using space data to provide space for the environment

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ESA DUE Innovator III

EARTH OBSERVATION IN SUPPORT OF THE CITY BIODIVERSITY INDEX

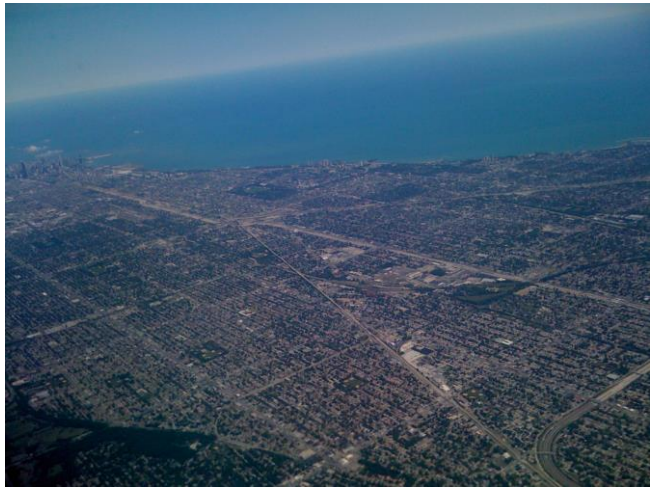
[PRESENTED BY: MIRKO GREGOR]

[GREEN SPACES IN URBAN AREAS - COLLOQUIUM
UNI LU, 18/05/2017]

UNIVERSITÉ Concordia UNIVERSITY

Background



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Background

- Increasing number of cities, increasing population (in Europe around 75%, globally almost 55%) → 2% of total land, but 70% of GDP and global waste, 60% of global energy consumption
  - „Cities are where the battle for sustainable development will be won or lost.“ (UN Habitat, HLP 2013)
- Trends in biodiversity and ecosystem services in urban areas (see the most recent policy documents, such as e.g. the Quito Declaration on the New Urban Agenda)
- The **City Biodiversity Index** (CBI, or Singapore Index on Cities' Biodiversity) was proposed during CBD's COP-10 in 2008
- a self-assessment tool to evaluate the state of biodiversity in cities and to provide insights for improving conservation efforts
  - Composed of 2 parts: city profile and indicators
  - Indicators part separated in 3 core components with in total 23 indicators (10-4-9)

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Background

SINGAPORE INDEX ON CITIES' BIODIVERSITY

PART I – Profile of the City

Location and size (geographical coordinates (latitudes and longitudes); climate (temperate or tropical); rainfall/precipitation (range and average); including maps or satellite images where city boundaries are clearly defined)

Physical features of the city (geography, altitude, area of impermeable surfaces, information on brownfield sites, etc.)

Demographics (including total population and population density; the population of the region could also be included if appropriate, and for the purpose of placing it in the regional context)

Economic parameters (Gross Domestic Product (GDP), Gross National Product (GNP), per capita income, key economic activities, drivers and pressures on biodiversity)

Biodiversity features (ecosystems within the city, species within the city, quantitative data on populations of key species of local importance, relevant qualitative biodiversity data)

Administration of biodiversity (relevant information includes agencies and departments responsible for biodiversity; how natural areas are protected (through national parks, nature reserves, forest reserves, secured areas, parks, etc.)

Links to relevant websites including the city's website, environmental or biodiversity themed websites, websites of agencies responsible for managing biodiversity

PART II - Indicators

Core Components		Indicators	Maximum Score
Native Biodiversity in the City	1.	Proportion of Natural Areas in the City	4 points
	2.	Connectivity Measures	4 points
	3.	Native Biodiversity in Built Up Areas (Bird Species)	4 points
	4.	Change in Number of Vascular Plant Species	4 points
	5.	Change in Number of Bird Species	4 points
	6.	Change in Number of Butterfly Species	4 points
	7.	Change in Number of Species (any other taxonomic group selected by the city)	4 points
	8.	Change in Number of Species (any other taxonomic group selected by the city)	4 points
	9.	Proportion of Protected Natural Areas	4 points
	10.	Proportion of Invasive Alien Species	4 points
Ecosystem Services provided by Biodiversity	11.	Regulation of Quantity of Water	4 points
	12.	Climate Regulation: Carbon Storage and Cooling Effect of Vegetation	4 points
	13.	Recreation and Education: Area of Parks with Natural Areas	4 points
	14.	Recreation and Education: Number of Formal Education Visits per Child Below 16 Years to Parks with Natural Areas per Year	4 points
Governance and Management of Biodiversity	15.	Budget Allocated to Biodiversity	4 points
	16.	Number of Biodiversity Projects Implemented by the City Annually	4 points
	17.	Existence of Local Biodiversity Strategy and Action Plan	4 points
	18.	Institutional Capacity: Number of Biodiversity Related Functions	4 points
	19.	Institutional Capacity: Number of City or Local Government Agencies Involved in Inter-agency Co-operation Pertaining to Biodiversity Matters	4 points
	20.	Participation and Partnership: Existence of Formal or Informal Public Consultation Process	4 points
	21.	Participation and Partnership: Number of Agencies/Private Companies/NGOs/Academic Institutions/International Organisations with which the City is Partnering in Biodiversity Activities, Projects and Programmes	4 points
	22.	Education and Awareness: Is Biodiversity or Nature Awareness Included in the School Curriculum	4 points
	23.	Education and Awareness: Number of Outreach or Public Awareness Events Held in the City per Year	4 points
		Native Biodiversity in the City (Sub-total for indicators 1-10)	**40 points**
		Ecosystem Services provided by Biodiversity (Sub-total for indicators 11-14)	**16 points**
		Governance and Management of Biodiversity (Sub-total for indicators 15-23)	**36 points**
		Maximum Total:	**92 points**

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Project objectives

EO4CBI project provides support for 4 selected CBI indicators, making use of satellite imagery (SPOT-5, SPOT-5 Take 5, RapidEye in phase 1, Sentinel-2 in phase 2):

- **Indicator 1** – Proportion of Natural Areas in the City = (Total area of natural, restored and naturalised areas) / (Total area of city) × 100%
- **Indicator 2** – Connectivity Measures or Ecological Networks to Counter Fragmentation

$$Indicator\,2 = \frac{1}{A_{\text{total}}}\left(A_1^2 + A_2^2 + A_3^2 + \ldots + A_n^2\right)$$

- **Indicator 11** – Proportion of permeable areas = (Total permeable area) / (Total terrestrial area of the city) × 100%
- **Indicator 12** – Extent of tree canopy cover = (Tree canopy cover) / (Total terrestrial area of the city) × 100%

„assess the potential of EO data to support the production of certain CBI indicators“

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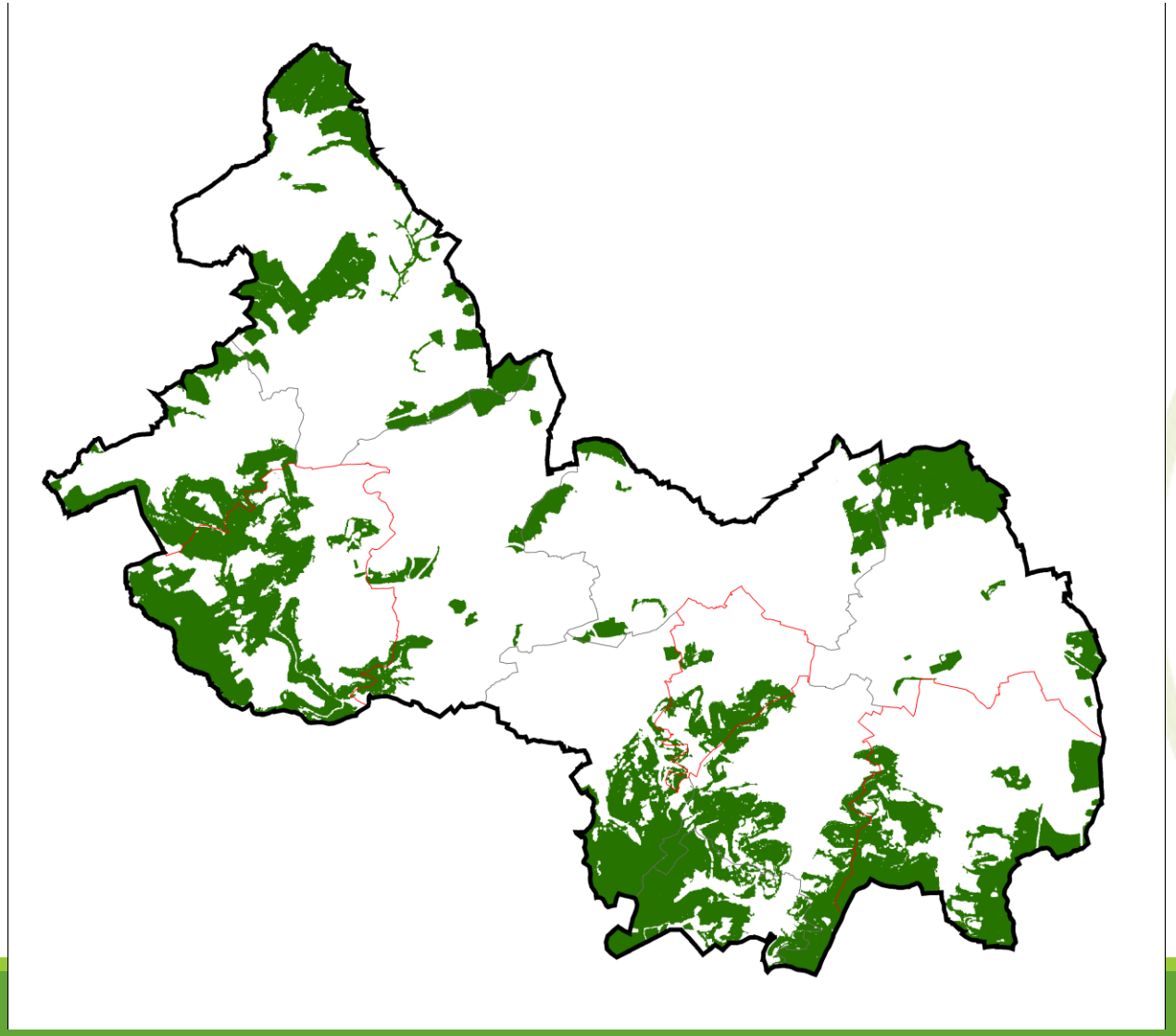
Study Areas


Edmonton
Portland
Stockholm
Tallinn
Luxembourg
Lisbon
Barcelona
Addis Ababa
Buenos Aires
Hamilton

Indicator 1: Proportion of natural areas



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Indicator 1: Proportion of natural areas

- Major challenges:
  - which land cover elements are „natural“?
  - how can they be mapped based on satellite images (land cover vs. land use or greenness vs. naturalness)?
  - achieving comparability? Required at all?
- Suggestion to create the most precise baseline possible (at high costs and where possible) and use EO data for (cheap) regular monitoring (or backdating)
- Problem: CBI scoring system

0 points: < 1.0%
1 point: 1.0% – 6.9%
2 points: 7.0% – 13.9%
3 points: 14.0% – 20.0%
4 points: > 20.0%

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Indicator 2: Connectivity

- measures the degree of connectivity of natural areas within cities
- Connectivity is defined as “the degree to which the landscape facilitates or impedes movement among resources” and it can be “measured by the probability of movement between all points or resource patches in a landscape” (effective mesh size) → threshold 100m (CBI User Manual)
- Input data
  - Indicator 1
  - Barriers and Connectors

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Original article

Implementing the connectivity of natural areas in cities as an indicator in the city biodiversity index (CBI)

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ABSTRACT

The City Biodiversity Index (CBI), or Singapore Index on Cities' Biodiversity, serves as a tool to monitor biodiversity in cities and was endorsed by the Convention on Biological Diversity in 2009. Indicator 2 of the CBI measures the connectivity of natural areas in cities. We propose an improved and straightforward method for measuring connectivity based on the effective mesh size metric to replace the previous method used in the CBI. The previous version did not account for intra-patch (within-patch) connectivity nor for major barriers. Our evaluation of the new version of Indicator 2 through its application to Montréal and Lisbon confirmed its reliability. In Montréal, natural areas have a total connectivity value of 581.7 ha, the majority of which exists between, rather than within, patches of natural area. Smaller patches (<15 ha) contribute significantly to overall connectivity, which may have implications for future conservation efforts. In Lisbon, connectivity (342 ha) is concentrated within patches. We also applied the new Indicator 2 to a case study in southwestern Montréal, where a greenway network (“green infrastructure”) has been proposed by a local community organization. We assessed the contribution of Meadowbrook Golf Course to connectivity in scenarios of the proposed greenway network and the effect that residential development would have. Not only would this development eliminate the golf course's current contribution to connectivity, but also its much greater potential contribution to connectivity in future scenarios. Restoring and establishing additional natural areas would significantly increase connectivity in the network. Our results demonstrate that the new version of Indicator 2 is a suitable and improved method in the CBI. It is equally useful for identifying options to increase the connectivity of natural areas within cities in the future and for determining the impacts of urban development on connectivity. More advanced methods for quantifying connectivity exist and may also be included in Part I of the CBI. However, they are often challenging to use and this frequently discourages city planners from including any indicator of connectivity in their biodiversity monitoring. The connectivity metric presented here overcomes this problem through its practicality in a wide range of planning structures while still generating meaningful results which may then inspire city planners to move towards using more advanced methods of measuring connectivity. We dedicate this paper to the memory of Bernice Goldsmith (1934–2014).

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1. Monitoring biodiversity in cities

Urban wildlife populations are negatively affected by habitat fragmentation, which limits access to resources and mating partners. This may result in the loss of genetic diversity and in higher rates of extinction, in particular among groups of species with highly specialized habitat requirements (Brook et al., 2003; Di Giulio et al., 2009; Taylor et al., 1993; Tischendorf and Fahrig, 2000). The City Biodiversity Index (CBI), or Singapore Index on Cities' Biodiversity, was developed as a tool to evaluate and monitor the state of biodiversity in cities and to provide insights for improving conservation efforts. It was proposed by the Minister of National Development in Singapore, Mr. Mah Bow Tan, at the 9th Meeting of the Conference of the Parties (COP-9) to the Convention on Biological Diversity (CBD) in May 2008. The CBI was established by the National Parks Board of Singapore and the Secretariat of the CBD in collaboration with the Global Partnership on Cities and Biodiversity from 2009 to 2011 (Chan et al., 2014). The Index is comprised of 23 indicators (Table 1), characterized as “native biodiversity in the city; ecosystem services provided by native biodiversity; and governance and management of native biodiversity” (Chan et al., 2014; p. 4). Few studies have analyzed the CBI and its implementation in urban areas. However, existing research focusing on the application of CBI indicators accounts for both biological and social factors, including the development of partnerships between academics and policy makers, which are important for promoting conservation efforts (Kohsaka, 2010; Kohsaka et al., 2013; Kohsaka and Okumura, 2014). We focus on Indicator 2, which measures the connectivity of natural areas in cities.

1.1. Connectivity

Connectivity is defined as “the degree to which the landscape facilitates or impedes movement among resource patches” and it can be

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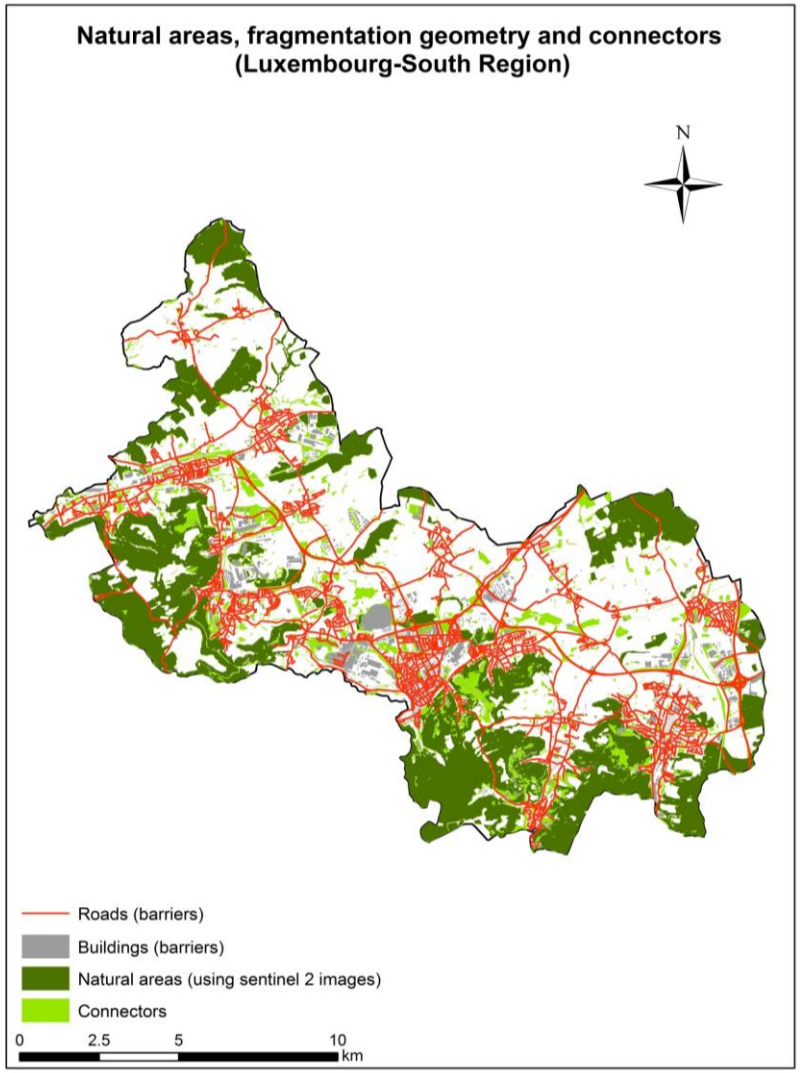
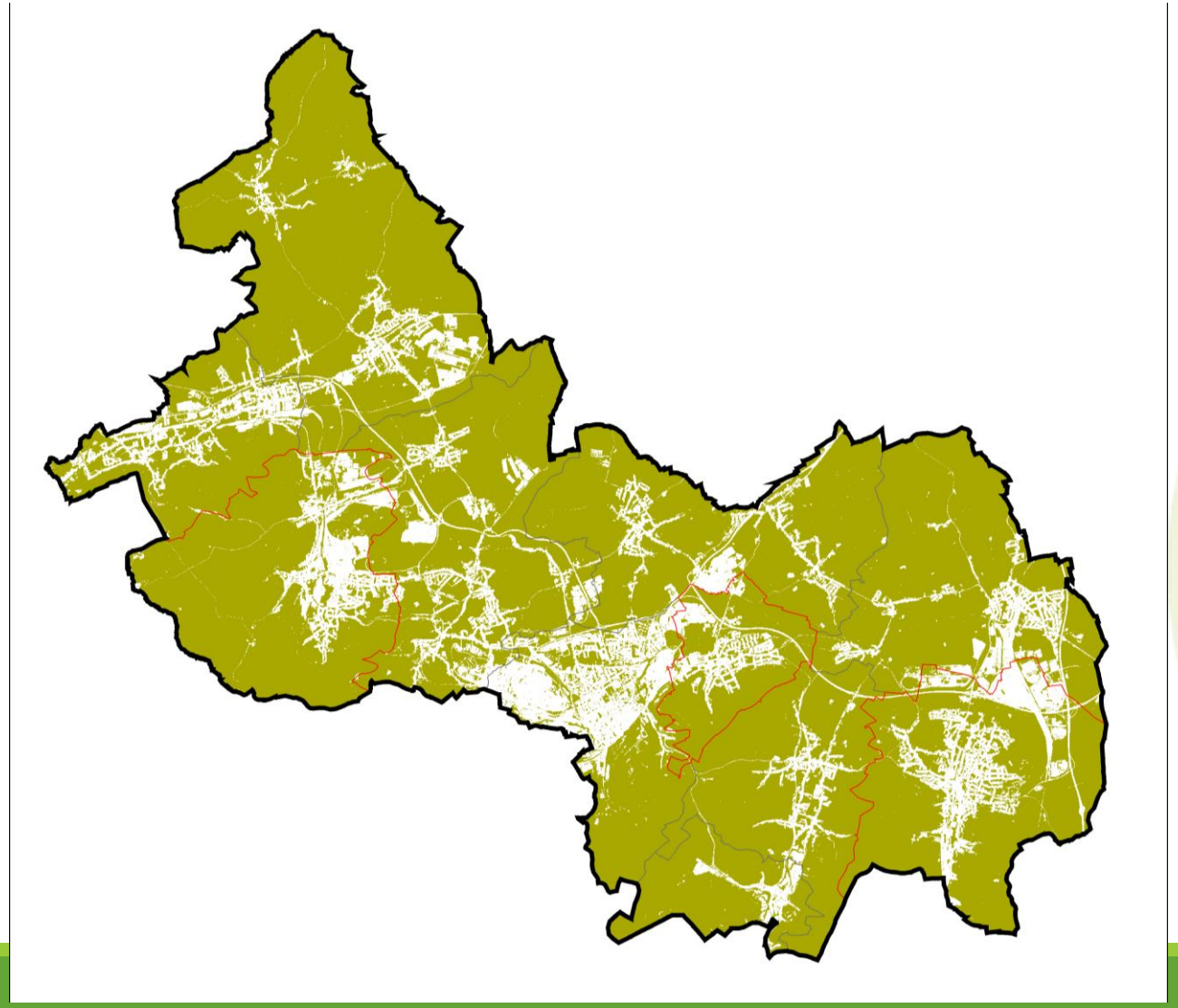
Indicator 2: Connectivity



Connectivity Analysis (Indicator 2 of CBI) entire Luxembourg-South region	With barriers/ Without connectors	With barriers/ With connectors	Without barriers/ Without connectors	Without barrier With connecto
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total Connectivity (ha)	Option A: 364.80 Option B: 368.64	Option A: 365.01 Option B: 368.85	807.89	1099.03
Intra/Within-Patch Connectivity (ha)	Option A: 340.04 Option B: 343.62	Option A: 340.04 Option B: 343.62	688.55	688.55
Inter/Between-Patch Connectivity (ha)	Option A: 24.76 Option B: 25.02	Option A: 24.97 Option B: 25.23	119.34	410.48
Total area of Natural Areas (ha)	Option A: 5314.35 Option B: 5259.02	Option A: 5314.35 Option B: 5259.02	5314.35	5314.35

Indicator 11: Proportion of permeable areas



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Indicator 11: Proportion of permeable areas

- CBI User Manual: indicator as proxy for the regulation of water quantities
  - Increased variability of precipitation because of climate change
  - Reduction of surface water flow/run-off by sufficient vegetation cover → all vegetation, not only „natural“ vegetation

- Production directly from the satellite image (here: S-2, reference year 2016, 3 acquisitions (May, August, September)) by computing the degrees of imperviousness and derive the inverse value for the share of permeable areas

- Issue: threshold above which a pixel is sealed/impervious or unsealed/permeable → majority rule, i.e. <50% degree of imperviousness = permeable

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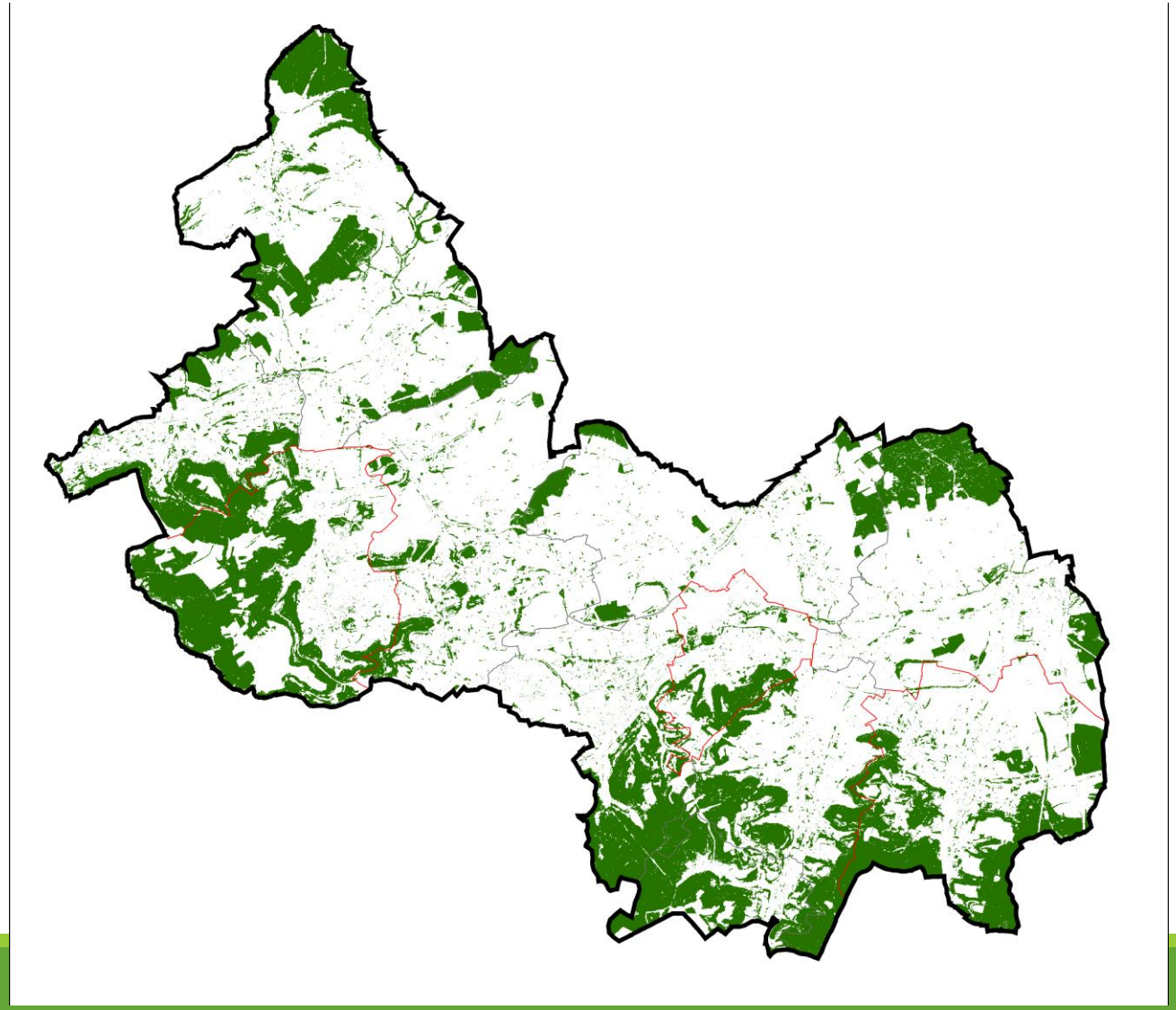
Indicator 12: Tree canopy cover



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Indicator 12: Tree canopy cover

- CBI User Manual: indicator as proxy for two important aspects of climate regulation, i.e. carbon storage and cooling effects
  → we consider a 2-D tree canopy cover as insufficient proxy for measuring carbon sequestration and storage
  → indirect measure of cooling effect
- Production directly from the satellite image using Boosted Regression Trees indices (similar to indicator 11)
- Issue: threshold above which a pixel is considered to be sufficiently covered
  → majority rule, i.e. >50% tree cover
- Second issue: spatial resolution of EO data sufficient for capturing single trees? Probably not …

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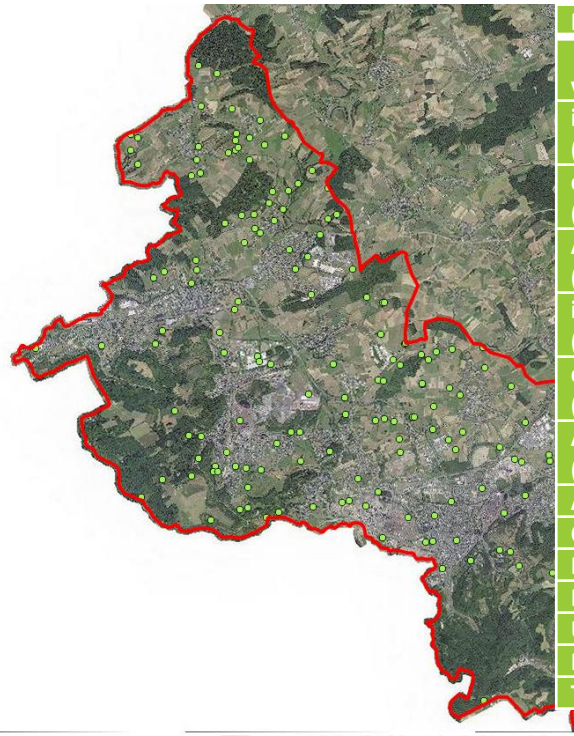
Validation/quality control

- Random point sampling approach for indicators 1, 11 and 12
  - Error of commission by locating points inside the product layer
  - Error of omission partly stratified sampling based on occurrence probability using other data sources (e.g., Urban Atlas or HRL IMP for validating the share of natural areas)
- Provision of accuracy statistics, such as overall accuracy, errors of commision and omission, uncertainty, and mean absolute error
- Scientifically and statistically meaningful proof-of-concept results Indicator 2: visual inspection of features, application of control conditions (comparison of the four scenarios) and scientific peer-review of papers describing and implementing the method



Natural areas	
validation code	count of points
incorrect points (commission)	9
correct points (commission)	91
All valid points (commission)	100
incorrect points (omission)	8
correct points (omission)	92
All valid points (omission)	100
All valid points (total)	200
Overall Accuracy [%]	91.5
Error of commission [%]	9.0
Error of omission [%]	8.0
Uncertainty	+/- 2.0 %
Mean Absolute Error	8.5
Target Error	<15%

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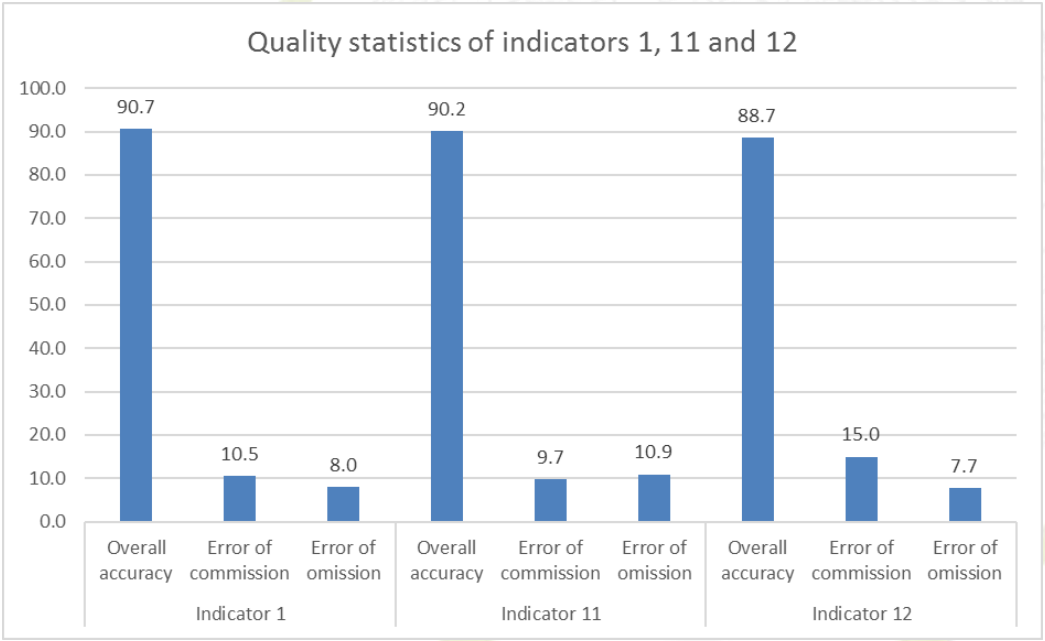
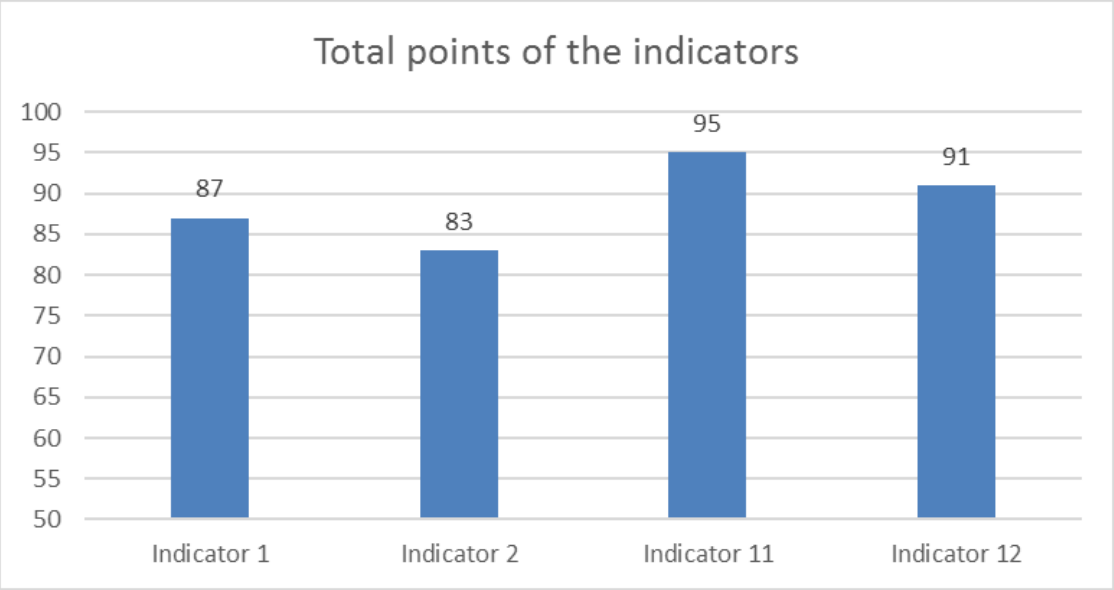
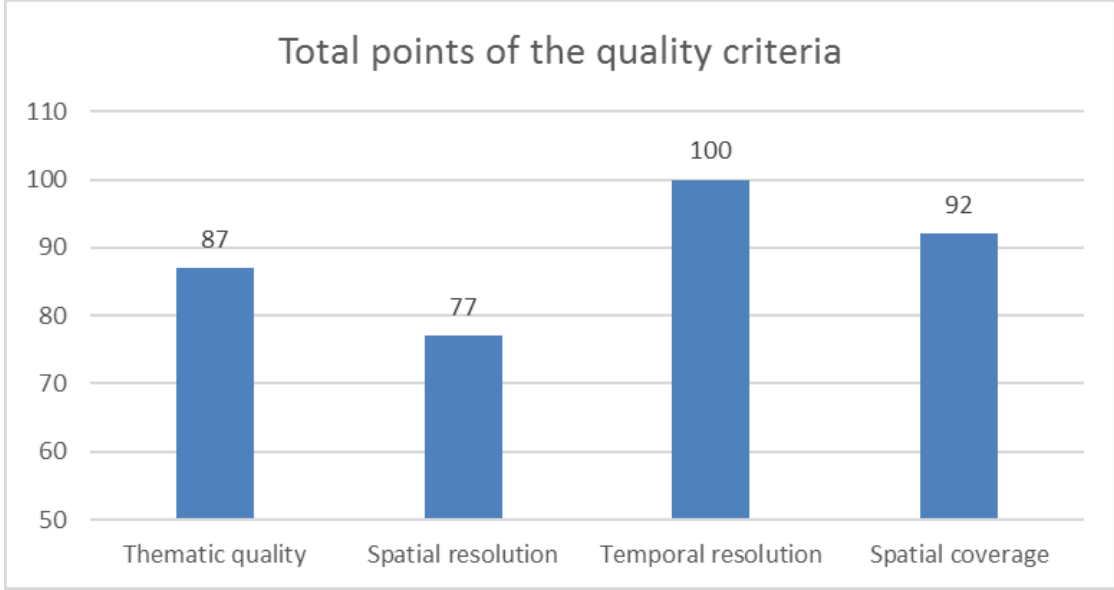
Validation/quality control

	Indicator 1			Indicator 11			Indicator 12		
	Overall accuracy	Error of commission	Error of omission	Overall accuracy	Error of commission	Error of omission	Overall accuracy	Error of commission	Error of omission
Barcelona (SPOT-5)*	93.8	4.4	8.0	89.5	16.8	4.3	90.2	11.2	8.4
Edmonton	86.2	9.5	18.2	96.3	4.3	3.0	91.9	11.9	4.5
Tallinn	89.8	11.2	9.2	90.6	3.3	15.8	90.3	6.6	12.8
Addis Ababa	95.0	5.0	5.0	88.0	12.0	12.0	96.0	6.0	2.0
Barcelona (S-2)	84.5	25.0	6.0	90.9	11.2	17.2	94.5	8.0	3.0
Buenos Aires	90.5	17.0	2.0	88.0	17.0	7.0	69.5	58.0	3.0
Hamilton	82.0	15.0	21.0	86.0	17.0	11.0	84.0	26.0	6.0
Lisbon	97.6	4.8	0.0	93.0	6.0	8.0	94.0	9.0	3.0
Luxembourg	91.5	9.0	8.0	85.0	3.0	27.0	94.0	8.0	4.0
Portland	95.0	8.0	2.0	96.5	3.0	4.0	87.0	7.0	19.0
Stockholm	92.0	7.0	9.0	88.0	13.0	11.0	84.0	13.0	19.0
SUM	997.8	115.9	88.4	991.8	106.6	120.3	975.4	164.7	84.7
Average	90.7	10.5	8.0	90.2	9.7	10.9	88.7	15.0	7.7



User perception





- Good approach, although oftentimes better (but expensive) local data exist (i.p. for ind. 1)
- Local baseline + annual or bi-annual monitoring using Sentinel-2
- Improve and clarify definitions

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Discussion: SWOT analysis

Strengths

- Free, comparable, wide-area, uniform and continuous EO data (S-2)
- EO time series
- Fast, harmonised, cost-efficient method
- IND2 is an intensive metric so comparison can be made between regions of differing sizes

Weaknesses

- S-2 spatial image resolution at the edge for urban applications
- Vague definition of indicators
- Identification of natural areas not always identical with the cities‘ definitions
- No fully automated processing chain

Opportunity

- Being prepared to support other cities and projects that deal with urban biodiversity in general and the CBI specifically
- Monitoring
- Increase awareness about biodiversity

Threats

- Too inaccurate to serve local needs?
- Low visibility and uptake
- Each city is different (→ automation)
- Is the use of EO too difficult for some cities?

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THANK YOU FOR YOUR ATTENTION!

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