ZonalMetrics - a Python toolbox for calculating landscape metrics in user defined zones

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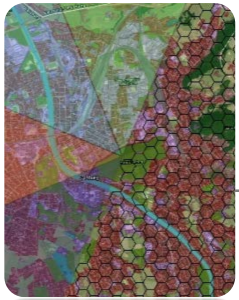

Introduction

"As indices of landscape structure, **landscape metrics** can be used to describe the composition and spatial arrangement of a landscape. They can be applied at different levels to describe single landscape elements by such features as size, shape, number or for whole landscapes by describing the arrangement of landscape elements and the diversity of landscape. The reason for using these metrics in spatial analysis may be to record the structure of a landscape quantitatively […] to document for purposes of monitoring; […] input parameters for landscape ecological simulation models."

(U. Walz (2011): Landscape Structure, Landscape Metrics and Biodiversity)

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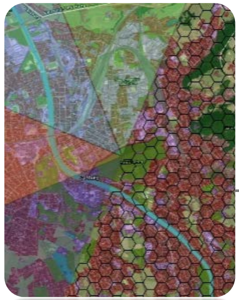
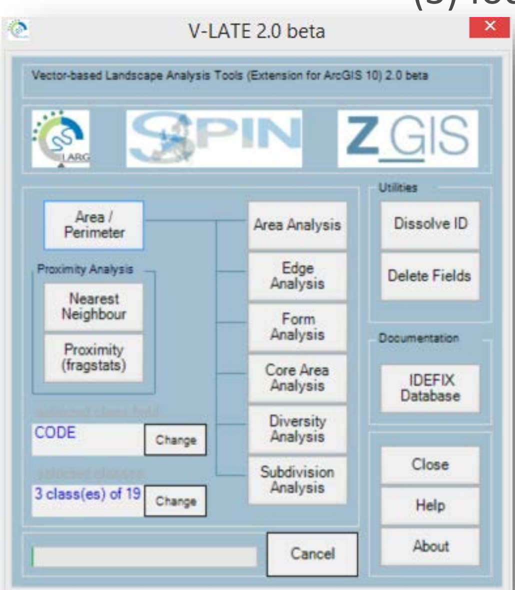


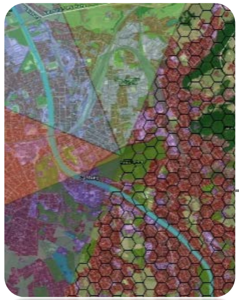
Introduction

- Landscape metrics originally developed to characterize landscape patterns in an ecological context (McGarigal and Marks 1995).
- Applications are continuously growing and operational applications related to regulation and information functions continue to emerge (Uuemaa et al. 2012).
- **Majority of the approaches use wall-to-wall datasets** that are **usually limited by the extent of administrative units or the available data**.
- Since first introduced by McGarigal and Marks (1995), the following levels of calculation are mainly used within such data extents:
  - (1) whole landscape
  - (2) focus on classes
  - (3) focus on single patches



Selection of the most common software packages for landscape structure analysis

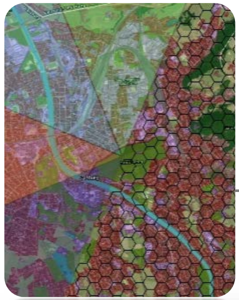
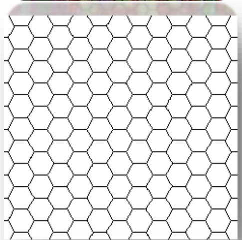
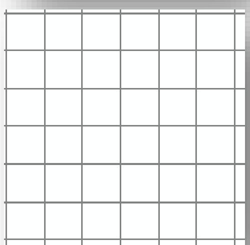
Software	Authors/programmers	raster/vector
FRAGSTATS	Mc Garigal, Marks 1995	raster
APACK/IAN	DeZonia and Mladenoff 2004	raster
V-LATE	Lang and Tiede 2003	vector
PatchAnalyst	Rempel et al. 2012	raster and vector (version 4)
DIY	Zaragozi et al. 2012	vector
Polyfrag	MacLean, Congalton 2013	vector

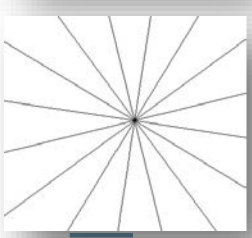


Why an additional tool?

- The zonal level of the landscape metrics calculation, rather than the focus area defined by the data set, has so far only been implemented in a few tools (Patch Analyst incorporates the functionality to calculate some landscape metrics in a hexagonal grid and Marxan)

- We propose the **ZonalMetrics toolbox**, a new open source tool with specialized functionality for calculating landscape metrics on the zone level, addressing the following needs:
  - Direct analysis of user-defined vector based categorical (polygon) layers
  - A set of available landscape metrics tailored for calculations within any user-defined zones (regular gridded zones, administration zones, environmental zones etc.)
  - Additional functionalities, such as specific zone generation (pies, hexagons) for specific applications
  - Free distribution in the form of a ready to use ArcGIS Python toolbox for the use of the algorithms with a user friendly GUI without additional pre-processing steps
  - The tools can also be easily integrated in ArcGIS models or Python scripts and are therefore extendable and usable for batch processing

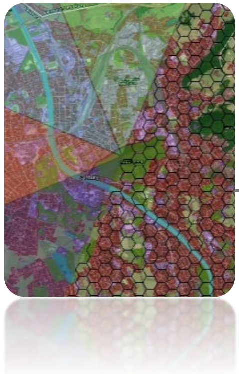


Theoretical background - statistical zones:

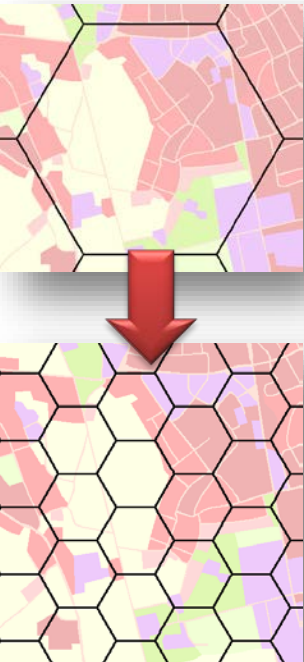
- The statistical zones used in the ZonalMetrics toolbox as the basis for the landscape metrics calculation are per definition freely selectable and generally divided into two main categories:

1. Regular tessellations (e.g. squares, hexagons, or triangles)
   - The main advantage of using regular sampling units is their equal area and perimeter, creating statistically similar units across the area being analyzed, and therefore providing a defensible statistical basis for sampling purposes

2. User-defined irregular zones
   - Most often administrative units are used that are delineated according to human management priorities. Despite the weaknesses (usually admin boundaries take no ecological units into consideration), analyses per administrative unit are often needed for regional or local planning purposes.
   - Fit usually better into existing data structures provided by the national repositories (reporting duties) and are therefore often requested in such extents.

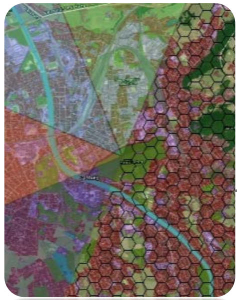


Theoretical background - statistical zones:



In a zonal approach some considerations have to be taken into account:

- The borders of regular zones do usually not capture real environmental units.
- The definition of zones is predefining a scale of analysis, which has to be taken into account since each phenomena to be analyzed may has a specific scale domain
- The sensitivity of the selected metrics to the extent of the analysis is important, especially for an artificially limited extent of statistical zones.
- A patch truncation effect - cut-offs by zone borders may cause underestimation of the value of some metrics (e.g. Mean Patch Size) and overestimation of other ones (e.g. Patch Density).
- The potential introduction of artificial patch edges when the analysis is performed by simply cutting the analyzed layer with statistical zones.



Theoretical background - Scale and statistical unit size:

- Scale of the analysis can significantly influence the conclusions, and landscape metrics are known to be sensitive to grain and scale (O'Neill et al. 1996, Turner et al. 1989).

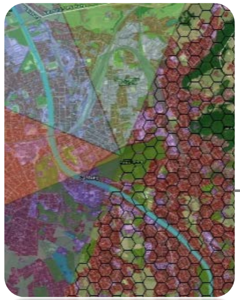
  ➔ the interpretation of the results is to be discussed in context of the components of scale (what holds true for every interpretation of landscape structure analysis)

- The zonal level of landscape metrics calculation switches the understanding of the term *extent* to each individual statistical zone where the local variance is captured. These zones may be freely compared according to users' needs.

  ➔ However, aggregation of their values to obtain the landscape level of analysis is not recommended (Hunsaker et al. 1994,Turner et al. 1989).

- The determination of the statistical zone extent (individual unit) remains a challenge, especially when regular tessellations are used.

  ➔ The literature provides no consistent recommendation regarding grid optimization, some estimates are available. The extent is fixed when landscape units, watersheds, or administrative units are applied.

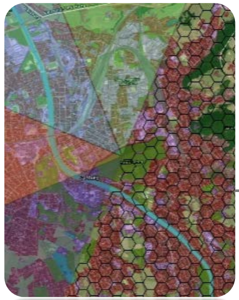


Theoretical background - selected set of landscape metrics:

- Not all landscape metrics are advisable to be calculated on a zone level e.g.:
  - area weighting is important for irregular zones
  - some metrics are sensitive to insufficient number of classes present
  - metrics should be calculated excluding artificial borders introduced

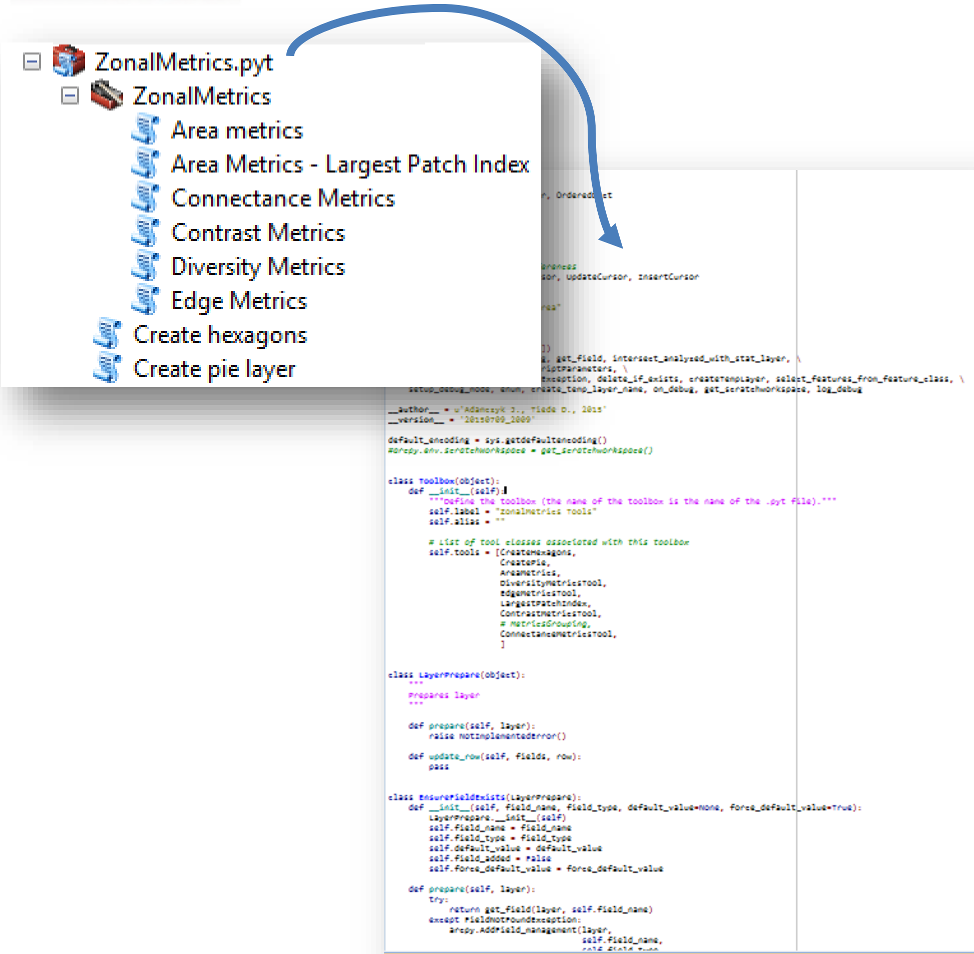
Metrics/tools for zonal metrics calculations available in the ZonalMetrics toolbox:

Group of metrics	Tool name	Calculation
AREA	Class Area (CA)	Area of the patches of the corresponding class within the statistical zone
	Number of patches per class (NPC)	Number of patches for each corresponding class within the statistical zone.
	Zone Area (ZA)	Area of the statistical zone in which landscape metrics are calculated
	Percentage of zone (PZONE)	Percentage of the area of the corresponding class per statistical zone.
	Largest Patch Index (LPI)	Looks for the patch covering the largest area within the statistical zone
EDGE	Total Class Edge (TCE)	Calculates Class Edge length (TCE) for edges of all patches of the selected class(es)
	Edge Density (ED)	Length of the edges within the statistical zone per area
DIVERSITY	Diversity (SHDI)	Shannon diversity index (SHDI) per zone, based on the selected classes.
CONTRAST	Contrast Class Edge (CCE)	Edge length of a selected focus class sharing a boundary with corresponding contrast classes (calculated per class).
CONNECTANCE	Connectance Index (CI)	Explores connectedness within the statistical zone within a defined distance:
		Connectance Index - number of distinct connected patches

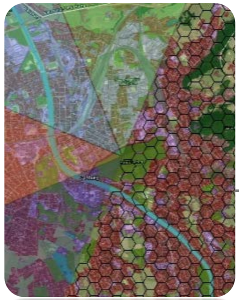


The ZonalMetrics toolbox

ZonalMetrics toolbox – Implementation:

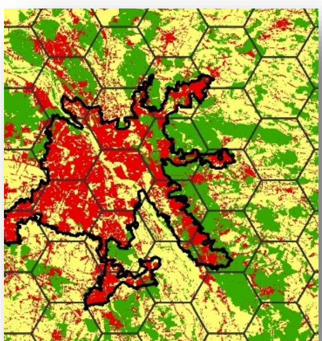


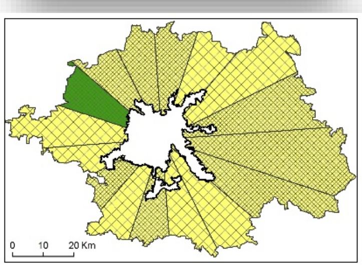
- open-source application written and implemented as a Python toolbox in ArcGIS (needs ArcGIS to be executed)
- Such Python toolboxes have the advantage over conventional tools in ArcGIS that their code and user interface to access the tool in ArcGIS are combined in one Python script (*.pyt)
- The script defines the available tools and their user interfaces (parameter selection, I/O data) as Python classes and includes the code for the execution of the tools.
- The tool itself makes use of the ArcPy site-package offering access to the whole geoprocessing functionality of ArcGIS

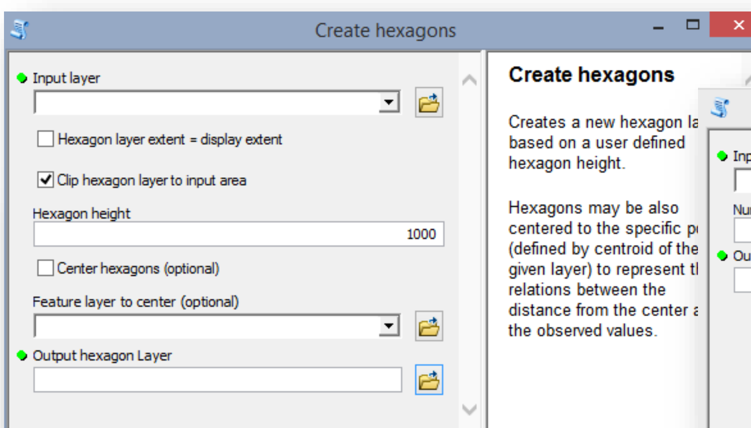


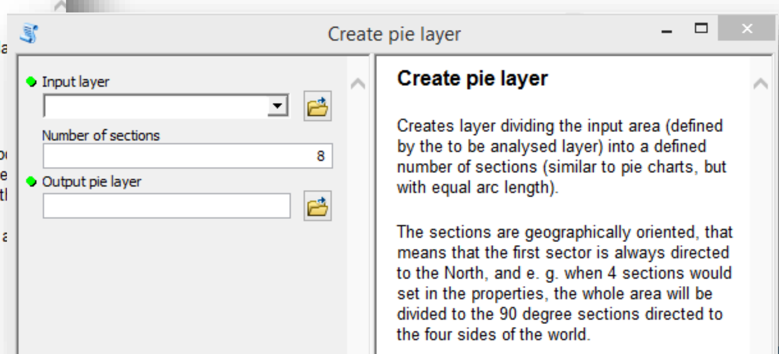
The ZonalMetrics toolbox – zonal layer calculation

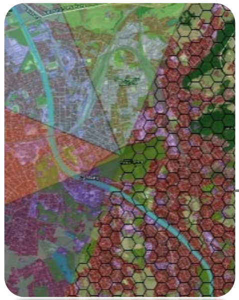
- The tool is designed to accept every polygonal shapefile or ESRI feature class as a zonal input layer.
- Both regular tessellations (such as square grids) and irregular (e.g. administrative units, landscape units) categorical layers can be used
- The toolbox offers the additional functionality for the creation of layers (usually not available in standard GIS):
  - **Hexagons** –size of the hexagons is based on the user-defined height.
  - **Pies** – structures similar to pie charts, but with equal arc length of each section, depending on the number of sections set in the tool options. Application examples could be the analysis of urban sprawl or something similar where developments / landscape structure follow a radial direction







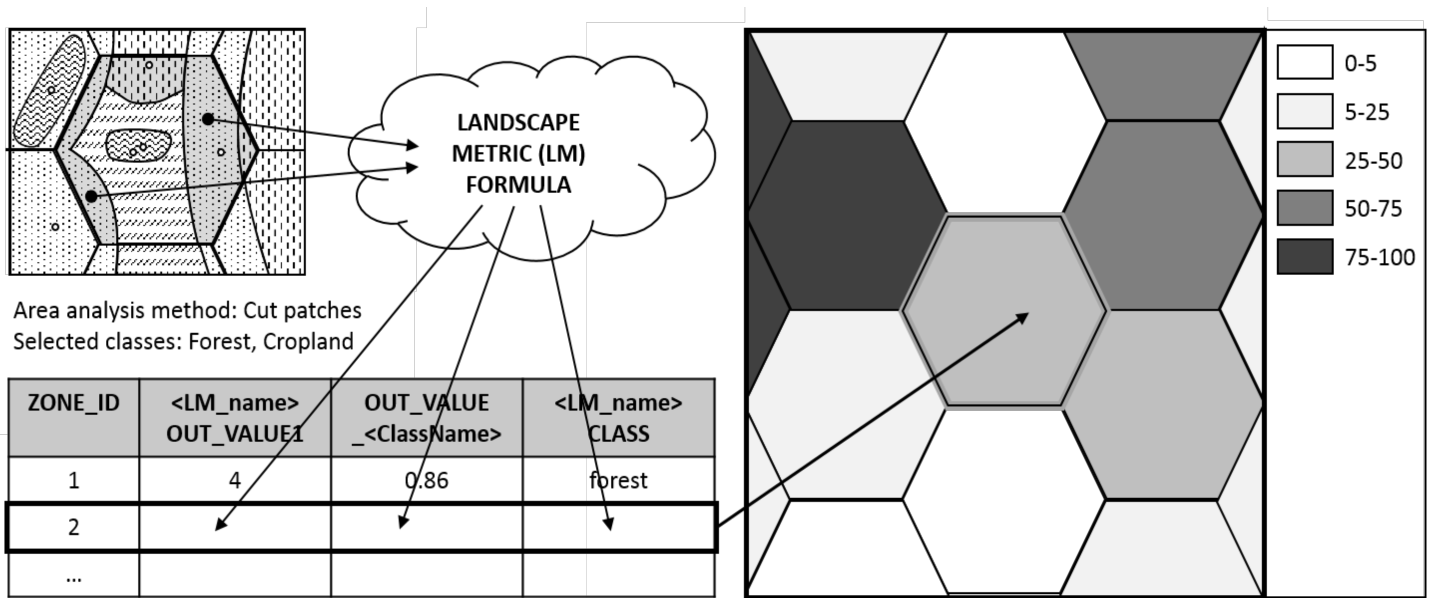




The ZonalMetrics toolbox - metrics calculation

Metrics calculation per zone:

- patches of the corresponding class are analyzed per zone
- results are aggregated to the individual zones.



Shannon's diversity | number of patches | % class per zone | patch area per zone

pie_sbg_8_urbanatlas2

FID	Shape	Input_FID	unitID	shdi	zone_area	npcRailway	pzRailways	caRailways	npcSports_	pzSports_a
0	Polygon	4	4	1.898032	16296067.0058	1	3.857	628545.95442	11	1.518
1	Polygon	1	1	1.968987	11968506.5344	3	8.594	1028553.08253	8	1.186

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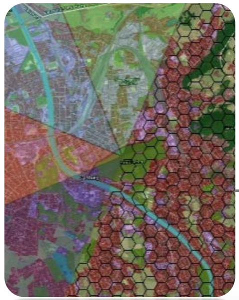
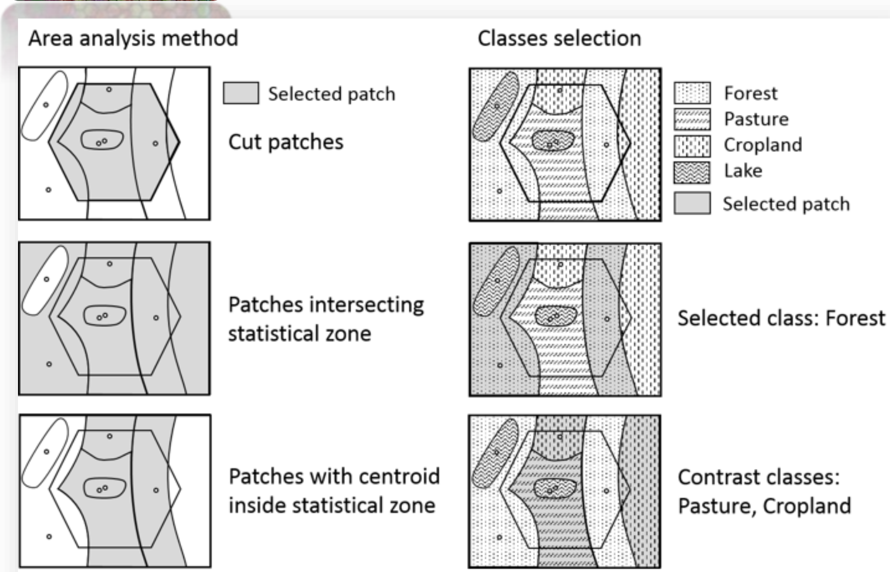
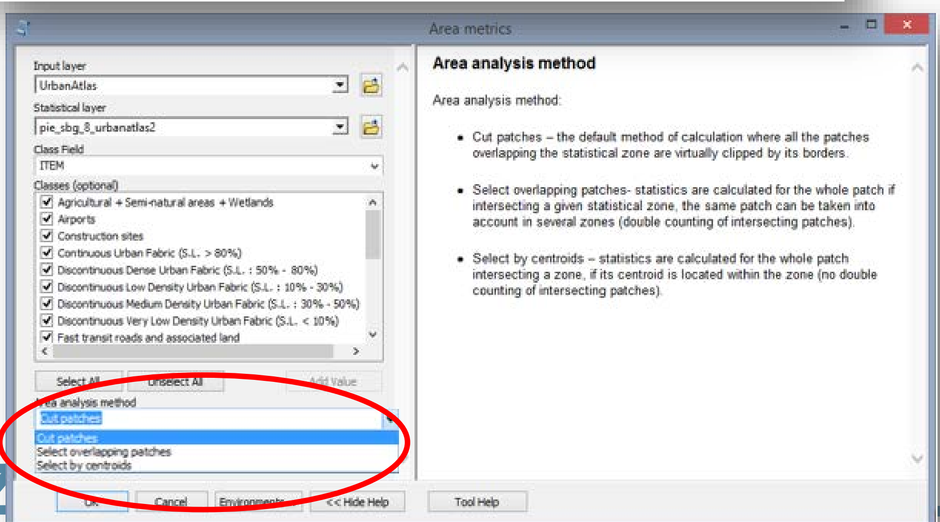


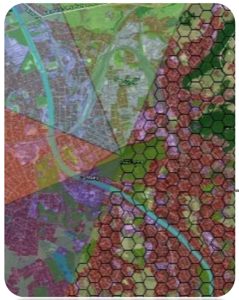
The ZonalMetrics toolbox - metrics calculation

Calculation options for patch and class selection:





- Patch selection (left, here for the area analysis method):
  - Cut of patches
  - Selection of intersecting patches
  - Selection of intersecting patches with centroid inside the zone
- Class selection (available in all tools) and contrast classes selection as implemented in the Contrast Class Edge (CCE).



Case study

- The implemented metrics within the ZonalMetrics toolbox are exemplarily presented for a case study of the Warsaw Metropolitan Area (WMA), Poland.
- 1950-80’s: A high percentage of the open spaces (understood as agricultural areas and related classes) and forests is preserved across the entire metropolitan area and within the administrative borders of Warsaw.
- Urban sprawl has influenced the land cover structure of this area since the political transformation in Poland in 1989.
- This results in highly spread small urban areas across the WMA.
- The freely available Urban Atlas (EC 2011, http://www.eea.europa.eu/data-and-maps/data/urban-atlas) was used as LULC data set.
- ➔ the following slides should give an impression how the ZonalMetrics toolbox can be used in the description of landscape structure based on different zonal approaches

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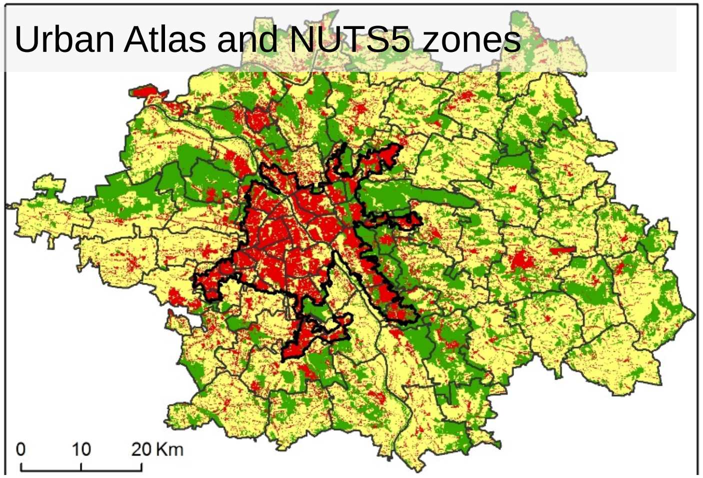
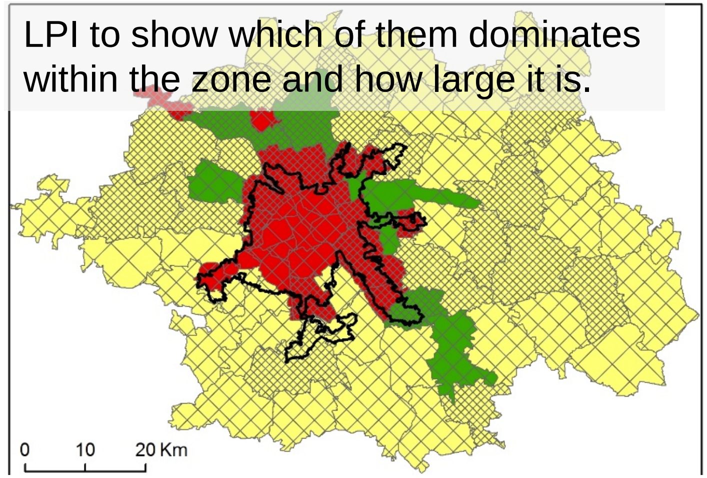
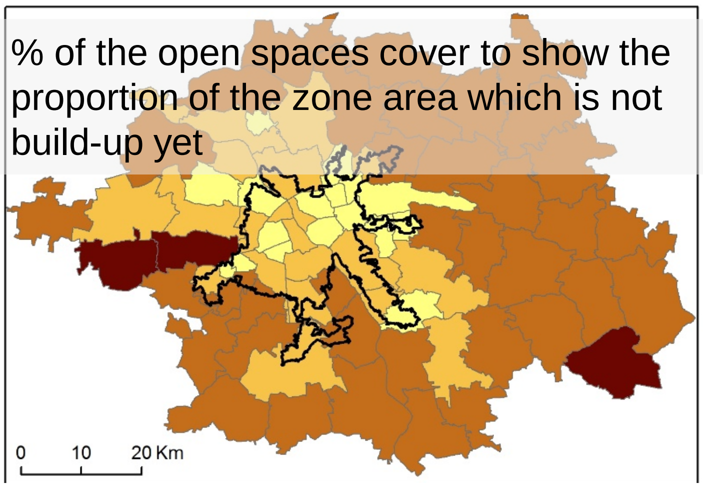
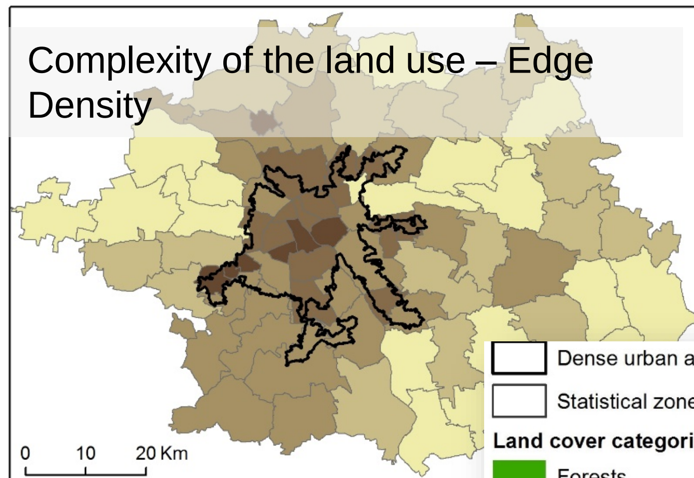
Case study

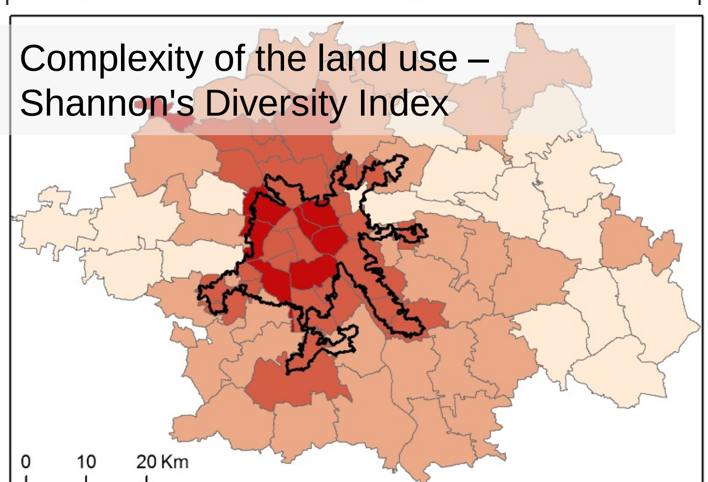
Administrative units are frequently used for planning and management purposes. Results maybe used to identify the intensity of the urban sprawl and as one of the important factors to be taken into account in the development of the local management plans for each commune and on a regional level.

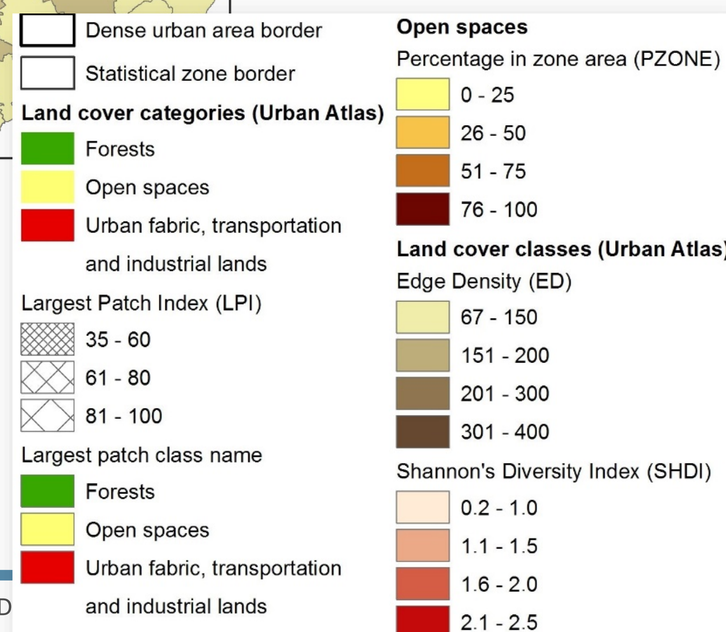






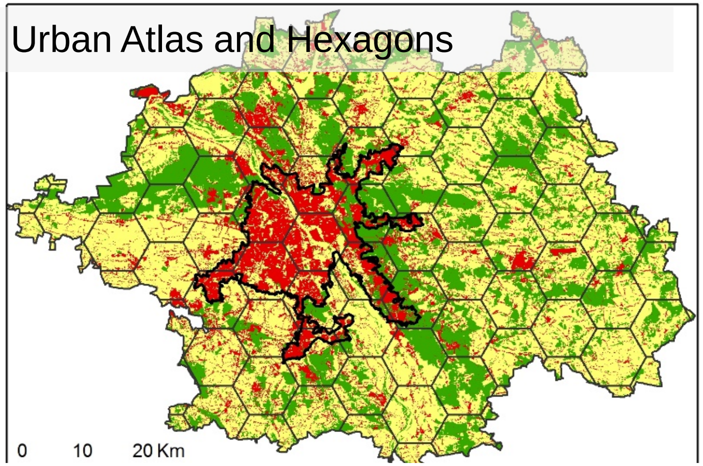


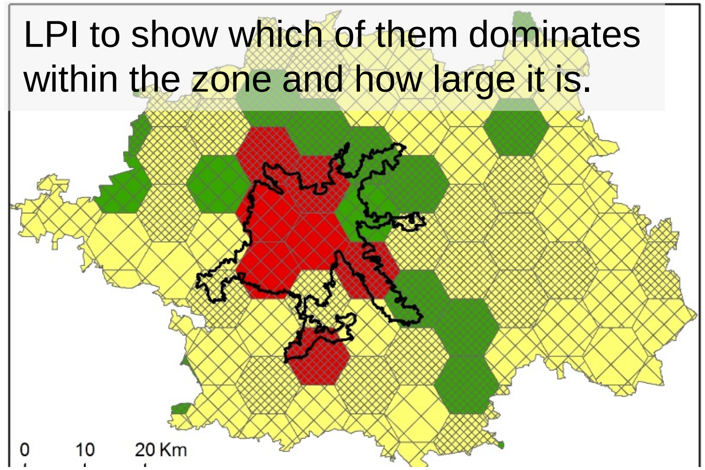


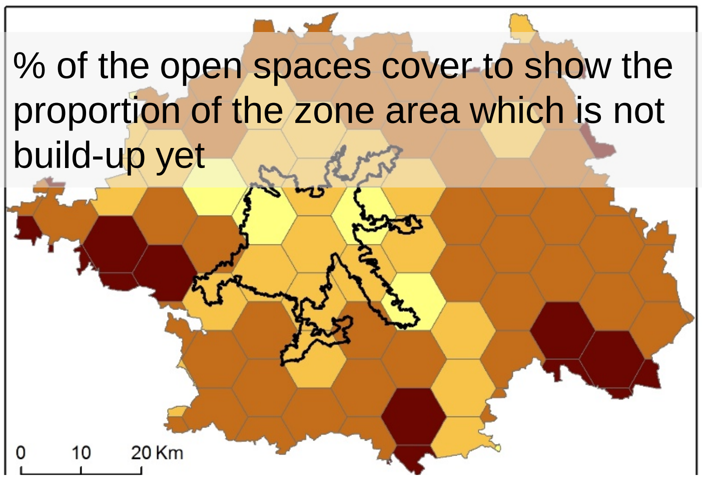


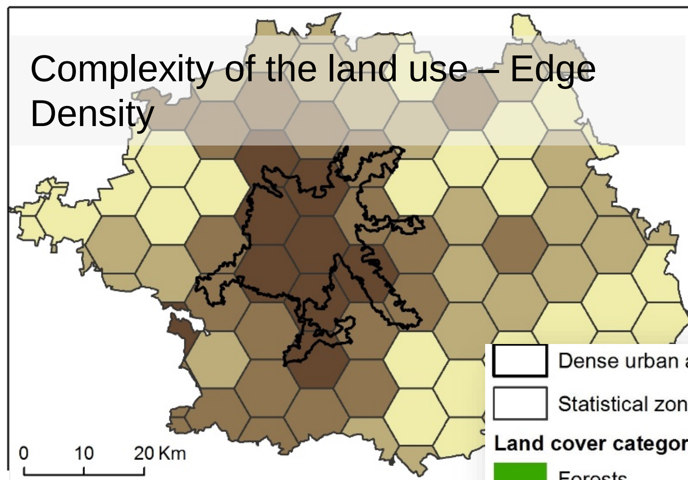
Case study

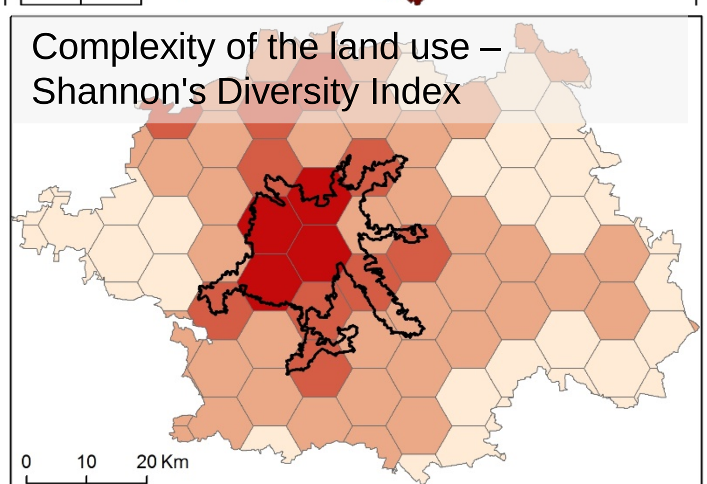
Hexagonal statistical zones aggregate the results within comparable units, which serve as a convenient basis for regional analysis and **show easy to grasp spatial patterns for the whole area not influenced by artificial admin-boundaries**.

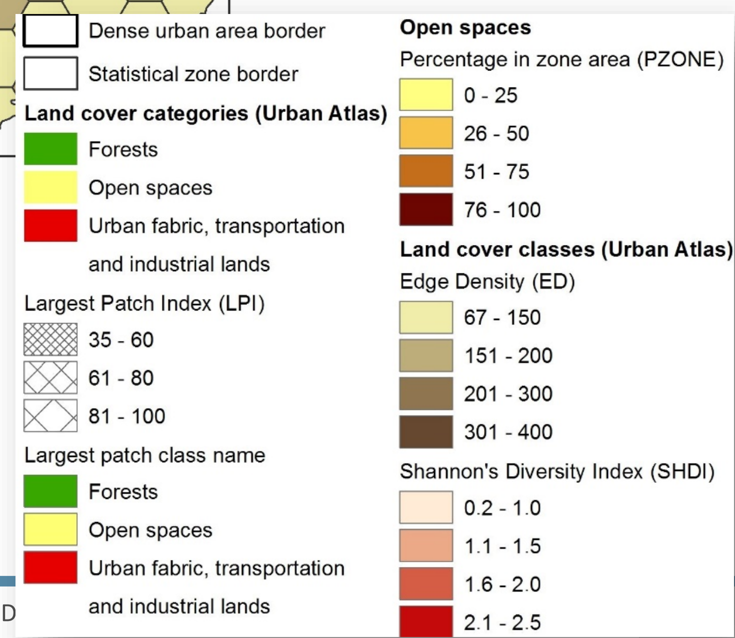




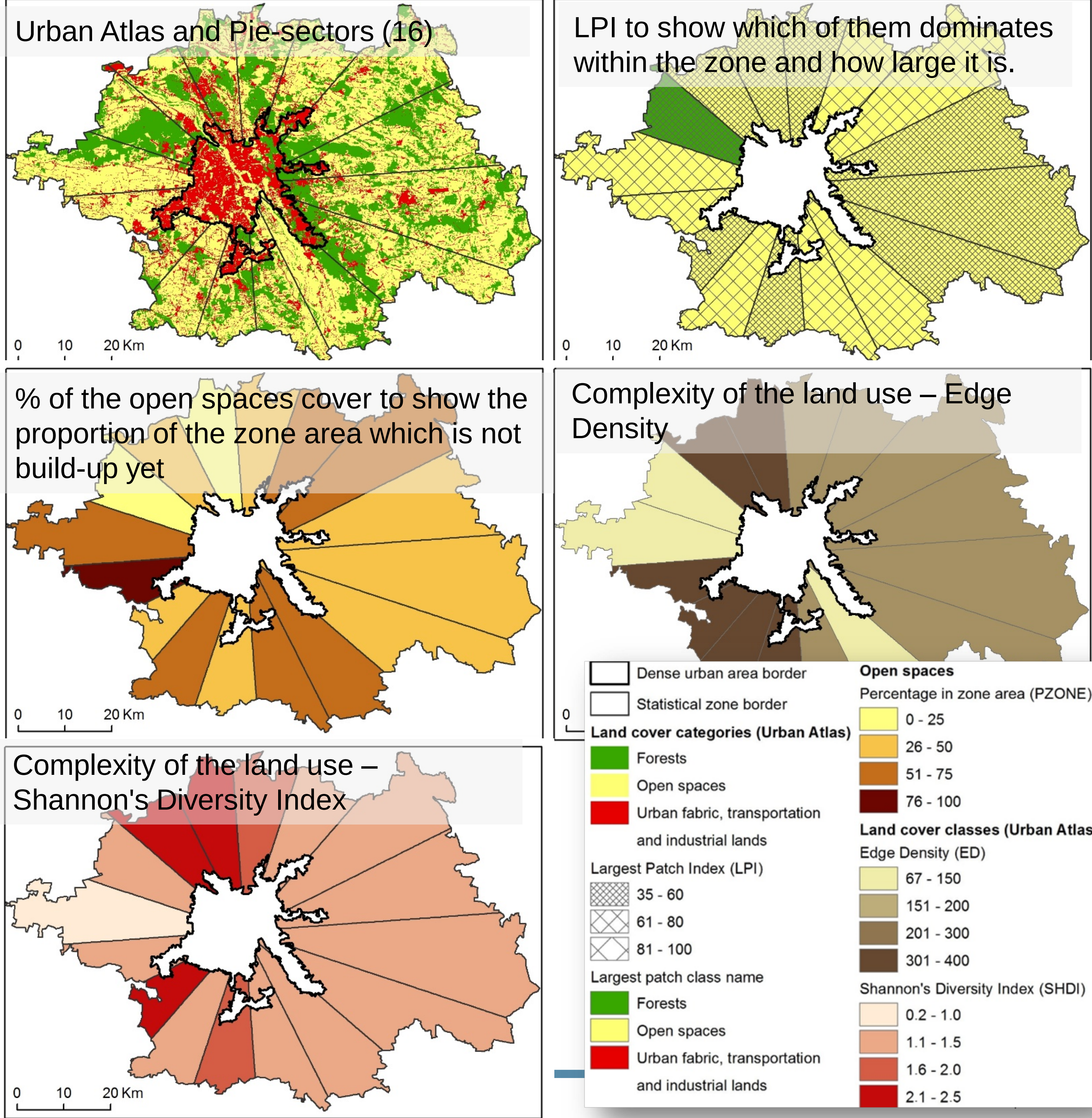




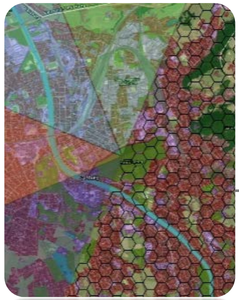




Case study



The same results shown within pies as statistical zones might not be significant in the above given applications, aside from monitoring e.g. urban sprawl along the main communication routes. Yet a high percentage of open spaces is conductive for fresh air supply, especially when it is related to the predominant wind directions (in case of WMA these are West and South). In this context, urbanization process within these areas might be interpreted as one of the main factors affecting local climatic conditions within the city.



Conclusion

- ZonalMetrics: A new toolbox for the calculation of landscape metrics in zones.
- In contrast to other tools, the ZonalMetrics-toolbox is able to use any polygonal input as zones as well as regular units
- The current version of the ZonalMetrics toolbox contains a first set of landscape metrics valid for within zone calculation
- Supports a more detailed regionalized landscape typology and can help with the interpretation of landscape changes over time, by making changes spatially explicitly visible compared to landscape level analyses that usually only quantify the changes.
- Python scripting used in the development of the tool allows researchers to implement further metrics according to their needs, but also to use the calculations in batch mode for automated analyses.

➔ will be freely available (ArcGIS Online) once published (Adamczyk & Tiede (under review), ZonalMetrics - a Python toolbox for zonal landscape structure analysis, expected 11/2015)

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Thank you for your attention

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