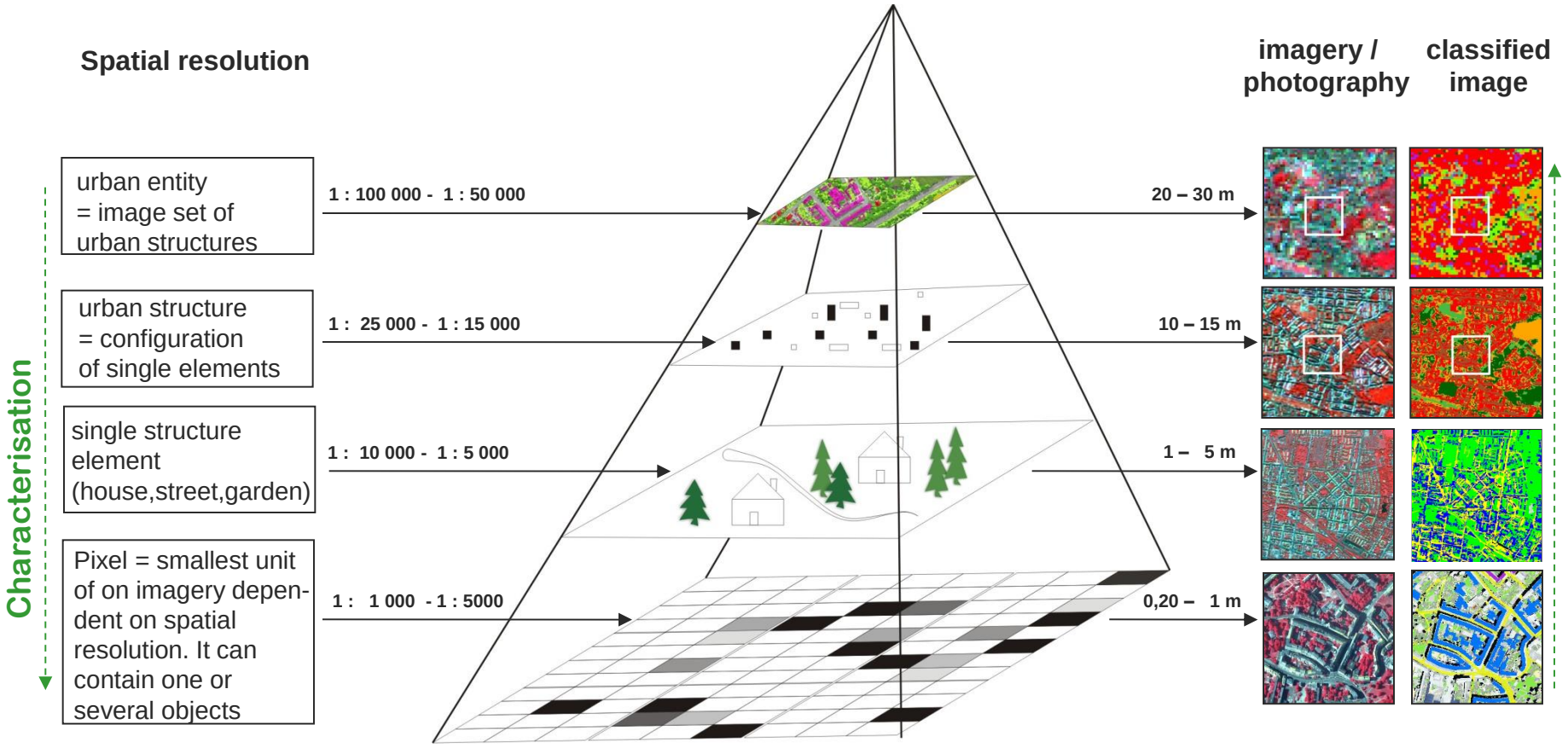
Scale-dependent analyses exemplified for urban remote sensing studies

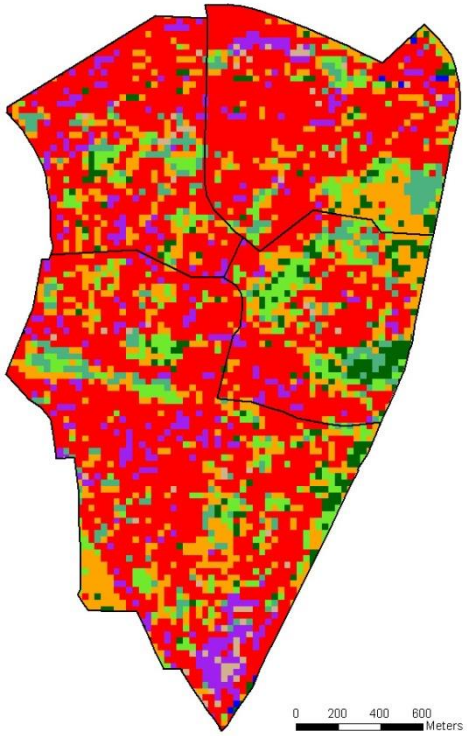


Modified after Weber et al. 2007

Scale-dependency: different sensors, resolutions, semantics

Four Local Districts in the City of Leipzig

Landsat-5-TM [30 m]
05-Sept-2005



Spot-5-XS [10 m]
07-Sept-2005

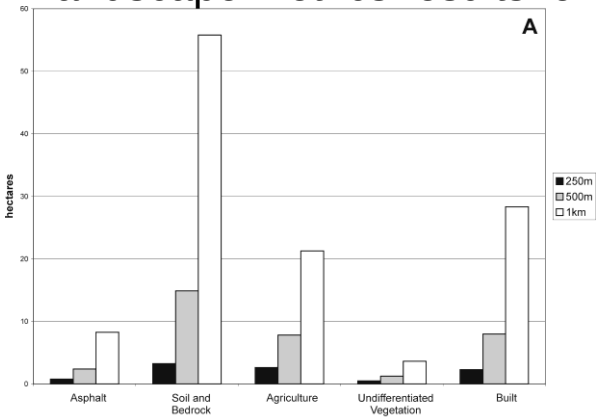
CIR photograph [40 cm]
21-Juni 2005

Urban structure:

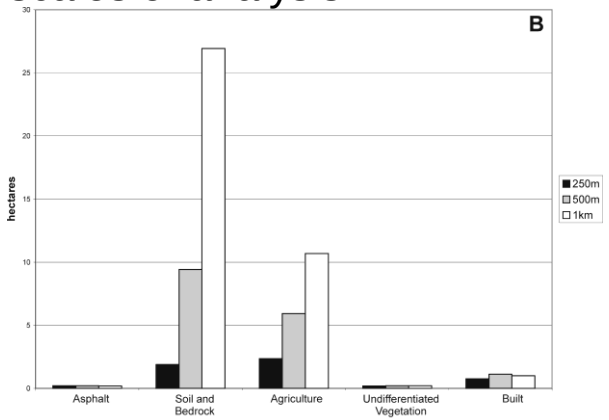
- Inner urban differentiation
- Different building structures, densities
- Amount, intensity, axes of infrastructure
- Amount and structure of vegetation

One system – several scales : Example from MODIS [1000 m],[500 m],[250 m

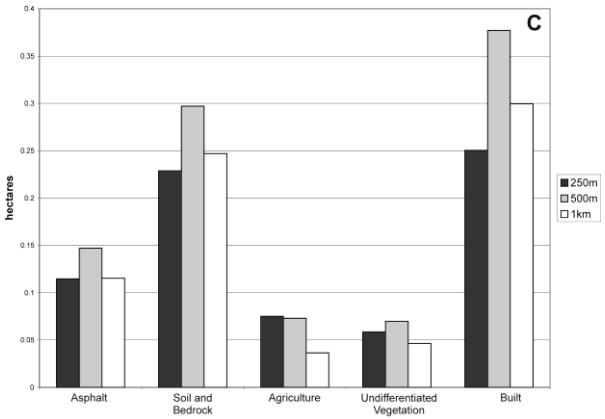
Landscape metrics results for three spatial scales of analysis



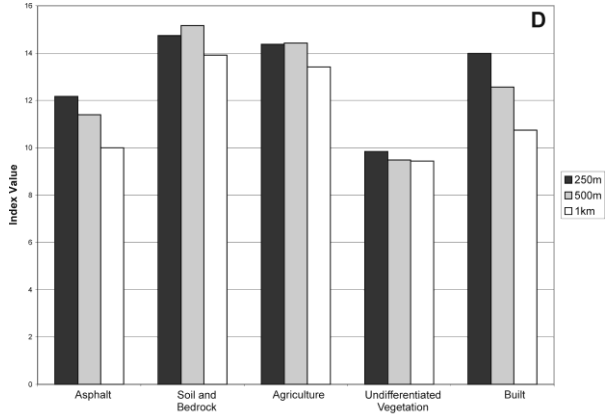
Class area



Mean patch size



Edge density

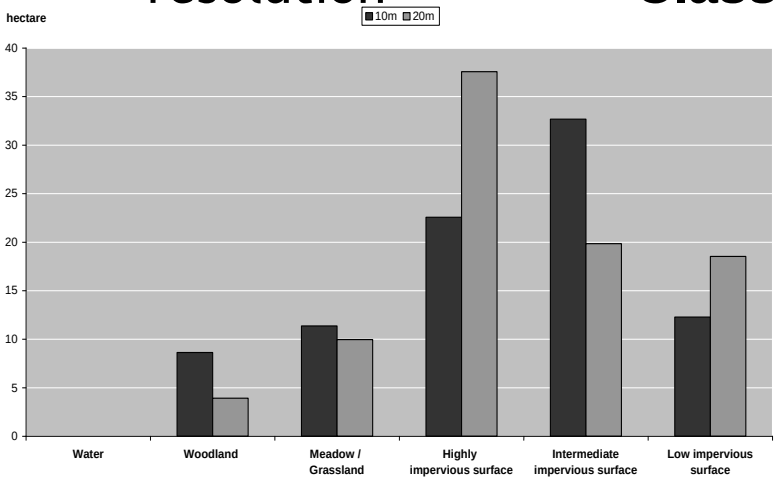


Interspersion / Juxtaposition

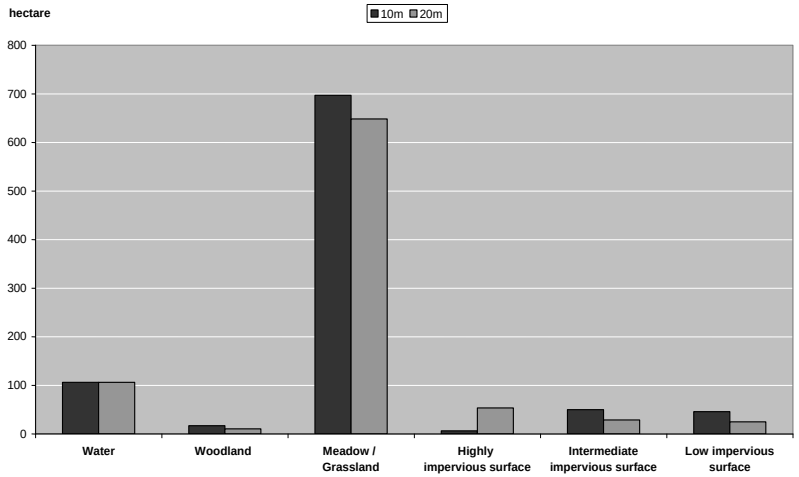
Stefanov & Netzband, 2005

One system-several scales: Spot [10 m] versus Spot [20 m] ground resolution

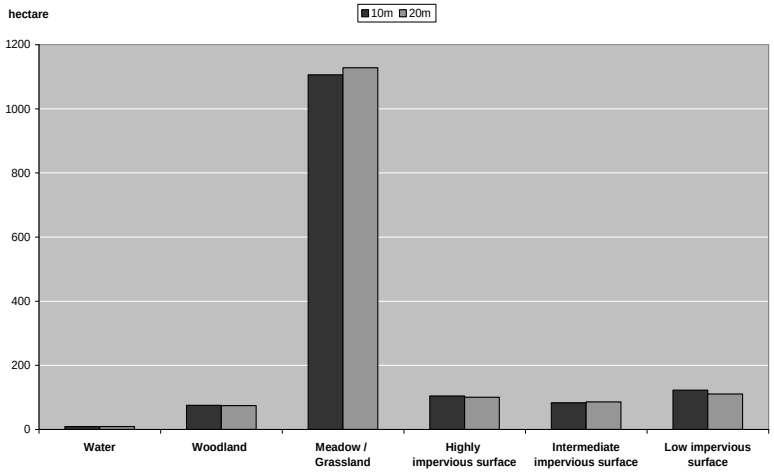
Classification results



1. Inner urban local district



2. Urban local district being incorporated into the City of Leipzig during the incorporation reform



3. Suburban commune being adjacent to the City limits

Banzhaf, Grescho, Kindler, 2008

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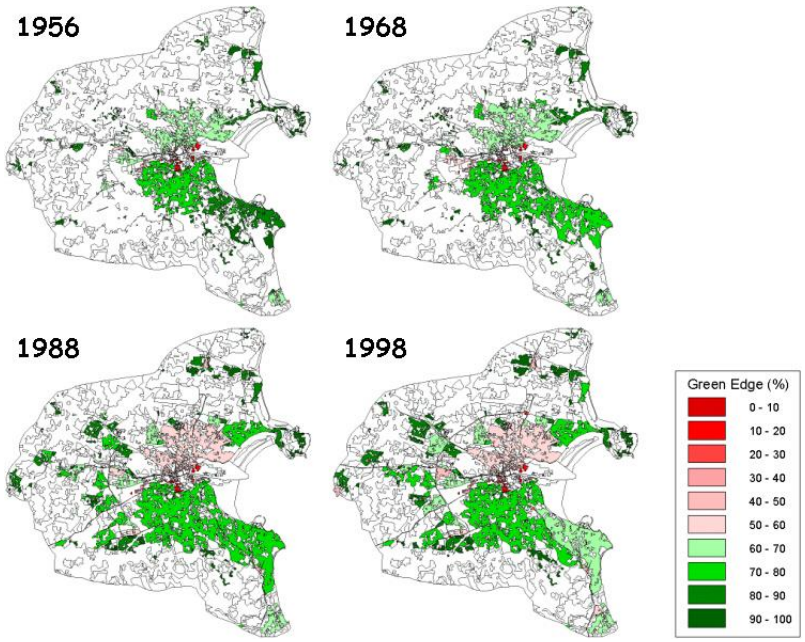
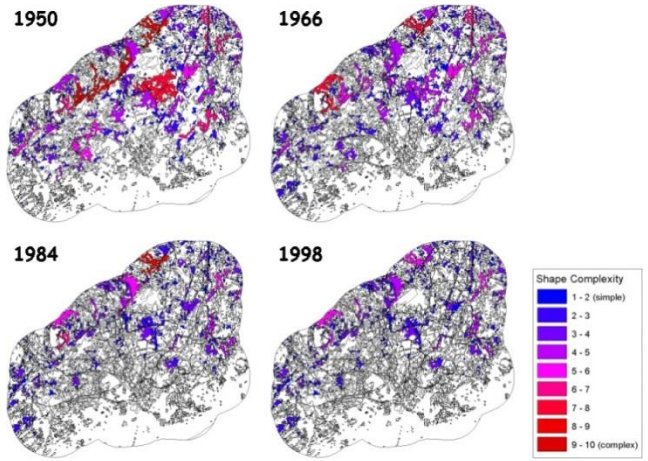
Indicators on the basis of remotely sensed data

MOLAND
Monitoring Land Use/Cover Dynamics
Towards Sustainable Urban and Regional Development



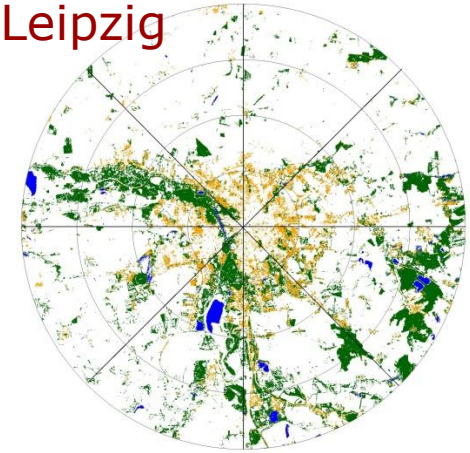
‘Green Edge Index’ for Urban Fabric in Dublin (1956-1998) - how much of a region’s urban fabric is adjacent to (i.e. has an edge with) vegetated areas.

Habitat Suitability Index (Shape Complexity for Arable Land in Helsinki (1950-1998)



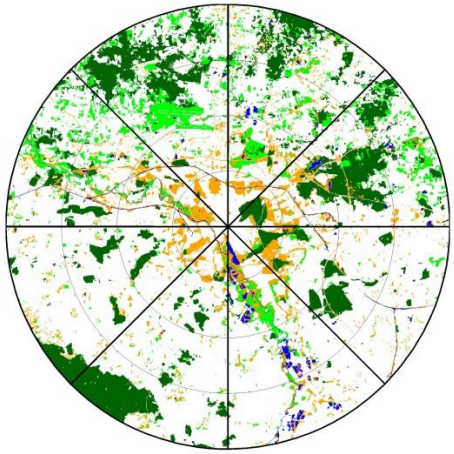
Geographisches Institut
GEO matik
Ruhr-Universität Bochum

Leipzig



Wald, Park (größere Bäume)
Kleinere Bäume und Buschvegetation, Kleingärten
Gewässer

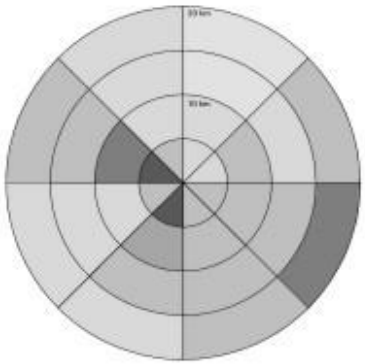
IRS 1C Satellite Image Data - Classified Vegetation Cover



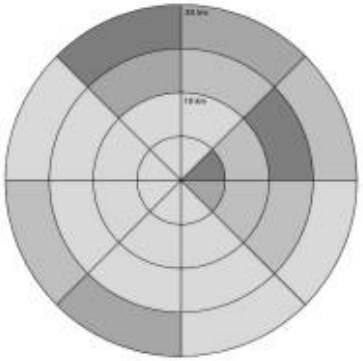
Hanover

Wald, Park (größere Bäume)
Kleinere Bäume und Buschvegetation, Kleingärten
Gewässer
Grünland

Trees, Forests

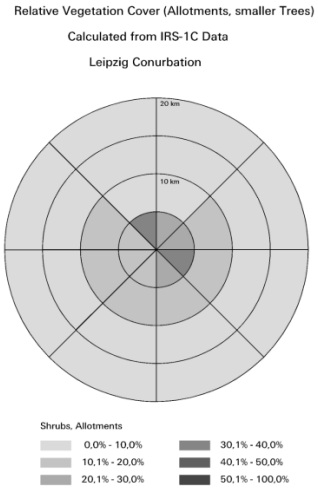


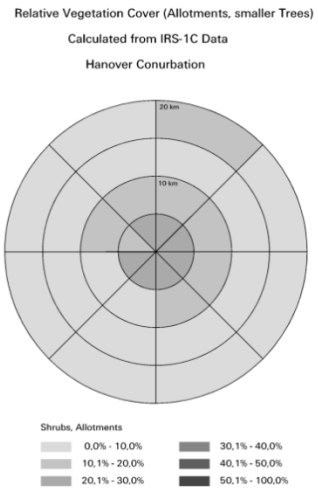
0,0% - 10,0%
10,1% - 20,0%
20,1% - 30,0%
30,1% - 40,0%
40,1% - 50,0%
50,1% - 100,0%



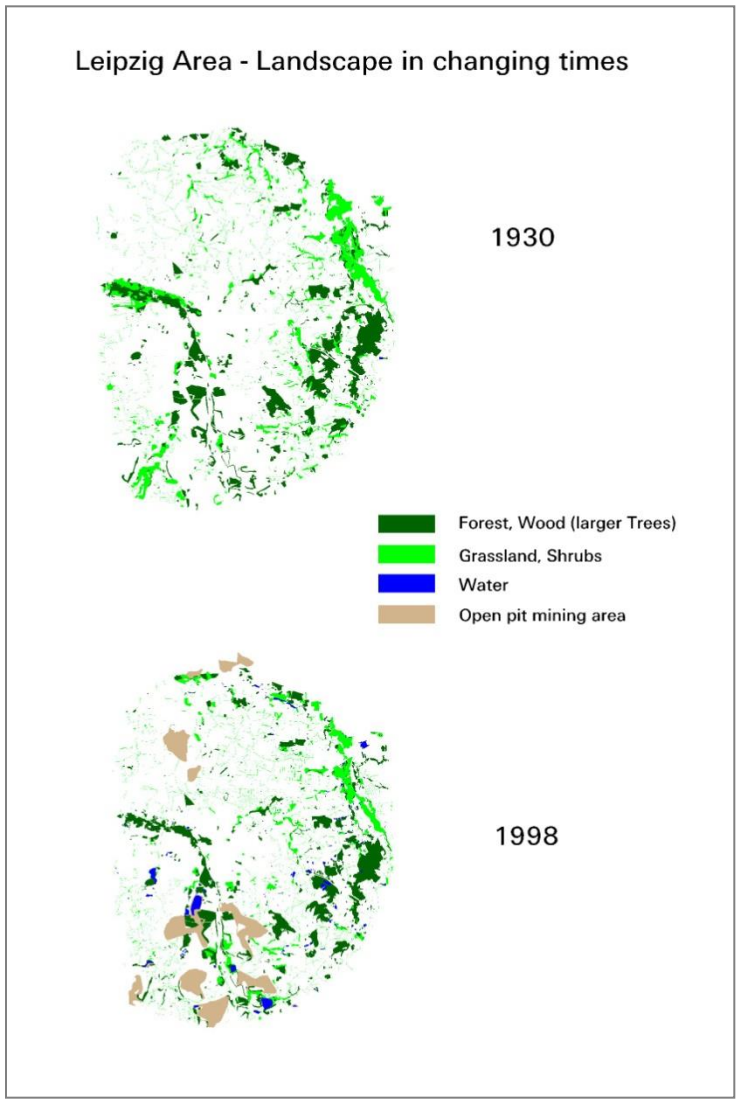
0,0% - 10,0%
10,1% - 20,0%
20,1% - 30,0%
30,1% - 40,0%
40,1% - 50,0%
50,1% - 100,0%

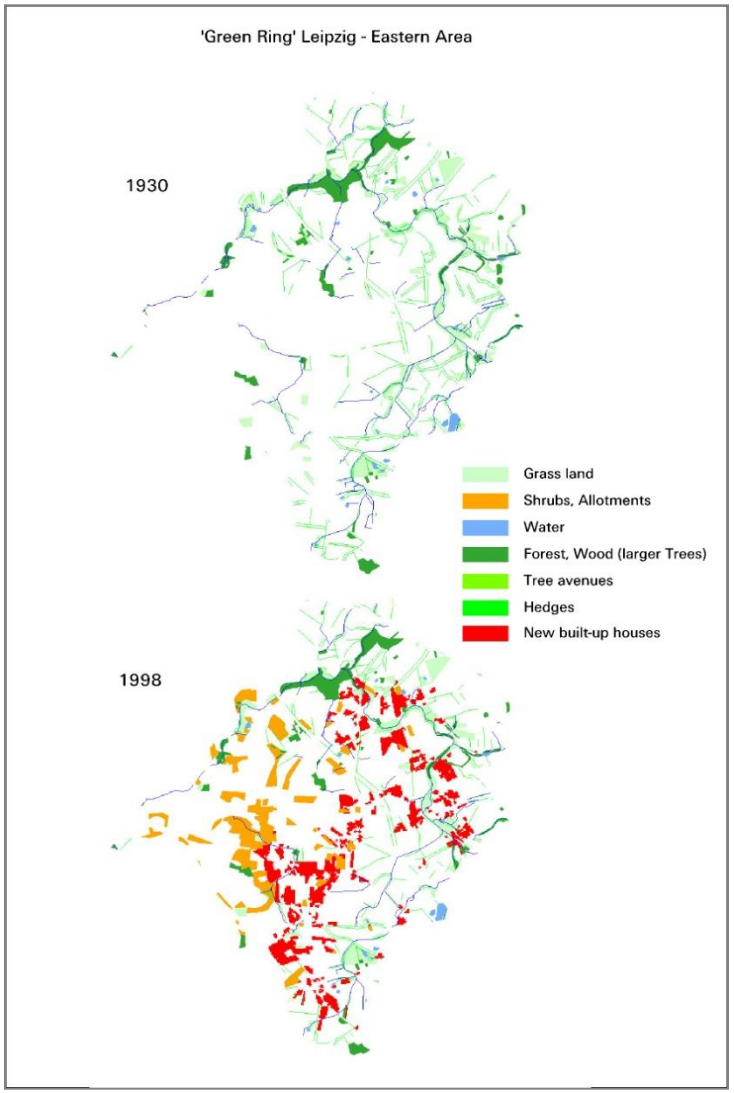
Allotments, House Gardens





Configuration of green spaces





Netzband & Banzhaf, 2000

Research on spatial shrinkage and growth patterns by means of remote sensing and GIS methods

Land use change (RS)

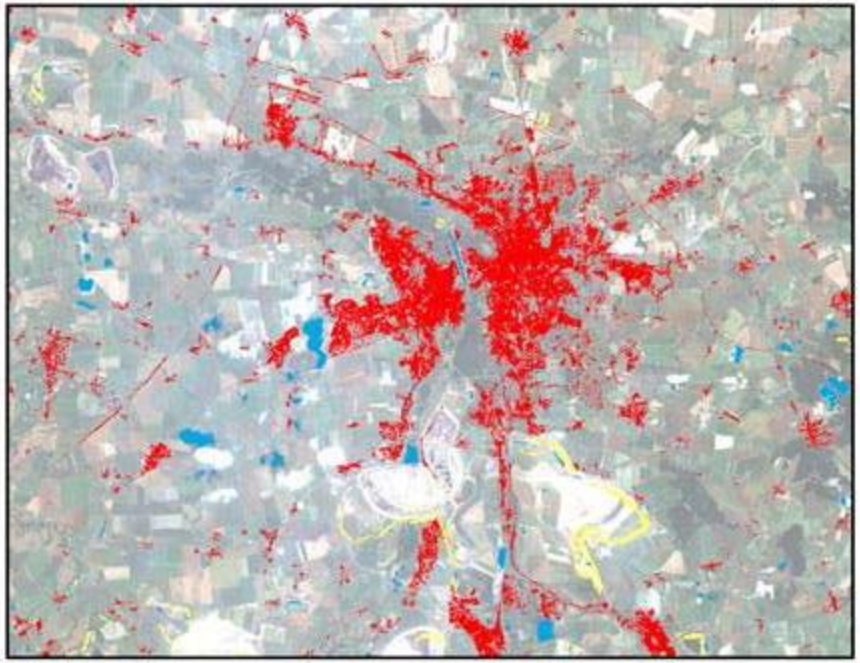
Demographic processes of deconcentration(GIS)

Detecting vegetation changes

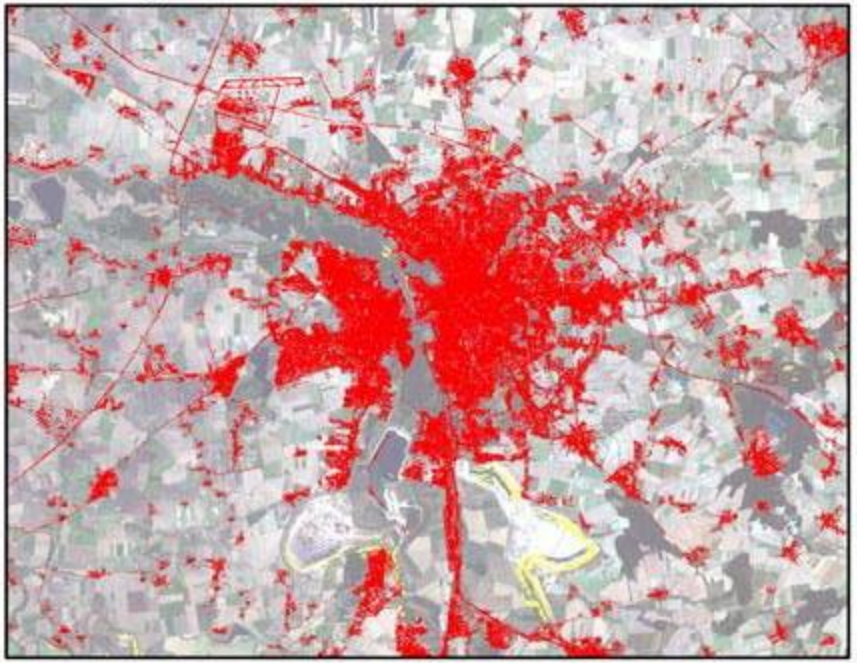
Exploring associations between the natural environment and demographic variables

Urban regions in Germany under high negative dynamic structural changes in terms of spatial, economic and demographic parameters

Leipzig, Germany



T_1: 7-Jul-89



T_2: 13-Sep-99

0 6 12 18 24 km

1:350,000

Water

Excessive slope

Built-up area

N

Measure	T_1	T_2	Annual % Change
Population	1,278,052	1,198,715	-0.63%
Built-Up Area (sq km)	188.43	406.64	7.85%
Average Density (persons / sq km)	6,782.66	2,947.83	-7.86%
Built-Up Area per Person (sq m)	147.43	339.23	8.53%
Average Slope of Built-Up Area (%)	2.10	2.26	0.73%
Maximum Slope of Built-Up Area (%)	13.19	14.16	0.70%
The Buildable Perimeter (%)	0.94	0.95	0.06%
The Contiguity Index	0.41	0.38	-0.92%
The Compactness Index	0.29	0.24	-1.82%
Per Capita Gross Domestic Product	$19,829.21	$23,622.87	1.73%

Monitoring spatial indicators

Processes of suburbanisation

- New infrastructures
- New residential areas
- Commercial sites
- Industrial plants

Processes in the central part of the city

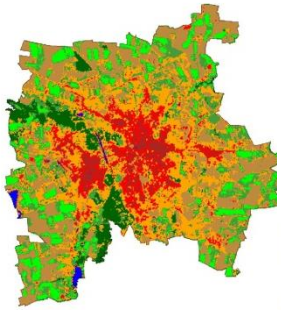
- Lack of inner urban density
- Demolition of housing and new buildings
- New green areas

Field site: City of Leipzig, Germany

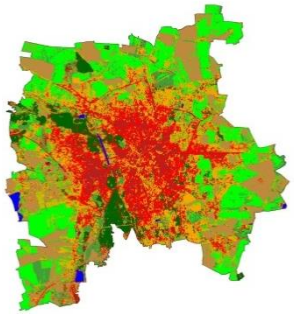
Communal incorporation reform:

1994: area 153,2 km², population density 3106 hab. / km²

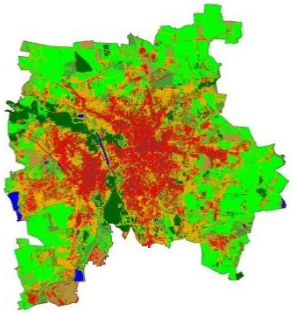
2002: area 298,1 km², population density 1614 hab. / km²



1972

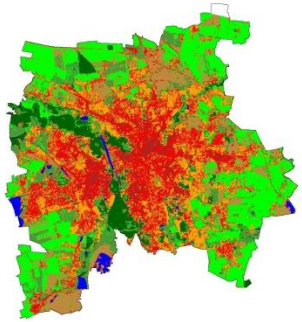


1984

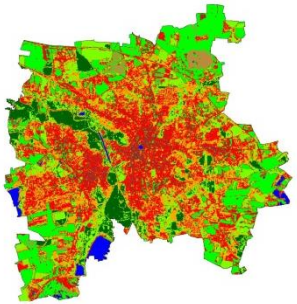


1989

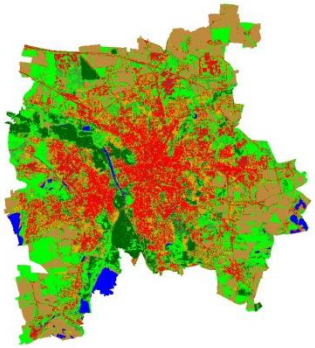
Land-use classifications derived from satellite images (Landsat series)



1994



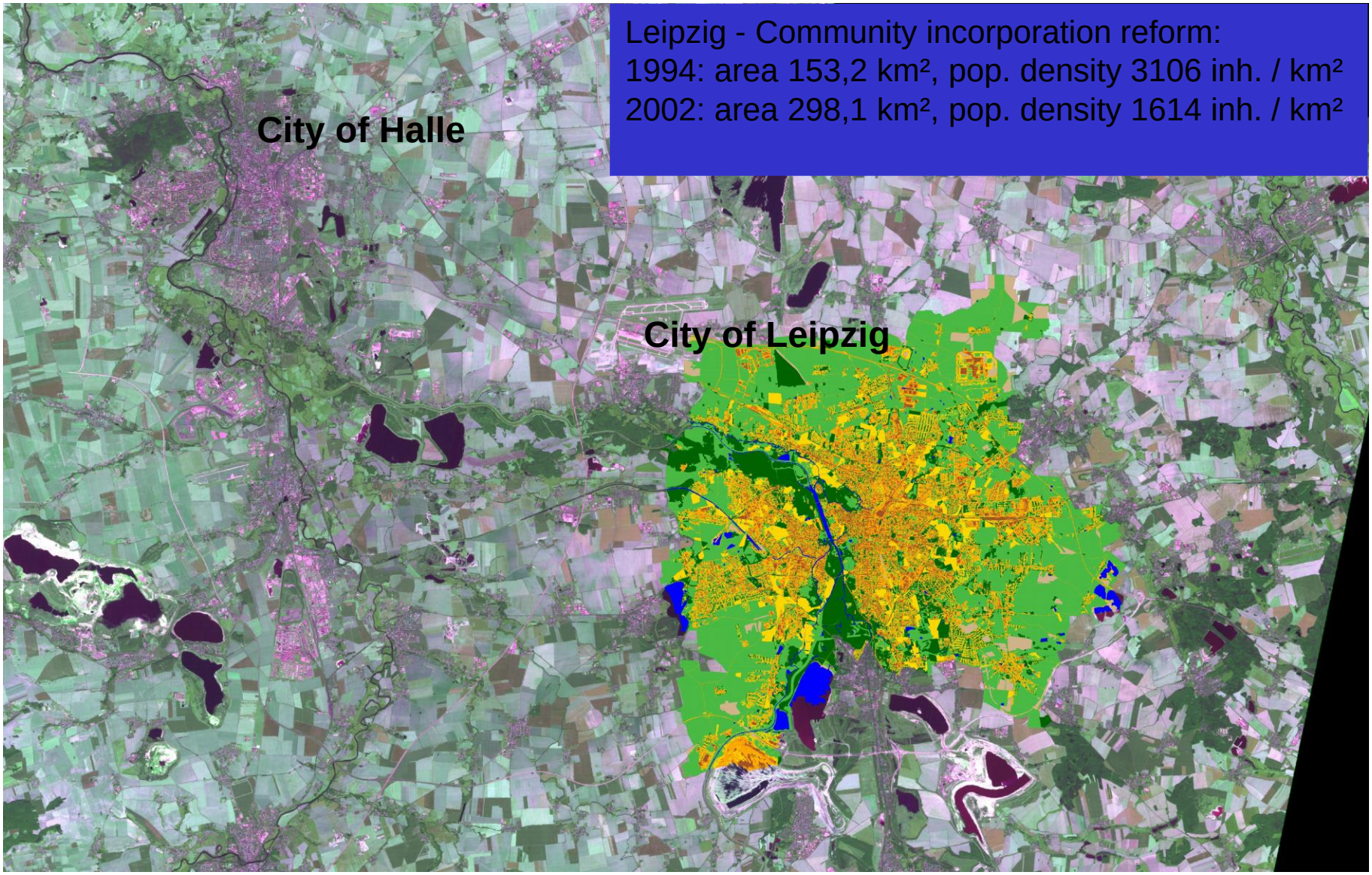
2002



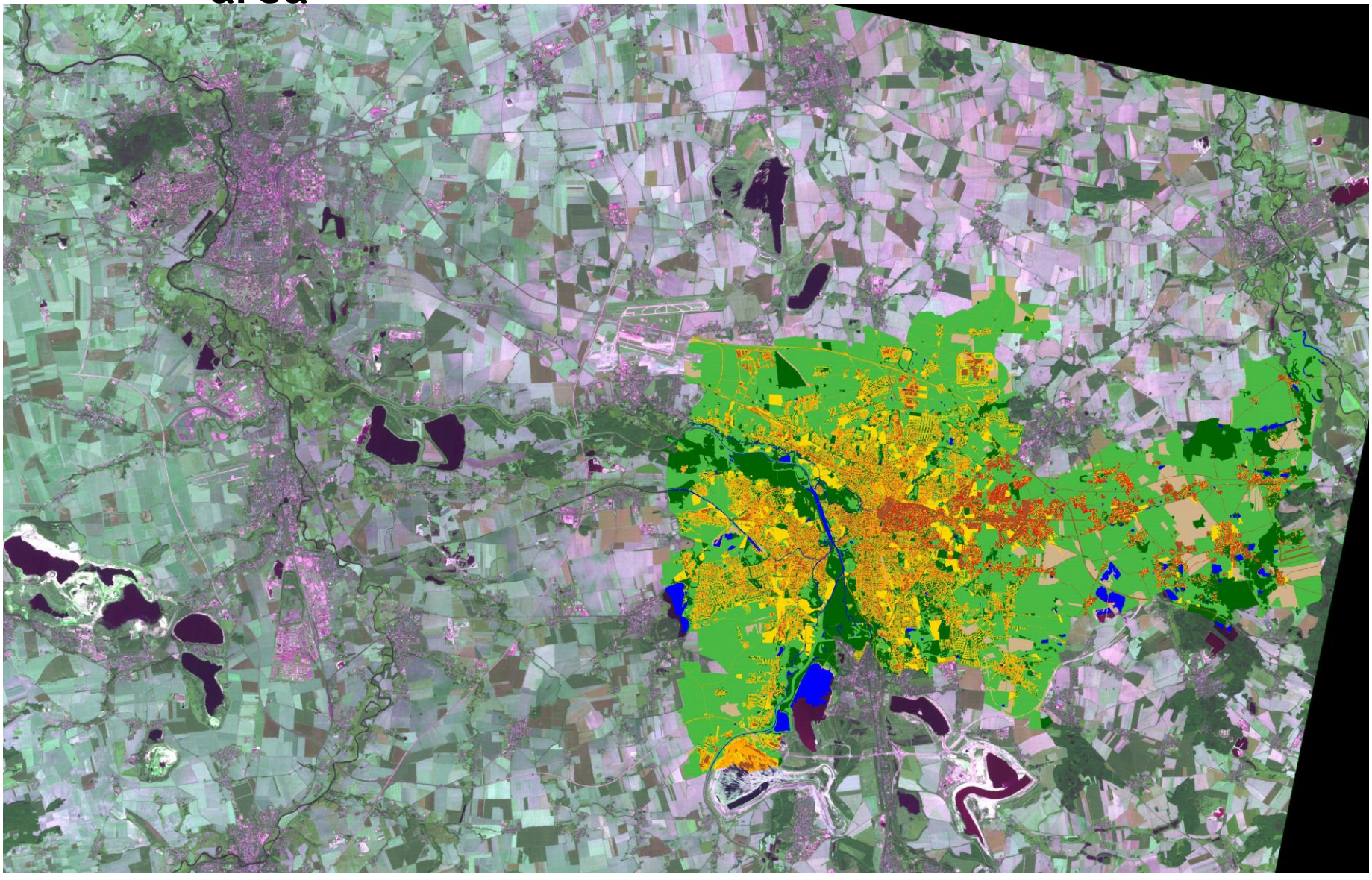
2005

Land-use classification key for all data

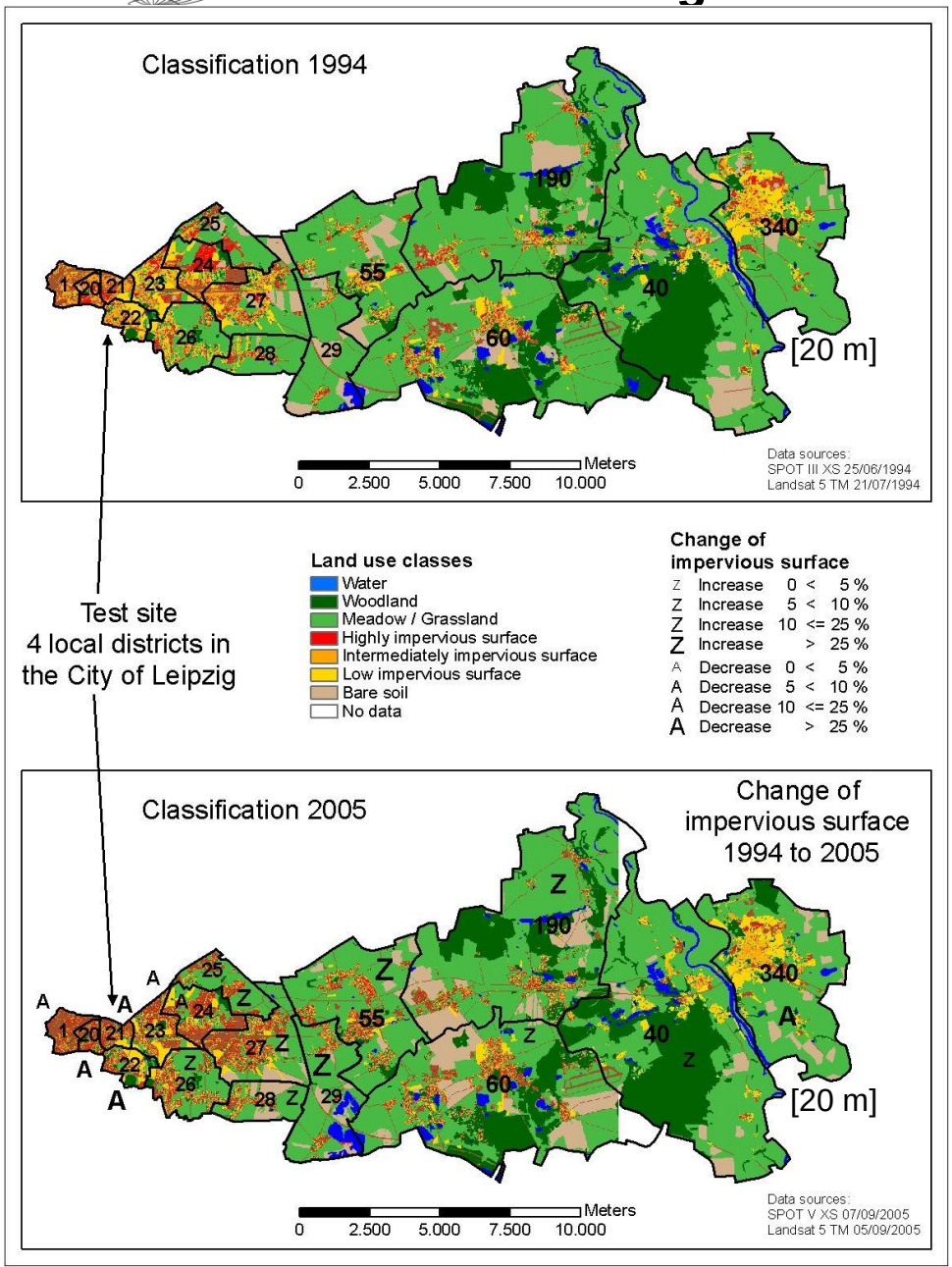
- No data
- Sistemas acuáticos
- Zona forestal urbana
- Parques y praderas
- Terreno agrícola
- Superficie muy impermeable
- Impermeabilidad media
- Impermeabilidad baja
- Suelo descubierto


Leipzig - Community incorporation reform:
1994: area 153,2 km², pop. density 3106 inh. / km²
2002: area 298,1 km², pop. density 1614 inh. / km²
City of Halle
City of Leipzig

Land-use classification of Leipzig and its suburban area



The urban – suburban gradient



	1994		2005	
Land use classes	[ha]	[%]	[ha]	[%]
Water	473	2	532	3
Woodland	3458	17	3513	17
Meadow / Grassland	11442	56	10747	53
Highly impervious surface	963	5	1368	7
Intermediately impervious surface	1466	7	1112	6
Low impervious surface	1195	6	1248	6
Bare soil	1427	7	1655	8

No. of commune / local district	Amount of imperviousness [%]		
	94-98	98-05	**94-05**
1	-1,2	-0,6	**-1,7**
20	-4,0	-4,8	**-8,6**
21	-2,7	-4,9	**-7,5**
22	-2,1	-10,3	**-12,2**
23	-2,9	-1,5	**-4,3**
24	4,0	-8,1	**-4,3**
25	5,6	2,1	**7,8**
26	12,6	-9,1	**2,3**
27	7,4	0,2	**7,6**
28	-0,7	5,6	**4,9**
29	33,5	0,3	**33,9**
40	1,0	0,1	**1,1**
55	37,4	2,9	**41,4**
60	3,5	-0,4	**3,0**
190	27,4	-5,7	**20,1**
340	-2,4	-11,2	**-13,3**

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Definition of Urban Structure Types (UST)

Urban structure types (UST) are spatial indicators that help to divide and differentiate the urban fabric into open and green spaces, infrastructure, building complexes so that their typical characteristics such as physical, functional and energetic factors can be identified.

(Arlt, G. et al. 2001)

With this instrument extrapolations can be made for local, regional and national investigations on such processes as urban compactness and differentiated land consumption.

UST and their individual characterization features

Characterisation of the urban structure :

- specific number of buildings
- a certain number and density of recreational facilities
- and green structure in the vicinity

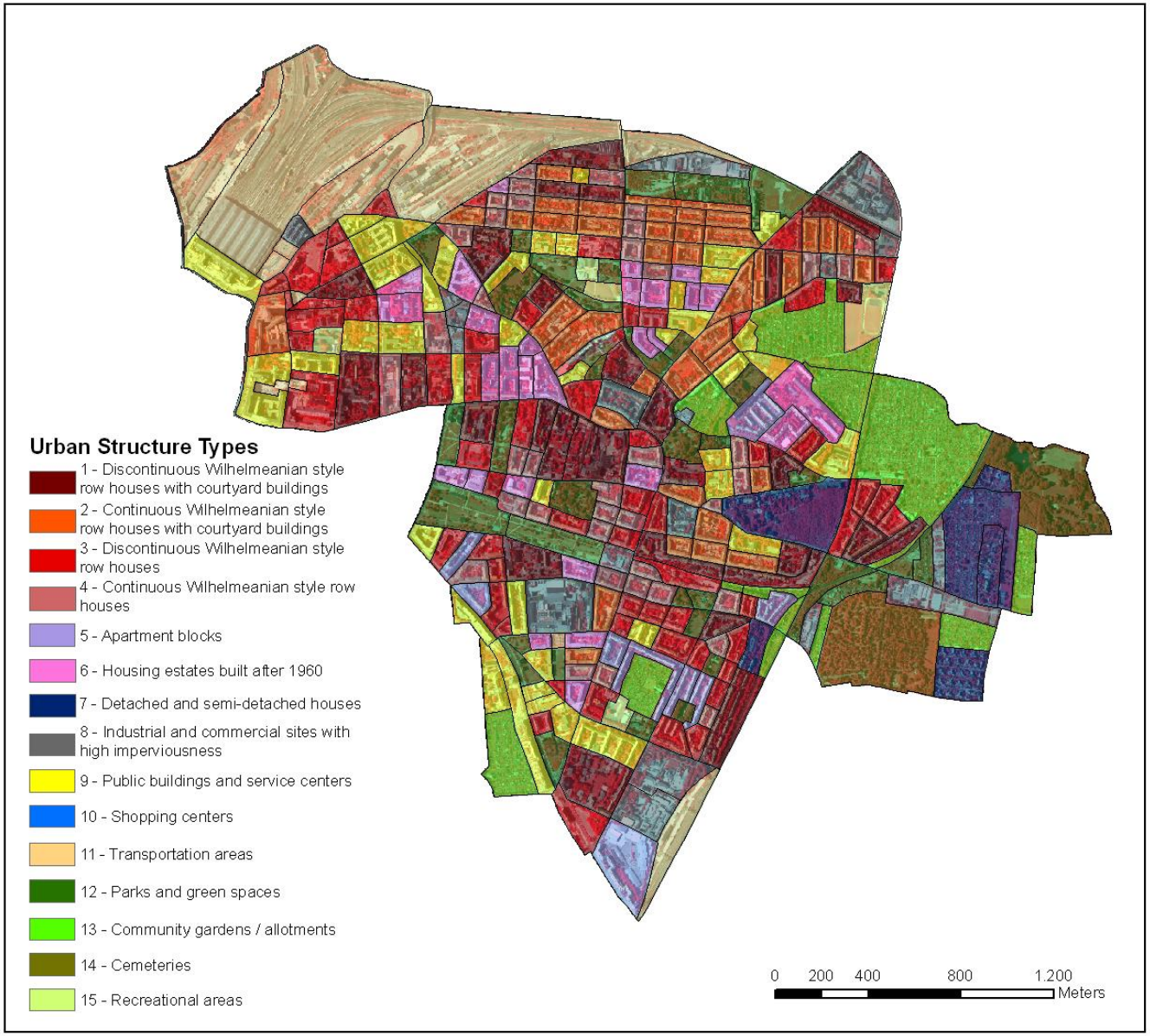
Urban structure types are identified at building block level

Relevant features:

- land-use
- type of buildings
- distribution and density of buildings
- green areas and biotope types
- degrees of impervious soils

The composition of two or several of these single features forms an urban structure type. So many different compositions are possible.

Urban structure types – four districts in the East of Leipzig



Urban structure types - three districts in the West of Leipzig

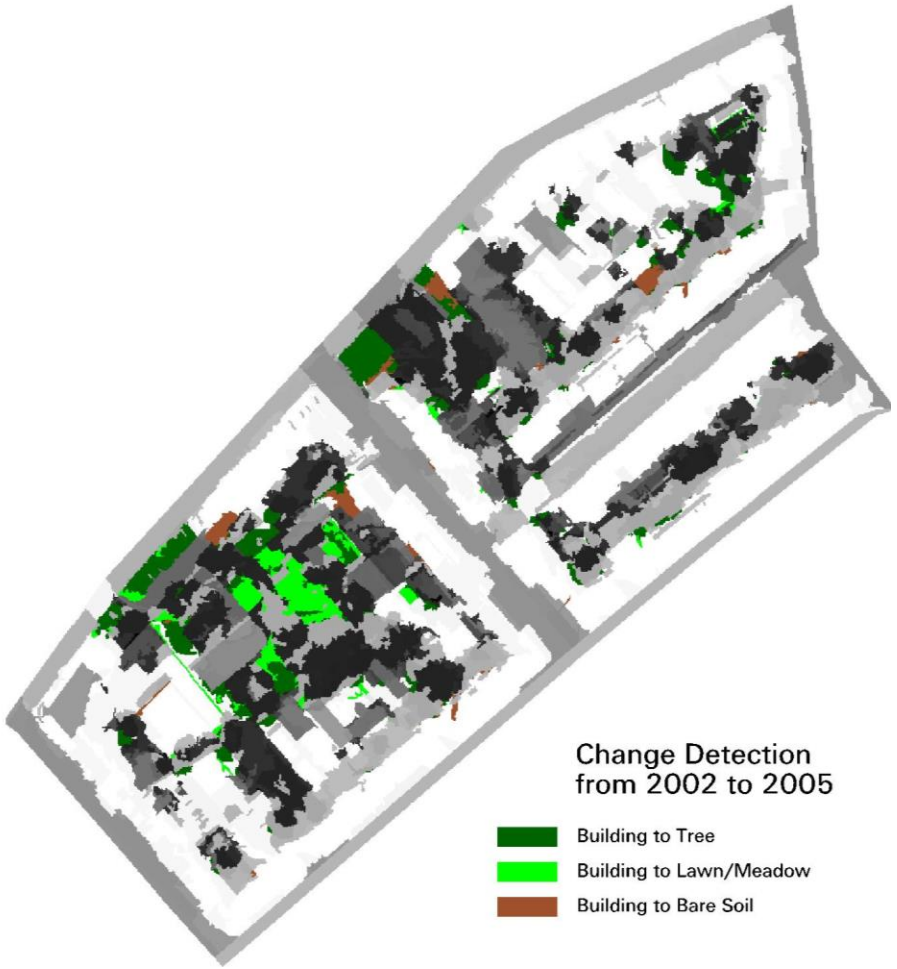
Geographisches Institut GEO matik Ruhr-Universität Bochum

Dominance / absence of certain UST in their local context

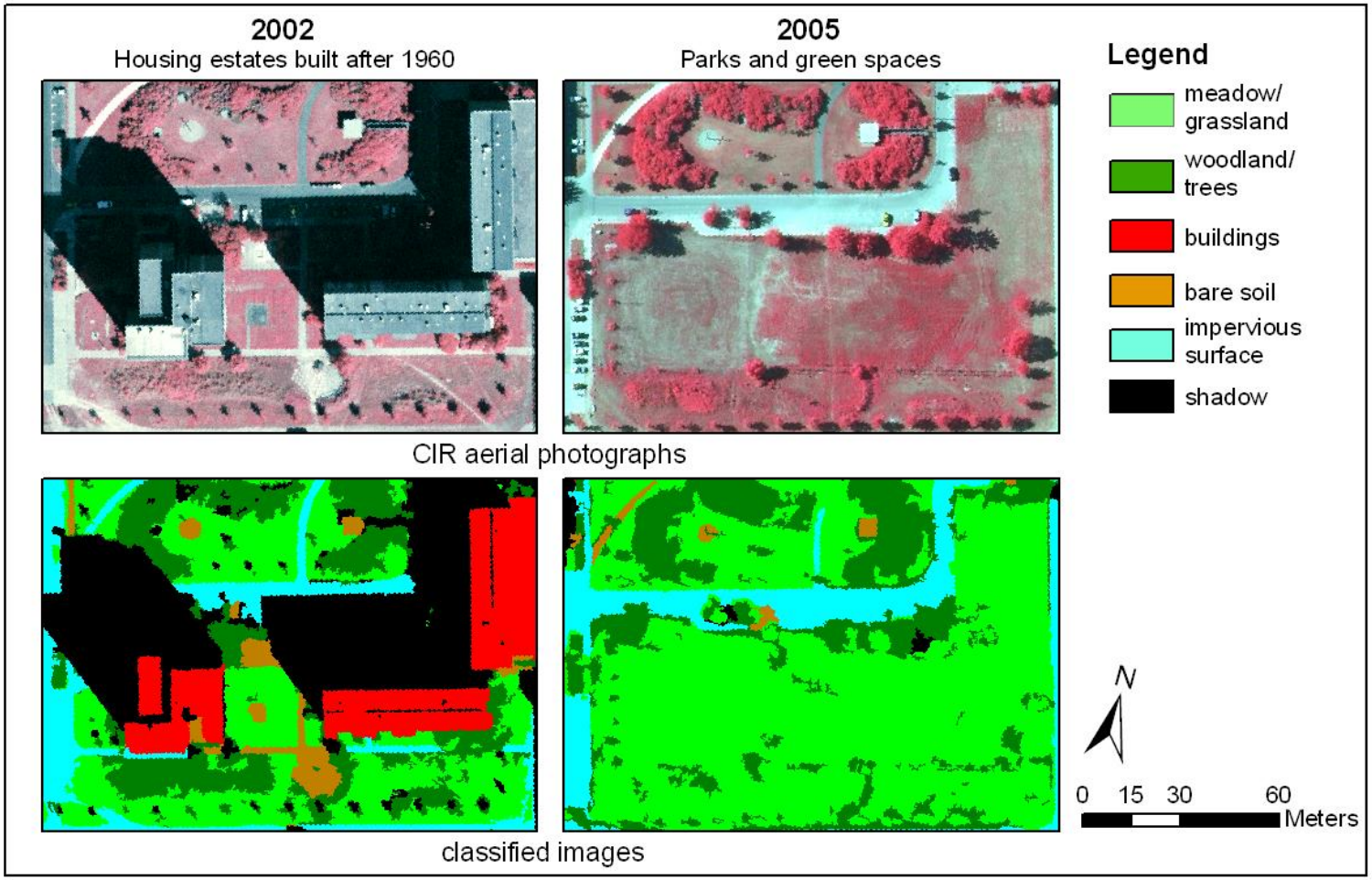
UST	user's accuracy [%]	
	west	east
Discontinuous Wilhelmeanian style row houses with courtyard buildings	not represented	77,53
Continuous Wilhelmeanian style row houses with courtyard buildings	not represented	80,05
Discontinuous Wilhelmeanian style row houses	not represented	57,40
Continuous Wilhelmeanian style row houses	not represented	71,91
Apartment blocks	not represented	44,51
Housing estates built after 1960	96,76	56,42
Detached and semi-detached houses	95,40	67,44
Industrial and commercial sites with	100,00	94,43
Public builings and service centers	97,03	77,40
Shopping centers	100,00	not represented
Transportation areas	100,00	100,00
Parks and green spaces	84,97	83,00
Community gardens / allotments	100,00	96,00
Cemeteries	not represented	100,00
Recreational area	100,00	100,00
overall accuray	93,40	73,15
kappa coefficient	0,92	0,70

Brownfields in Inner Districts: Project “Dunkler Wald”

2002



Change in the urban structure



Banzhaf & Höfer, 2008

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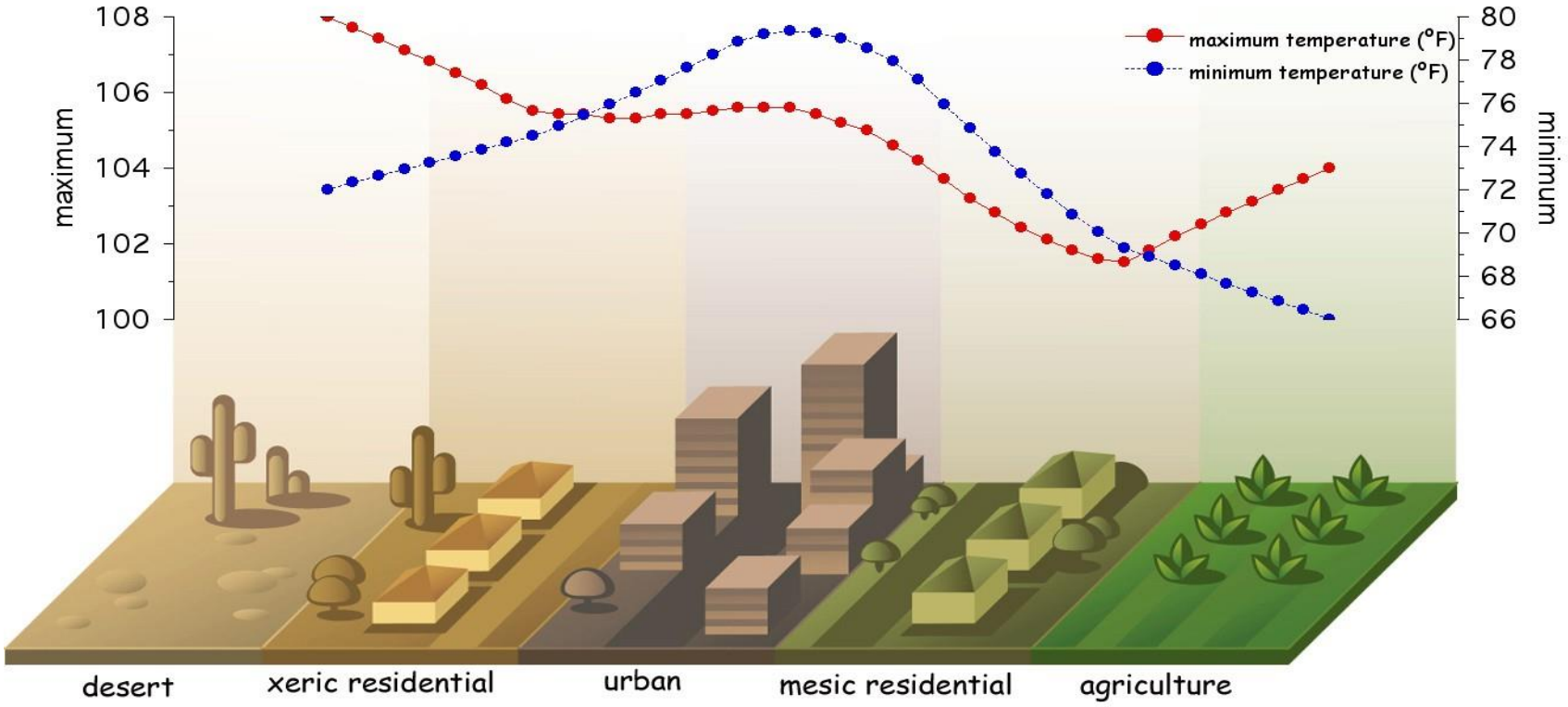
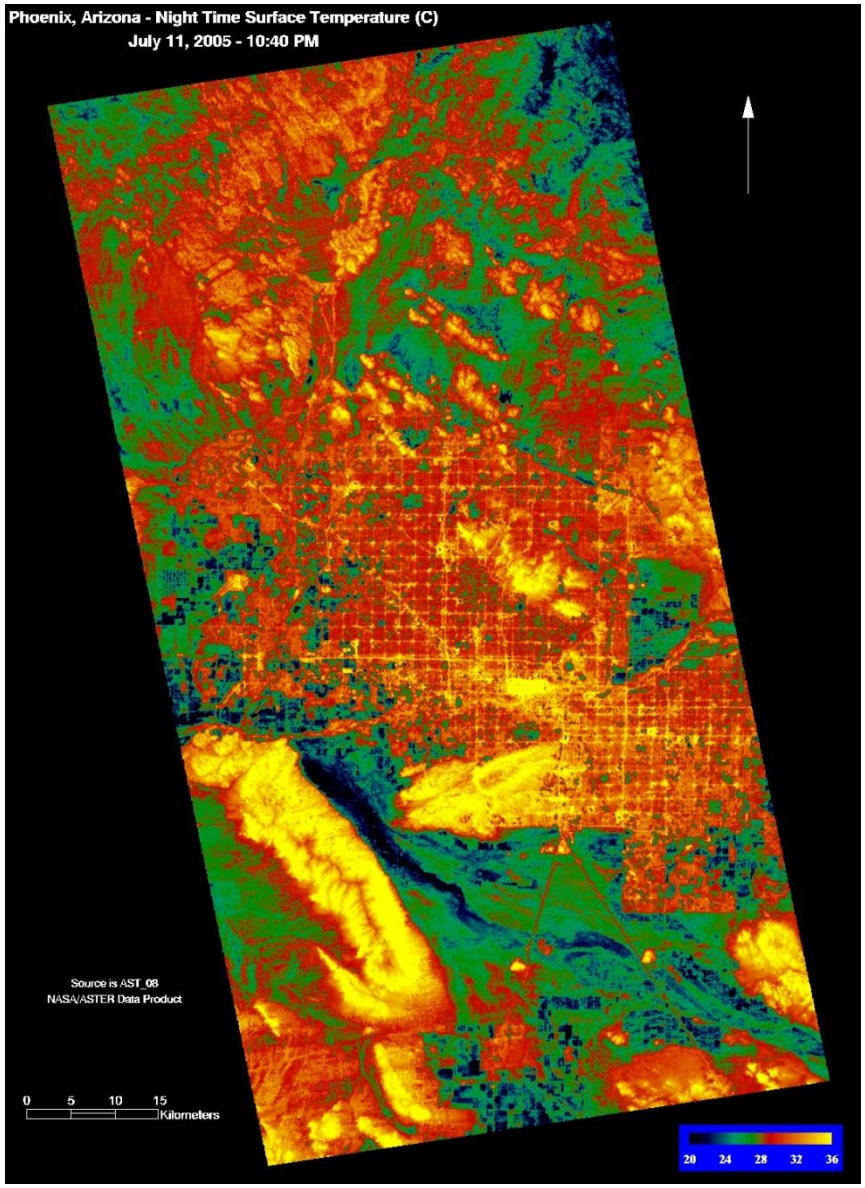
- Application of geometrically high resolution sensors (VHR)

Urban Heat Island



The heat island is a nighttime phenomenon in semi-arid regions. Residential and agricultural irrigation mitigate the heat island during the day.

(Zehnder 2004)



ASTER Phoenix Nighttime Surface Temperature

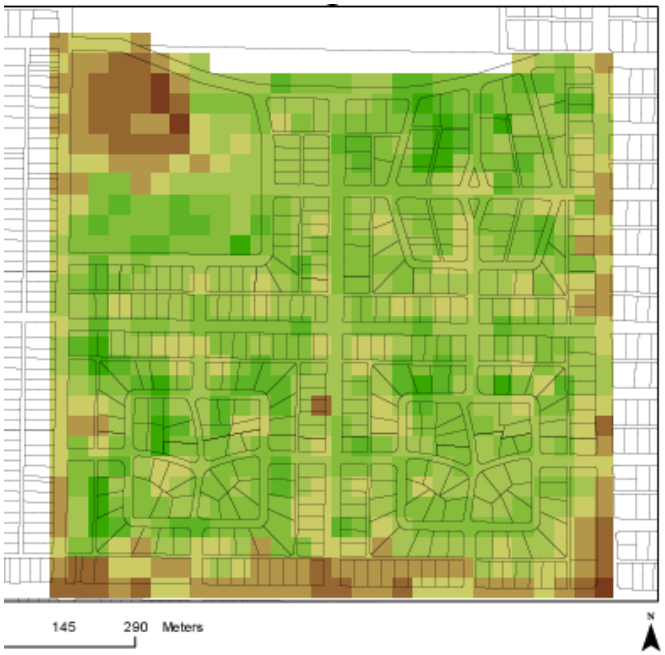
NWS Data July 11, 2005

Max Daytime Temperature

43 ° C / 111 ° F

Time	Temperature
10:51 PM	98.1 ° F / 36.7 ° C

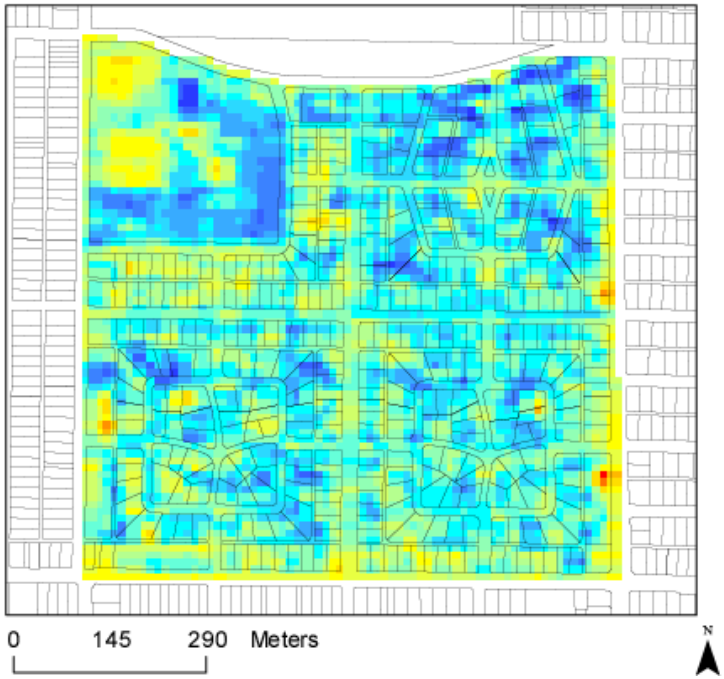
Encanto Vegetation Index



SAVI Derived from 2000 Landsat

0.35 - 0.39	0.50 - 0.54
0.40 - 0.44	0.55 - 0.59
0.45 - 0.49	0.60 - 0.64
	0.65 - 0.69
	0.70 - 0.74

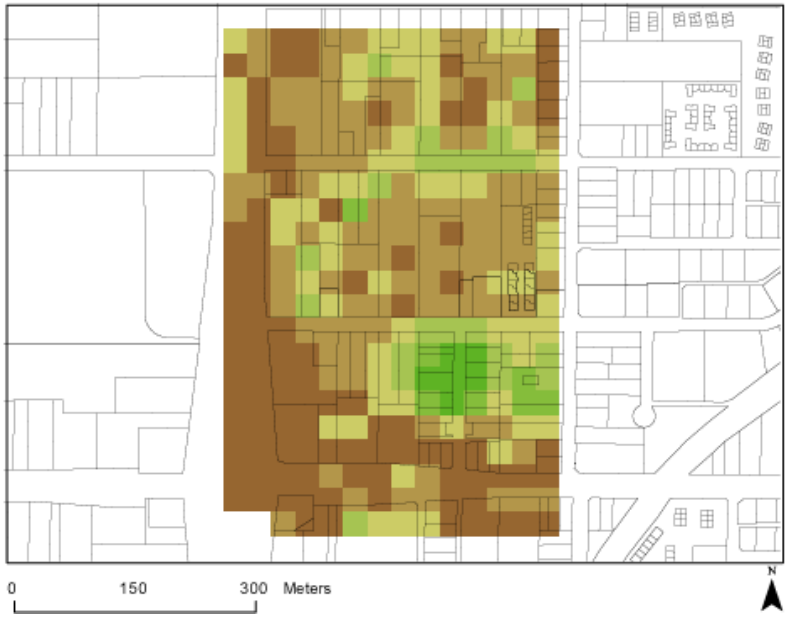
Encanto Surface Temperature



Surface Temperature in C

41 - 44	59 - 60
45 - 46	61 - 62
47 - 48	63 - 64
49 - 50	65 - 66
51 - 52	67 - 68
53 - 54	69 - 70
55 - 56	71 - 72
57 - 58	73 - 74
	75 - 76
	77 - 78

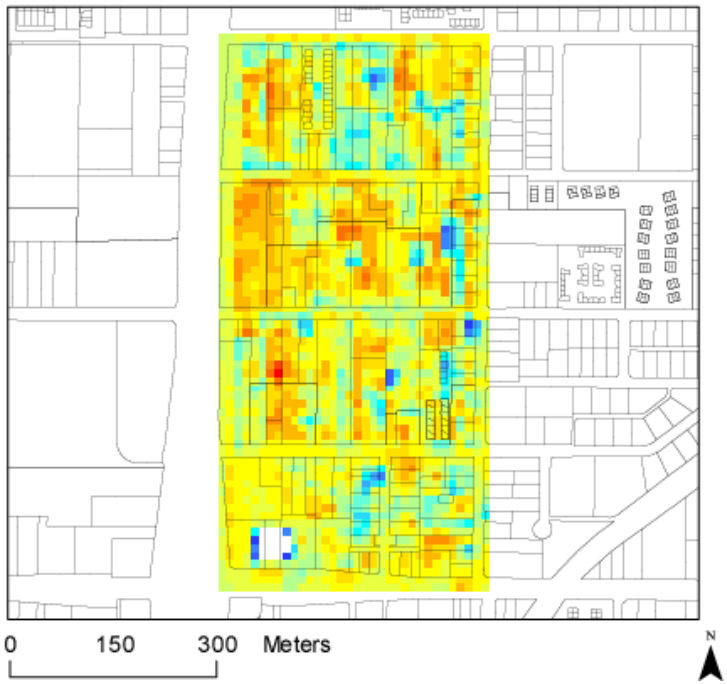
T15 Vegetation Index



SAVI Derived from 2000 Landsat

0.35 - 0.39	0.50 - 0.54
0.40 - 0.44	0.55 - 0.59
0.45 - 0.49	0.60 - 0.64
	0.65 - 0.69
	0.70 - 0.74

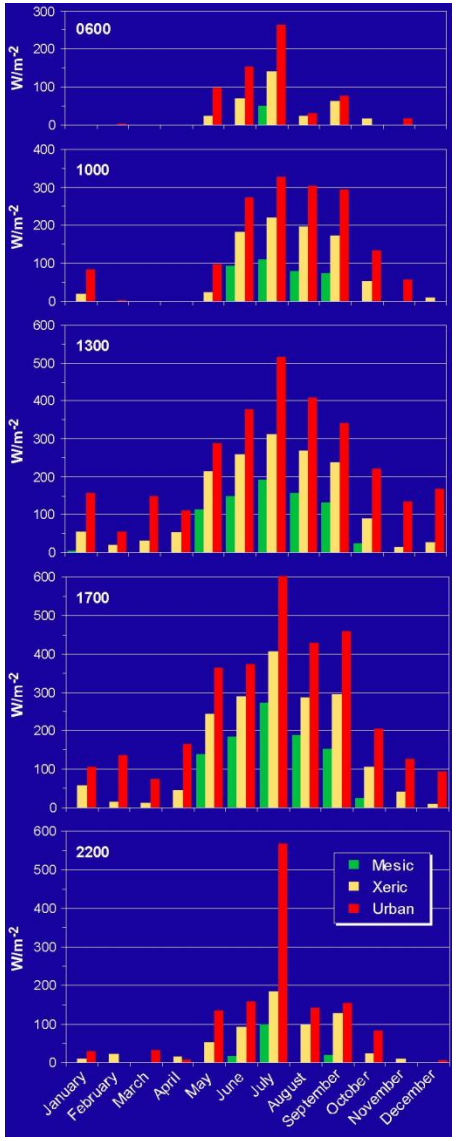
T15 Surface Temperature



Surface Temperature in C

41 - 44	59 - 60
45 - 46	61 - 62
47 - 48	63 - 64
49 - 50	65 - 66
51 - 52	67 - 68
53 - 54	69 - 70
55 - 56	71 - 72
57 - 58	73 - 74
	75 - 76
	77 - 78

Human Comfort



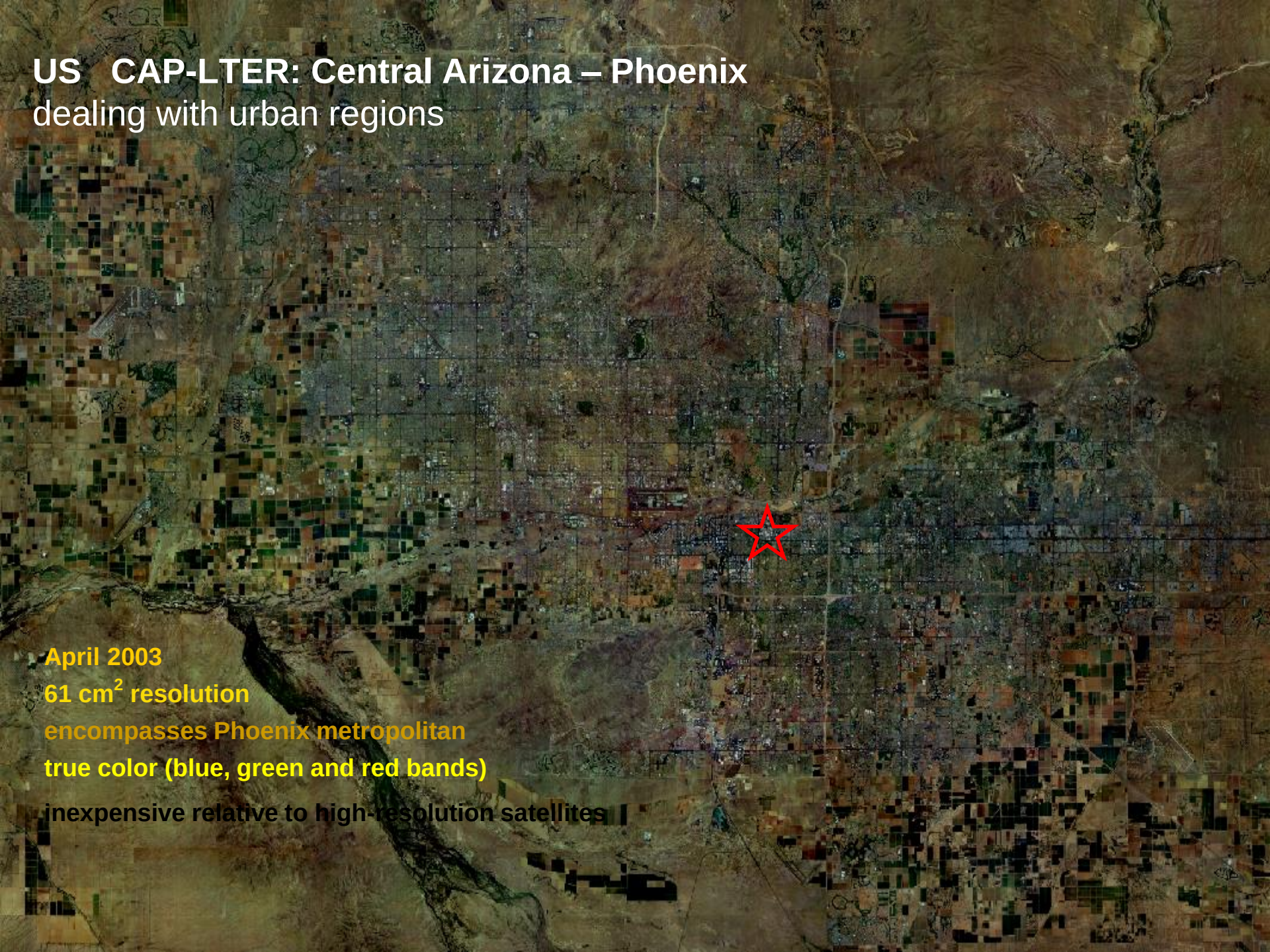
Urban residential or "zeroscape"

Mesic residential

Xeric residential

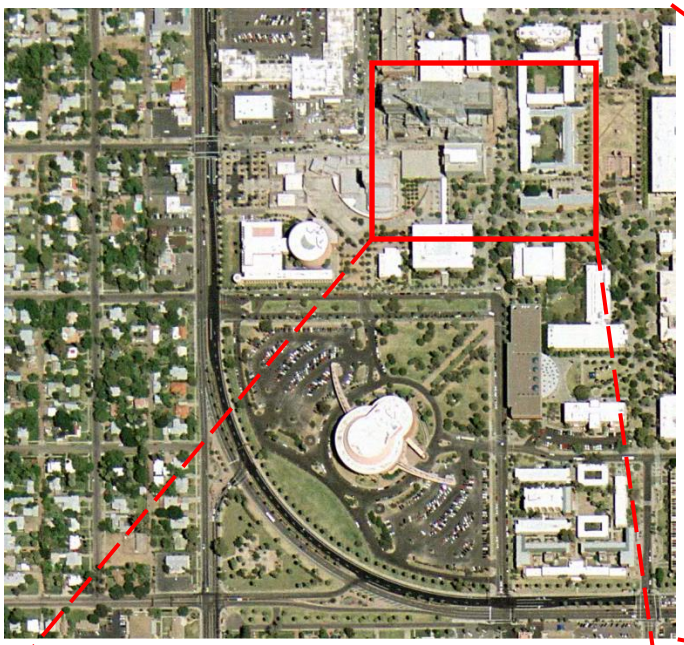
NSF Biocomplexity Grant
to Harlan, Brazel, Larson, Stefanov

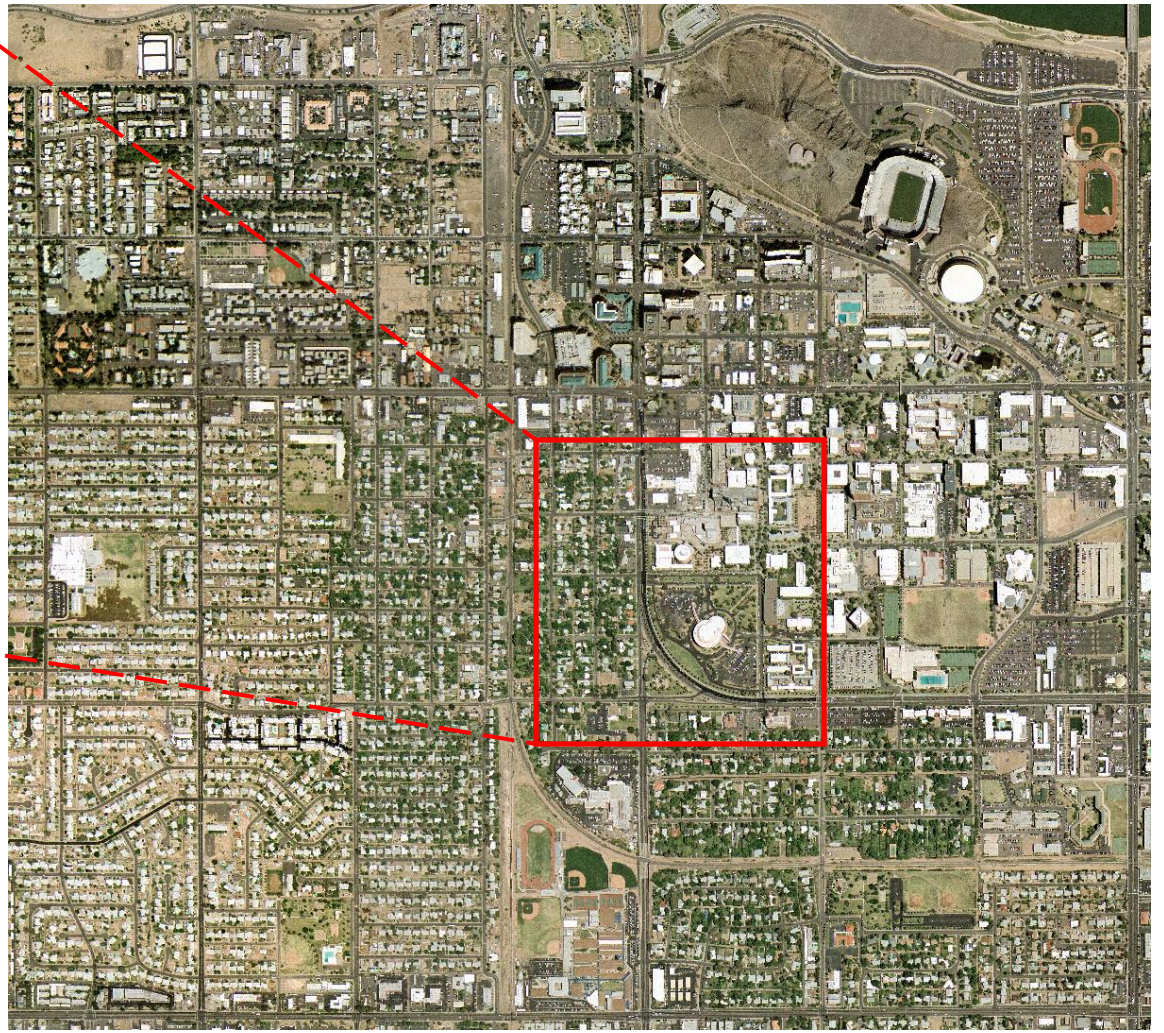
US CAP-LTER: Central Arizona – Phoenix
dealing with urban regions



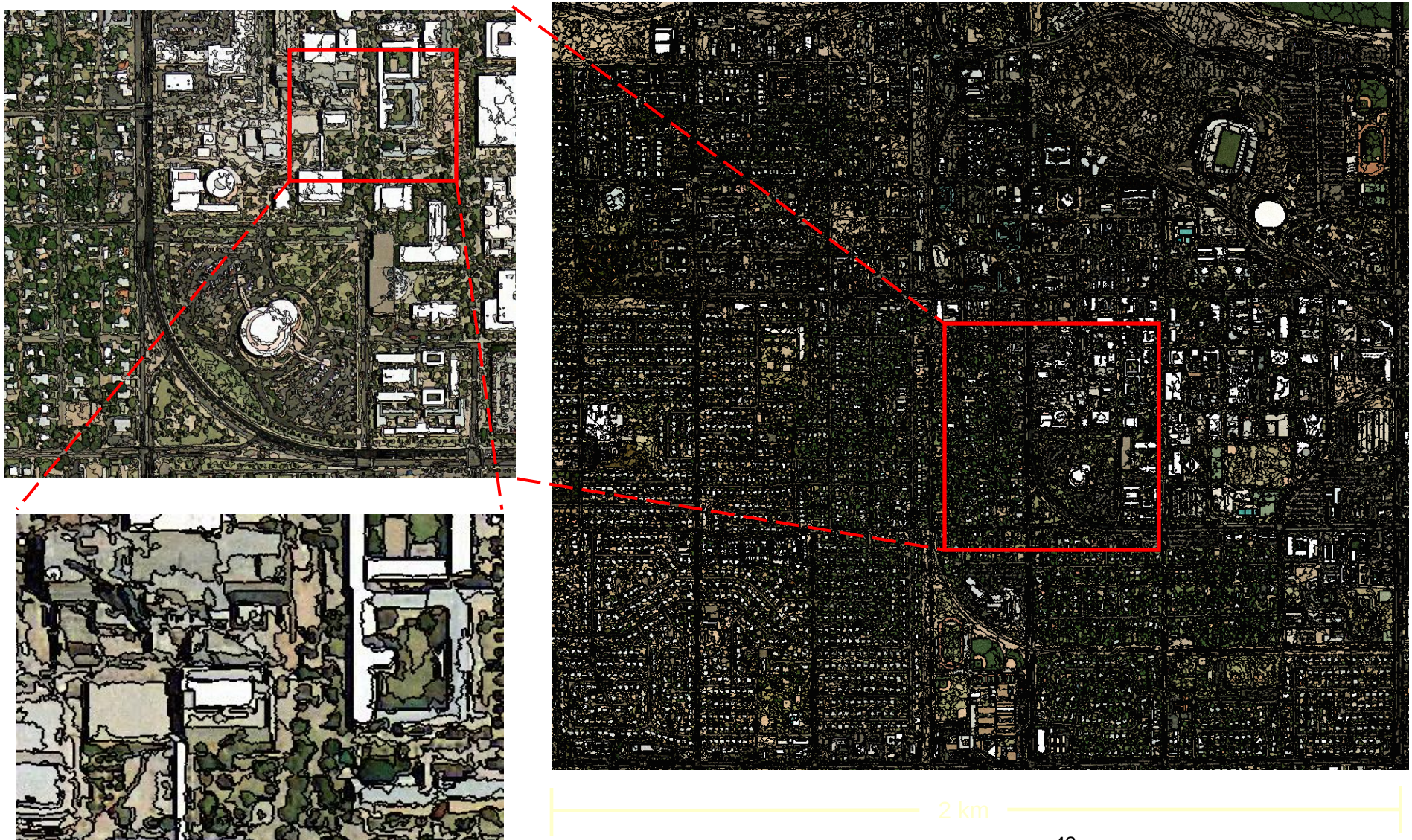
April 2003
61 cm^2 resolution
encompasses Phoenix metropolitan
true color (blue, green and red bands)
inexpensive relative to high-resolution satellites

Imagery

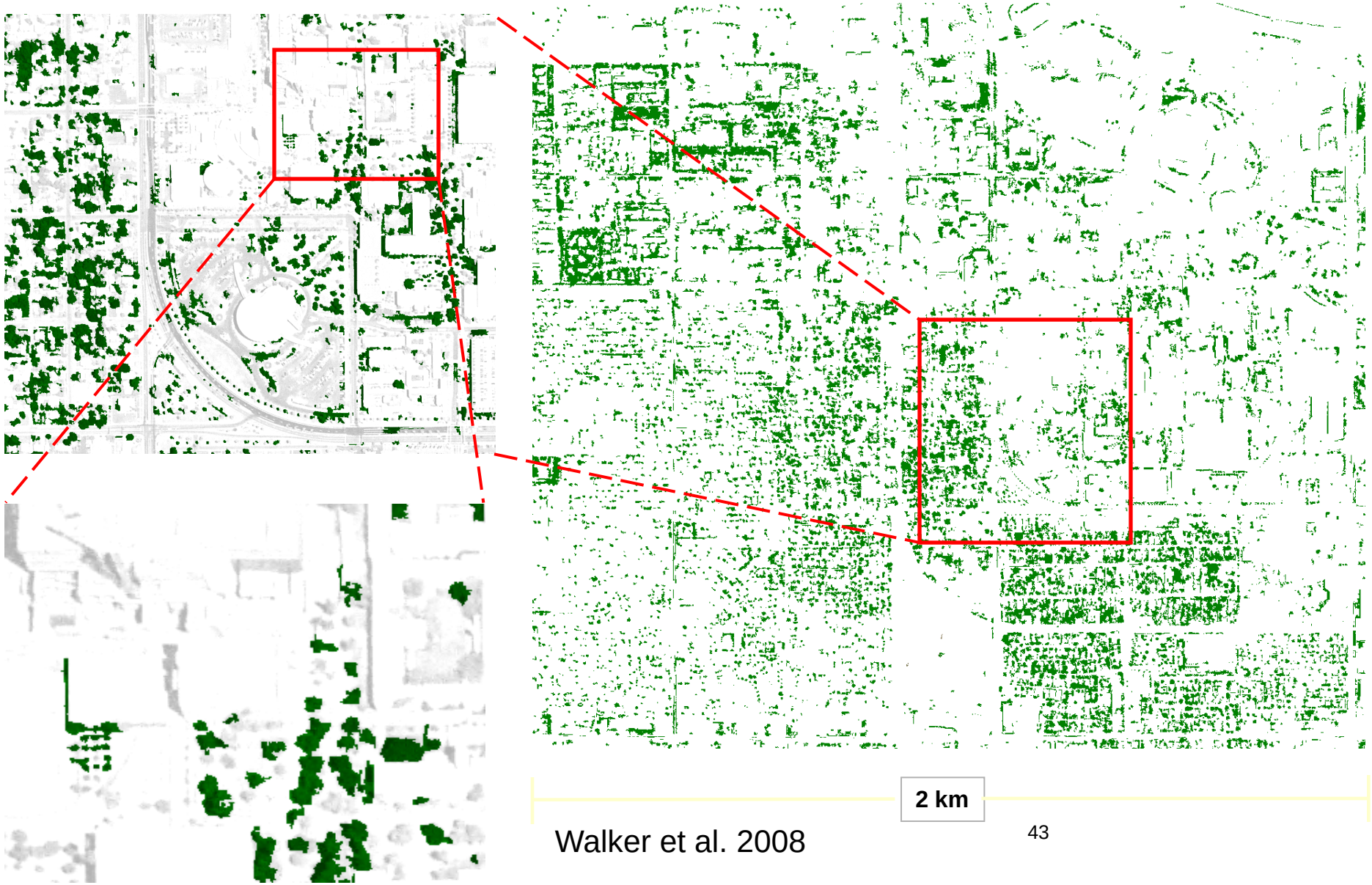




Segmentation



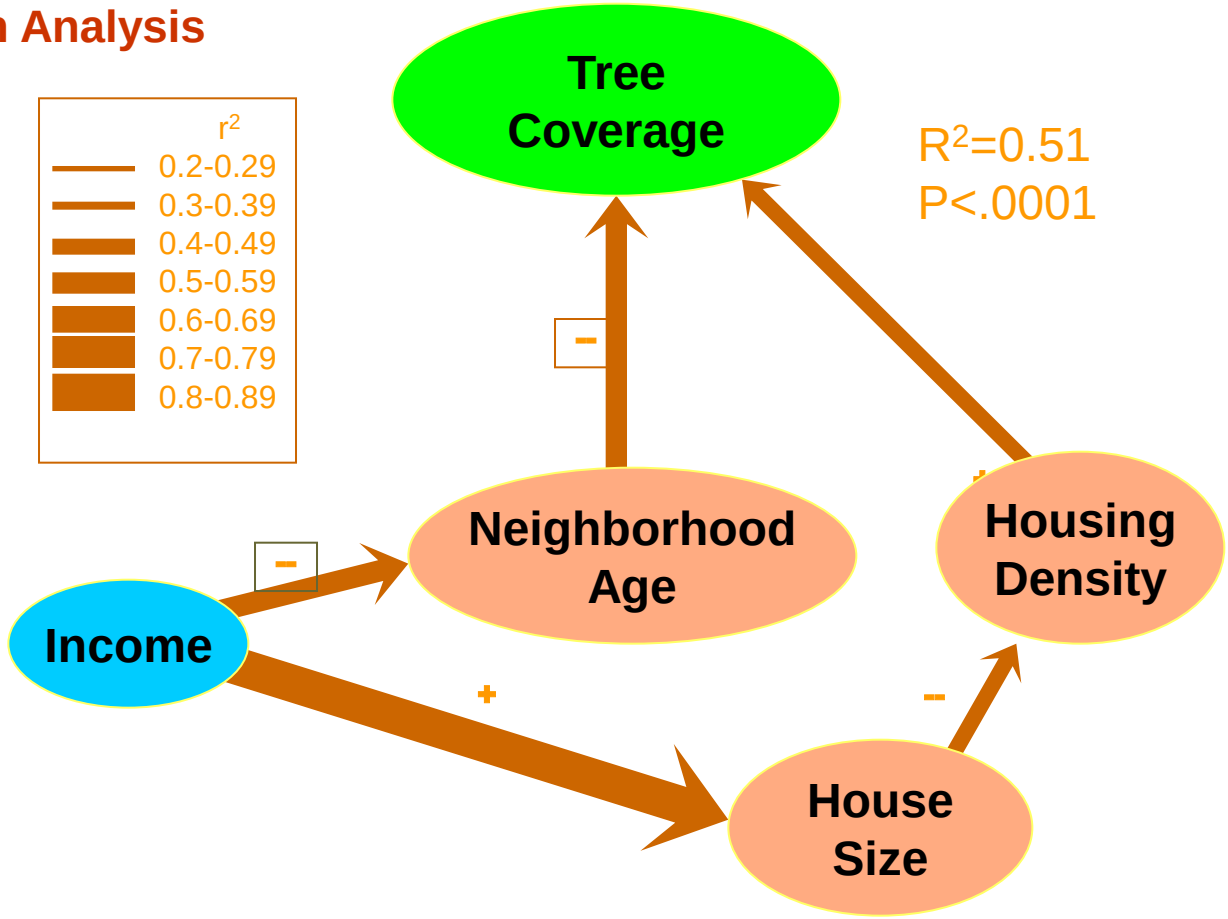
Classification of trees



Walker et al. 2008

Bird species diversity in CAP area - Who is feeding birds?

Path Analysis



Anderies, Katti, Shochat, 2007

Foci of Urban Remote Sensing in Urban Ecology

- Scale-dependent analysis of a city and its surroundings
- Land-use / land-cover analysis in urban regions
- Investigation of urban structures and potential changes
- Combined analysis of spatial and socio-demographic data
- Application of geometrically high resolution sensors (VHR)

- Superobject Segmentation Level 3
- Object Segmentation Level 2
- Subobject Segmentation Level 1

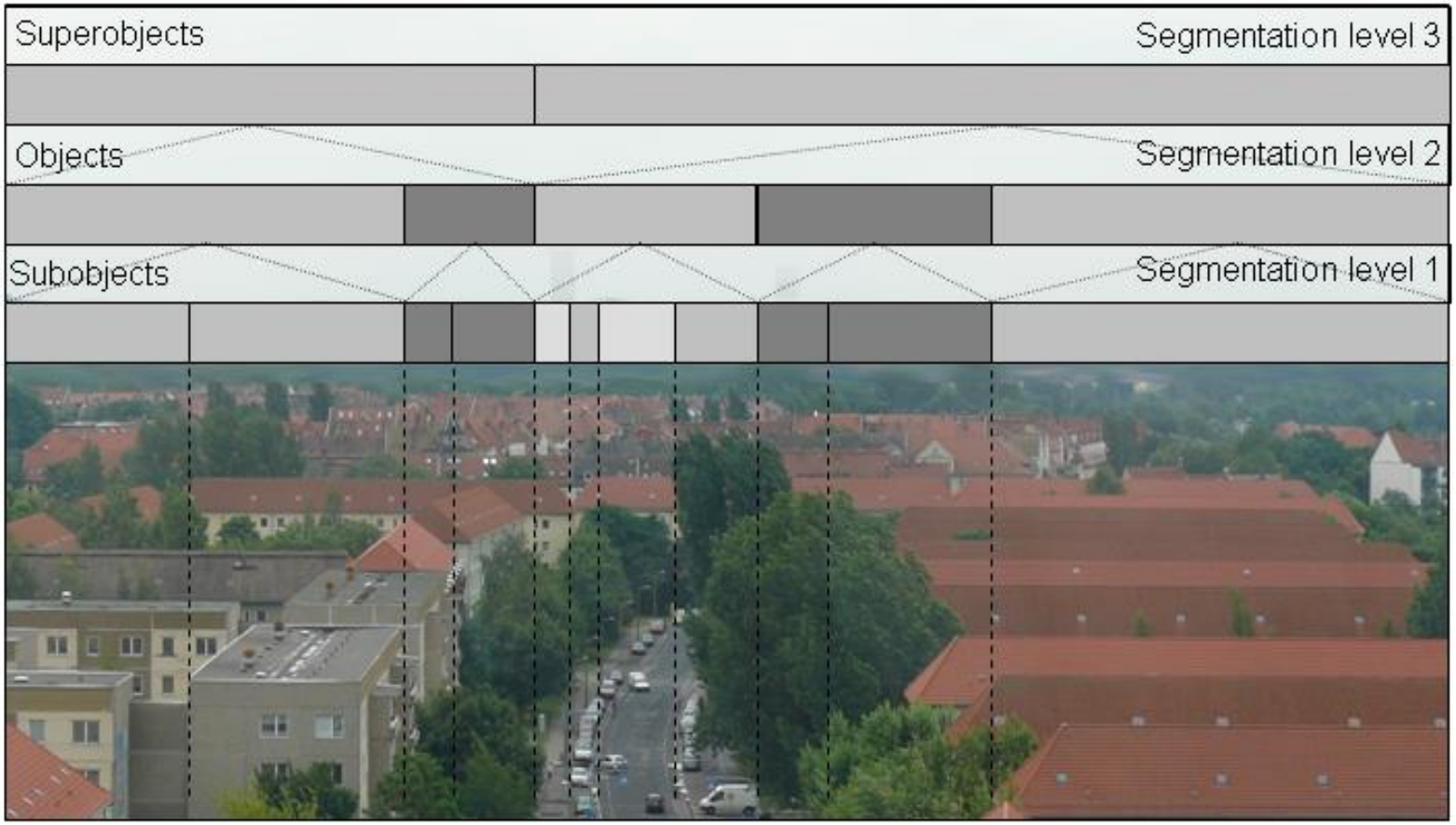
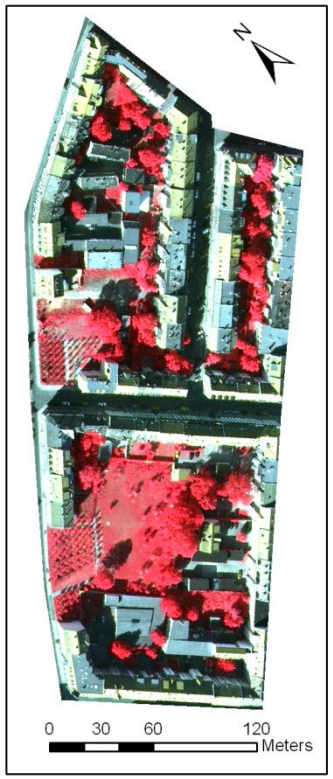
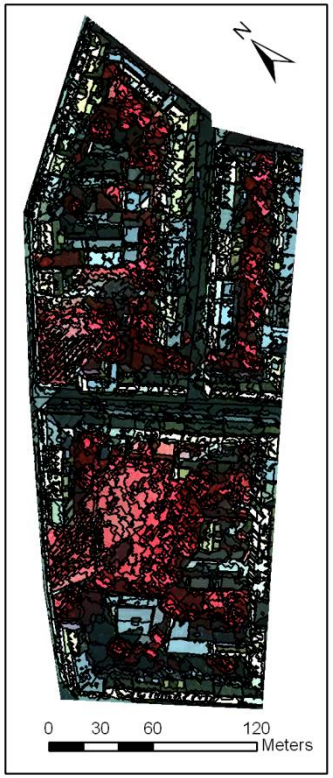


Image – segmentation – object-oriented classification



Segmentation

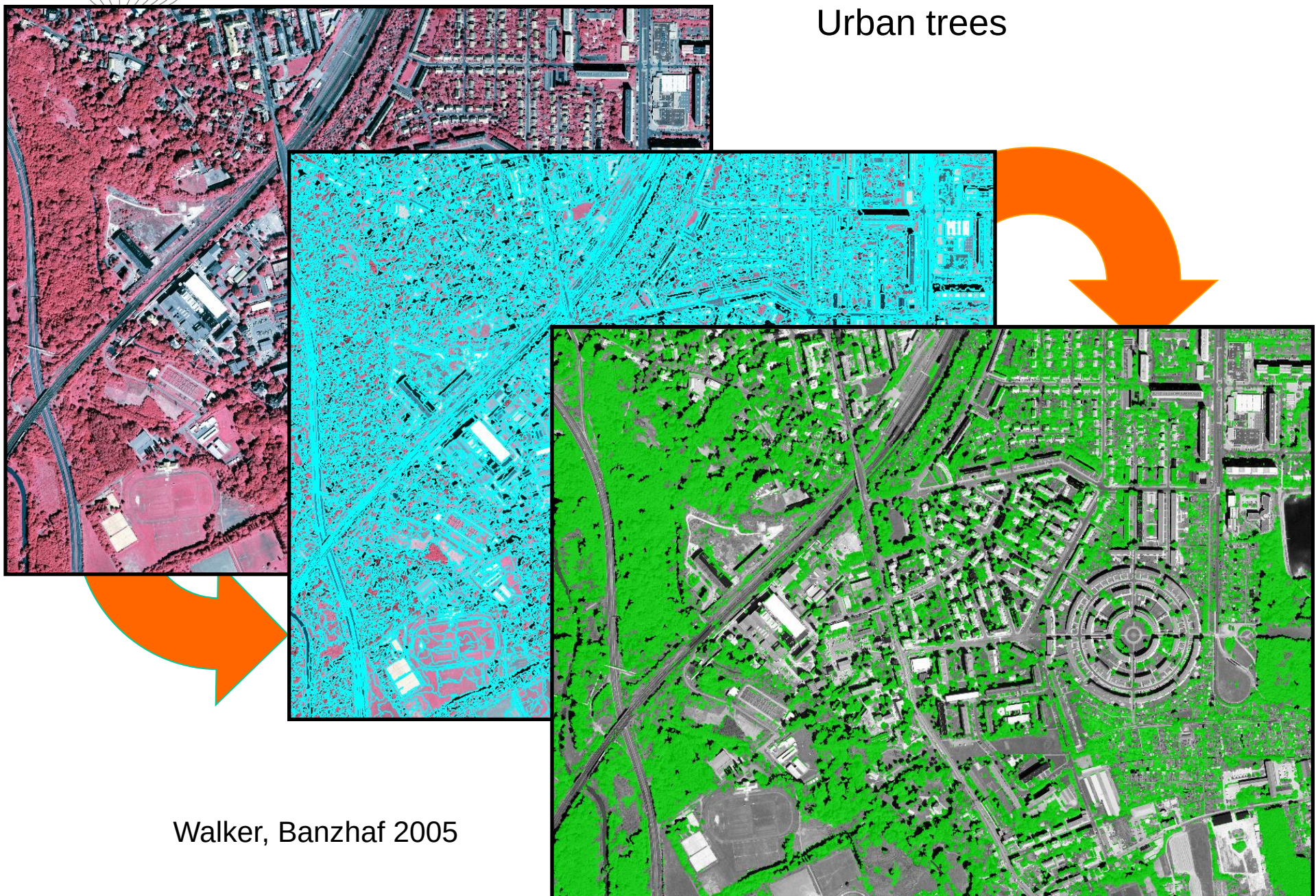


Classification

- parses raster into image objects
- formulates basic units for analysis
- calculated at different levels to highlight various objects

- Rule-based
- Intrinsic spectral information
- Shape characteristics of objects

Urban trees



Walker, Banzhaf 2005

(Pre-) Conclusions and Outlook

- Remote Sensing, GIS and Landscape Metrics widely used during the last decade for evaluating spatio-temporal dynamics in urban regions
- Need to standardize/harmonize methods for a real evaluation, especially for inter-urban comparisons, LU/LC budgets and prognosis
- How can we integrate case studies into a common and widely accepted framework?

Thanks for your attention !

Tasks for the groups I

- Challenge for developing the habitat classification for a city is to develop a mapping methodology that reflects habitat characteristics specific to the urban context that might also be transferable across urban areas, and has ecological integrity as well as practical planning applications.

Tasks for the groups II

- It is important to decide on the extent of coverage as this would determine the degree of detail needed in the habitat classification. As a general rule, urban habitat surveys can be carried out in three different ways:
  - Selective (surveying only habitats worth protecting);
  - Representative (habitat survey covers only exemplary habitats);
  - Overall (covering all habitats in a defined area).

Tasks for the groups III

- Develop a coarse concept for the achievement of the ecological mapping of private gardens and allotments for your own city.
- Research what has been done in this area.
- Synthesize and conclude what has been achieved and what is missing so far in terms of establishing a continuous GIS-based ecological mapping framework for your cities.

Tasks for the groups IV

- Group 1: Ecological Mapping
- Group 2: Land Use Classification
- Group 3: Habitat Classification
- Group 4: Private Garden Extraction
- Group 5: Mapping Accuracy
- Group 6: Regional Green Infrastructure Evaluation

Topics for Discussion

- ‘All maps often show mistakes’
- ‘But still, they are very valuable to get an overview, tendencies and problem areas can be identified relatively easy.’
- Rating scales don’t exist, so related to analyzing or planning items, personal brainpower is required.
- Issues: missing standards, missing conversations between planners (map producers) and ecologists, local activists, etc. and missing support by the national authorities?! Planners might be overburdened…?
- Others…