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Measuring the Accessibility of Urban Green Areas

*A comparison of the Green
ESM with other datasets in
four European cities*

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Table of contents

Abstract	3
1. Introduction	4
2. Goal of the study	6
3. Methodology	7
3.1 Input data	7
3.2 Tools used	9
3.3 Selection and definition of study areas	10
3.4 The Workflow for the calculation of the green areas	12
3.4.1 Definition of the green areas	12
3.4.2 Creation of serviced areas around the green polygons	13
3.4.3 Calculation of the population in served areas	13
3.5 The Workflow for the street indexes	14
4. Results	15
5. Conclusion	29
Annex	32
Complete workflow script	32
References	35
List of abbreviations and definitions	37
List of figures	37
List of tables	37

Abstract

Urban green areas have received increasing attention in the field of planning and urban design but data comparable at regional level are hardly available.

A methodology was developed in order to measure the accessibility to urban green area. The report aims at illustrating the methodology elaborated to calculate the accessibility using the Green European Settlement Map 2016.

The report contains the criteria established to perform the test, the input data, methodology, and the results of the tests performed on four European cities comparing the Green ESM with other available datasets.

1. Introduction

Demographic projections indicate that by 2050 66% of the world population will live in cities [1]. This shift in the distribution is due to many factors and implies many effects. The two main consequences of this phenomenon are, on the one hand, the expansion of the existing urban settlements and the creation of new ones, and on the other hand the increasing of density and use of urban areas. This puts stress on urban infrastructures such as road network and transport infrastructures, but also impacts the use of open and green spaces. Frequently, existing open and green spaces in cities are under the threat of privatization or loss of their original functions.

As the General Assembly of the United Nations approved the post-2015 Development Agenda in September 2015 [2], a set of new Sustainable Development Goals (SDGs) has been launched: they address a number of relevant issues to ensure a sustainable development and reduce disparities among people and countries.

The SDGs include the Urban Goal (SDG 11):

"Make cities and human settlements inclusive, safe, resilient and sustainable"

and a specific target on Public Space (SDG 11.7):

"by 2030, provide universal access to safe, inclusive and accessible, green and public spaces, particularly for women and children, older persons and persons with disabilities".

This target highlights the importance attributed to public (open and green) space amongst the global development community. Public space is interlinked with a number of other development issues, such as: security, environment and climate change, gender and social equality, economic development, and urban poverty. The setting of this goal and target constitute the most significant attention ever attributed to public space in the global policy arena.

In addition, the third United Nations Conference on Housing and Sustainable Urban Development (Habitat III), to be held in Quito in October 2016, will implement a *"New Urban Agenda"* containing a strong thematic commitment to spatial development and public space. One of the 22 Issue Papers, which constitute the core of the New Urban Agenda, published by UN-Habitat in May 2015 is on public space [3].

In the paper, UN-Habitat's experts call for *"strengthen knowledge, tools and approaches for viable public space at city level. Attention on the quality, distribution and accessibility of public space has been piecemeal, especially lack of comparative data. Although some cities measure percentage of open space, there are no agreed tools or indicators for assessing either the quantity or quality of public space. There is a key role for academia and research in developing these tools and indicators for and bringing this to the fore"* [3, p. 5].

Despite the fact that many steps forward have been taken to draw the attention of researchers, city-makers, and policy-makers on public space in urban context, very little has been done to agree on how to monitor the current status and the improvements in achieving the Target 11.7 in cities.

At the current state, UN-Habitat is proposing a set of targets for the amount of land allocated to streets and public space in urban areas to ensure adequate foundation for the city. A proposed goal/target for public space suggests that a specific proportion of land should be allocated to streets and public space. This should also be complemented by a qualitative target assessing accessibility, use and safety among other aspects.

Also the World Health Organization has underlined how open and green space contribute to improvements in public health and set the indicator of public space as square meters

of green space per capita [4]. This indicator, along with the ones on public and non-motorized transportation, is relevant in particular in relation to the non-communicable diseases (NCDs) (which are mainly heart diseases, chronic lung diseases, cancers, and diabetes), because the presence of open and green spaces, as well as transportation are correlated to the incidence of NCDs in cities.

Most of the studies in urban green areas focus mostly on one benefit or related specific benefits, including the following: a) mental and physical health benefits; b) economic benefits such as increased real estate prices because of green spaces in the vicinity; c) social benefits such as supporting social interaction and integration; and d) environmental benefits such as climate mitigation potential in the form of cooling through shade provision and moisture, noise reduction and air filtration of pollutants through trees or the promotion of biodiversity [5, p. 26].

Recently the European Commission has demonstrated its interest in the field with the working paper "*A walk to the park? - assessing access to green urban areas in Europe's cities*" [6]; and Kabischet al. analysed the Urban Atlas dataset on green areas [7].

While some cities have detailed datasets about their own public realm, consistent global or regional datasets about open and green space in urban settlements are not easily available. This makes comparing information from different cities or regions challenging. In addition to that, such kind of analyses require an adequate spatial resolution to be meaningful.

One valid option is represented by the European Settlement Map (ESM). The ESM is a spatial raster dataset that maps human settlements in Europe based on SPOT5 and SPOT6 satellite imagery. It has been produced with GHSL technology by the European Commission, Joint Research Centre, JRC Directorate E - Space, Security and Migration, Disaster Risk Management Unit.

The ESM 2016 is released both at 100 m and 10 m resolution (i.e. the spatial unit is a pixel of respectively 100x100m and 10x10 m) and includes several layers representing different information, such as the percentage of built-up, green space, open space, street, and water expressed as area coverage per spatial unit.

Both the ESM 100 and 10m originate from average aggregation of raster data outputs at 10m resolution produced by automatic information extraction processes from SPOT5 and SPOT6 satellite images at 2.5m resolution.

This dataset, due to its detailed resolution, homogeneity, and regional coverage, is a good tool to study how European cities perform in relation to specific urban indicators such as open spaces, street network and its connectivity, and green space [8].

Using the ESM 2016 at 10 m of resolution, this study aims at demonstrating that this dataset is useful to measure urban indicators in a consistent way across the European region. These indicators can be used to assess the SDG target 11.7 related indicators and other targets agreed at international level.

The study identifies the dataset available, the methodology, and reports the results of tests conducted on some European cities and compare the results obtained using other local datasets.

2. Goal of the study

The study aims at demonstrating that the Green ESM 2016 is a dataset useful to measure how cities perform in providing accessible green spaces to city dwellers.

The Green ESM 2016 is good input data to measure the improvements to European cities in achieving the SDGs target 11.7: "*By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities*".

This target is part of the so-called Urban Goal (SGD11) that aims at making cities and human settlements inclusive, safe, resilient and sustainable.

One other international target set by the World Health Organization deals with green spaces, and it states that cities should provide with **9 m² per capita within 15 minutes of walking distance** from their home place [4].

The goals of the feasibility study are:

- a) Defining a method to measure the accessibility of urban green areas using an available and consistent dataset: the Green ESM;
- b) Testing the method on a number of European cities and compare the results with other available datasets;
- c) Measuring the percentage of urban land allocated to street in the study areas and the number of road intersections. These two indicators have been already tested by UN-Habitat on a number of cities [9] and the results can be compared.

The final aim of this study is to understand if these indexes can be used to measure the improving in achieving the SDG 11.7 and which is the potential contribution of the ESM.

3. Methodology

3.1 Input data

Several different datasets have been used to perform the model.

Table 1 - Input datasets

DATA SET	SOURCE	DATE	DATA STRUCTURE	SCALE, CELL SIZE
European Settlement Map (ESM)	ESM 2016	2016 (publication) 2012-2015 (input data)	raster	10m x 10m
GEOSTAT	GEOSTAT 2006	2006	vector	
EU 100m pop mosaic	ESM and best available input data per each country	2016	raster	100m x 100m
Tele Atlas		2006	raster	
European Urban Atlas	European Commission	2012	vector	0.25ha minimum mapping unit
CBS stock land use WMS 2010	Dutch national geo register	2010	vector	
Plán využití ploch (Land use plan)	Prague Institute of Planning and Development	2010	vector	0.25ha minimum mapping unit
Città di Torino – Aree Verdi – Map Service – 100000327	Città di Torino - geoportale	2013	vector	

Data from the **European Settlement Map (ESM) 2016 at 10m of resolution** have been used to extract the green urban areas. The specific spatial layers used for this calculation are the following: '40' and '41'. These layers map two types of green areas in built-up areas: the layer 40 represents the Green NDVI¹ in BU Areas [10], the layer 41 represents those green areas which are not detected by the NDVI, but are included in the Urban Atlas Green in BU Areas [10, p. 13].

In order to calculate the percentage of land allocated to streets, the layers 35 and 45 of the ESM 2016 have been used. These two layers represent respectively the streets and the *green streets* [10, p. 12].

The city boundaries have been defined using the urban cluster of the **urban clusters** elaborated by **GEOSTAT² in 2006 intersected with the Urban Atlas coverage**. The workflow includes an intersection of the two polygons: the GEOSTAT clusters and the Urban Atlas areas of each city. The GEOSTAT database contains urban clusters, based on local population data of 2006, produced using the Eurostat-GEOSTAT grid. Urban clusters are defined as groups of contiguous raster cells of 1 Km² size, having a population density of at least 300 inhabitants/Km² and a total population of at least 5000. The definition of

¹ NDVI is defined as the pseudo-NDVI, an index which indicates the presence of green [16].

² The GEOSTAT initiative was taken jointly by Eurostat and the National Statistical Institutes to establish a data and production infrastructure for geospatial statistics. This infrastructure is to be defined and designed through a series of ESSnet projects, the GEOSTAT projects (<http://ec.europa.eu/eurostat/web/gisco/gisco-activities/integrating-statistics-geospatial-information/geostat-initiative>).

urban clusters underpins the urban/rural typology of NUTS3 regions³ and the degree of urbanisation classification of local administrative units (LAU2). Data are available for EU countries (excluding Cyprus and the outermost regions of France), Norway, Switzerland, Liechtenstein and Iceland.⁴

In order to calculate the total population of the city and number of inhabitants served with an adequate provision of green areas, the **EU 100m pop mosaic**, created by downscaling the Global Human Settlement Layer (GHSL) and the best available input census data [11], has been used.

The accessibility of the green areas and the related served population needed a network-based analysis, which was performed using the ArcMap Network Analysis Toolbox (Esri). The road network has been created using the **Tele Atlas dataset**, levels from 3 to 8.

The same method applied using the ESM has been done also with the **European Urban Atlas 2012**, selecting as the feature class '**14100: Green urban areas**' (European Environment Agency, 2015). The Urban Atlas is part of the local component of the GMES/Copernicus land monitoring services. It provides land use maps for 695 Functional Urban Areas (FUA) and their surroundings (more than 50,000 inhabitants) for the reference year 2012⁵. The GIS data can be downloaded together with a map for each urban area covered and a report with the metadata. The geometric resolution (Minimum Mapping Unit) is 0.25 ha. The positional accuracy of the dataset is +/- 5 meters.⁶

The last step of the study aimed at comparing the results obtained using the ESM 2016 with other local datasets that could be available.

Specifically, for the **city of Amsterdam (the Netherlands)**, the dataset CBS stock land use WMS 2010 was used. The file contains digital geometry of 2010 land use in the Netherlands. Examples of land use are traffic area, cultivation, recreation grounds and internal and external waters. The data was gathered in summer 2010.⁷ This dataset is available on the national geoportal: www.geodata.nationaalgeoregister.nl. The layer used is the *BG2012* and the feature classes selected are the following: 40-41-42-43-44-60-61-62.

For the **city of Prague (Czech Republic)**, an open dataset is available on the city geoportal, developed and managed by the Prague Institute of Planning and Development⁸. The specific layer used is called *Plán využití ploch (Land use plan) - funkční plochy (územní plán) - functional areas (land use plan)* – file named: *PVP_fvu_p*. The feature classes used are the following: *LR - lesní porosty (woodlands)*, *NL - louky a pastviny (grassland)*, *PS - sady, zahrady a vinice (orchards, gardens and vineyards)*, *PZA - zahradnictví (gardens)*,

³ NUTS 3: small regions for specific diagnoses, as defined by EUROSTAT (<http://ec.europa.eu/eurostat/web/nuts/overview>)

⁴ Data are available here: <http://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/population-distribution-demography/clusters#clustershd11>

⁵ Available for download in about 300 urban centres <http://land.copernicus.eu/local/urban-atlas/urban-atlas-2012>

⁶ Available for download for 305 urban centres <http://land.copernicus.eu/local/urban-atlas/urban-atlas-2006>

⁷ <http://www.europeandataportal.eu/data/en/dataset/a6e9b44a-d932-4458-8dd0-cc46d8fc9e94>

⁸ <http://en.iprpraha.cz/clanek/1362/geographical-data>

ZMK - zeleň městská a krajinná (Greenery and urban landscape), ZP - parky, historické zahrady a hřbitovy (parks, historic gardens and cemeteries).⁹

For **the city of Turin (Italy)**, a local dataset available on the municipal geoportal has been used¹⁰: Città di Torino – Aree Verdi – Map Service – 10000327. Feature classes used: forest, concession, garden, park, green square, river banks, green in schools, green for sports, general green.

For Athens no local dataset was available.

3.2 Tools used

The spatial analysis of this workflow has been implemented using ESRI ArcGIS tool, including the toolbox Network Analyst, and scripted using Python language and the ArcPy library for ArcGIS version 10.2.

⁹ Available for free download here <http://www.geoportalpraha.cz/>

¹⁰ Available here: http://www.comune.torino.it/geoportale/ser_professionali_2.htm

3.3 Selection and definition of study areas

The first step of the study has been the selection and definition of study areas.

It has been excluded to use the NUTS administrative boundaries for the following reasons:

1. NUTS correspond to different administrative levels in each member states and there is not a unique correspondence.
2. NUTS do not match with the urban settlement extension: in many cases they include the city centre but not the whole city cluster.

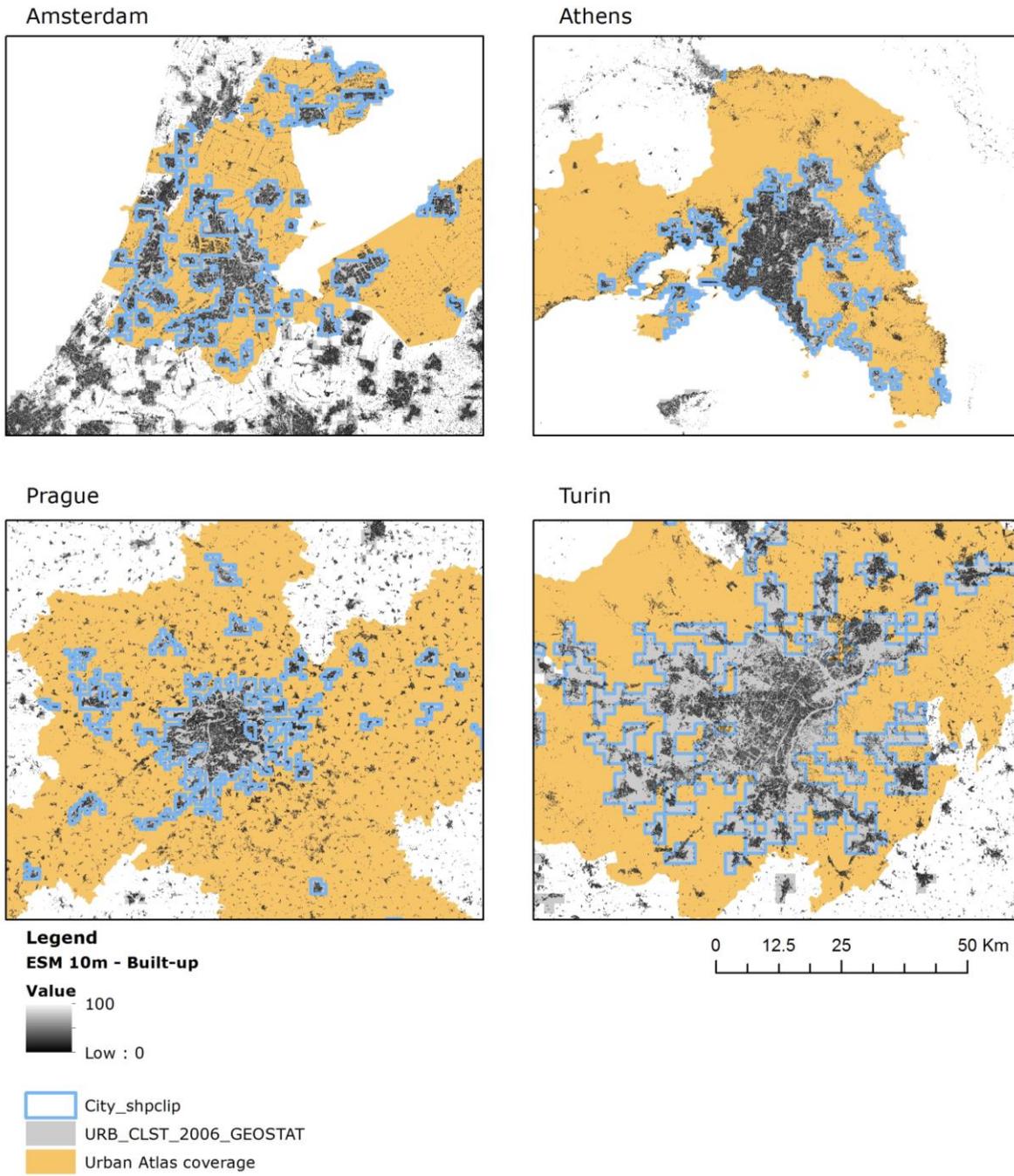
The urban clusters elaborated by GEOSTAT would be a good alternative, but in order to compare the data with the Urban Atlas, we have to ensure that the areas are covered also by this dataset. So new city boundaries resulting from the intersection of these two datasets are created.

Figure 1 shows the differences between UA area boundaries and the urban cluster elaborated by GEOSTAT for the four cities in which the method has been tested: Amsterdam, Athens, Prague, and Torino.

UA, in most of the cases, represents a much larger perimeter of what can be considers the urban cluster. The type of study that deals with the urban green areas has to be done specifically in the urban and not in those parts of the city which are inside the administrative boundaries but are not urban. If we would decide to include also those peripheral and non-urban areas, the results would be misleading.

These cities have been chosen because they differ in dimension, in geographical area, but also because local datasets on urban green areas were available.

Figure 1 – Maps showing the different city borders of the NDU and Urban Atlas coverage: Amsterdam, Athens, Prague and Turin



3.4 The Workflow for the calculation of the green areas

The following paragraphs describe the complete workflow necessary to perform the calculation of the accessibility to the green areas.

3.4.1 Definition of the green areas

Preparation of the data

The first steps of the workflow are devoted to the preparation of the data and the environment. The creation of a Geodatabase is useful in order to avoid hard coding and facilitating the scripting in Python [step 1]. The workspace is defined in the same geodatabase [step 2]. An array containing the list of ESM layers is done [step 3].

1. *Arcpy Create File GDB*
2. *Arcpy Definition of workshop (geodatabase)*
3. *List of layers.*

Definition of the city masks

The tiff layer containing the urban clusters elaborated by GEOSTAT is converted from raster to polygons [step 4]. The UA feature classes are dissolved to obtain the city boundary polygons of the UA [step 5]. The two different city masks (Geostat and UA) are intersected to obtain the city mask [step 6].

4. *Arcpy Geoprocess - Conversion of GEOSTAT urban clusters from raster to polygons*
5. *Arcpy Geoprocess - Dissolve the UA shape files to obtain the UA city boundaries.*
6. *Arcpy Geoprocess - Intersection of the Urban cluster boundary with the UA city boundaries.*

Clipping the datasets with the city masks

This part of the workflow is devoted to clipping input datasets and to the raster calculator process on ESM. The UA feature class '14100' is extracted [step7] and clipped with the city mask [step 8]. The local dataset is clipped [step 9]. The ESM is processed through the following steps: the layers are clipped [steps 10-11]; the two layers '40' and '41' are merged, with 'no data' value is assigned as 255, and the pixels with values greater than 50 (meaning that more than half of the pixel is green) are re-classified as green (value = 1) [step 12]; the raster layer is then converted into single part polygons [steps 13-14]; the polygons larger than 2500 m² (minimum mapping unit of the UA) are selected [step 15].

7. *Arcpy Extraction of the UA feature class 14100 - urban green*
8. *Arcpy Clipping of UA feature class 14100 with the city mask*
9. *Arcmap Clipping of the local dataset*
10. *Arcpy Clipping of the ESM layer 40 with the city mask*
11. *Arcpy Clipping of the ESM layer 41 with the city mask*
12. *Arcpy Raster calculator to merge the ESM layers 40 and 41*
This step merges two layers of the ESM and assign to all pixel with value bigger than 50, the value 1. We obtain a new layer (index_40_41.tif) with value 0 and 1, where 0 is no green and 1 is green.
The script executes the following formula:
where $\sum(\text{index}_{40_{\text{city}}} + \text{index}_{41_{\text{city}}}) > 50$, index_40_41.tif =1
where $\sum(\text{index}_{40_{\text{city}}} + \text{index}_{41_{\text{city}}}) \leq 50$, index_40_41.tif =0

13. *Arcpy Conversion of ESM raster to polygons*
14. *Arcpy Conversion of ESM from multipart to single part*
15. *Arcpy Feature Class to Feature Class*

These last three steps aim at transforming raster data into single polygons bigger than 2500 m² in order to perform the network analysis: transformation from raster to polygons (Green Areas), from multipart to single part (Green Areas_single) and finally the export of those single polygons with value 1 and shape area bigger than 0.25 into a new feature class (GreenArea_2500).

3.4.2 Creation of serviced areas around the green polygons

The second part of the model deals with the performance of the Network Analysis (Esri) and the calculation of the areas from which a green area can be reached within 15 minutes walking time.

This phase included the preparation of the road network and the running of the Network Analysis Tool.

Preparation of the road network

This step includes the preparation of the road network, clipping the different feature classes of the road within the city boundaries [steps 16-17], and the creation of a new dataset.

16. *Arcpy Clipping the road network levels (from 3 to 8) (Tool: Clip)*
17. *Arcpy – Merge the roads in a single feature class (arcpy.Merge_management)*

Intersection of borders of the green areas with the road network

We need points resulting from the intersection between the green areas bigger than 2500 m² and the road network, which stands for the entrance to the parks or the green areas [step 18]. These intersection points will be the facilities to be used in the service area analysis done with the network analyst tool.

18. *Arcpy Process: intersection_analysis (output type: POINTS)*

Creation of the network dataset

Creation of the dataset (ESRI Network Analyst) importing the road network created in the previous steps, with the following characteristics.

- Setting of the mode of travelling = pedestrian – shape length.
- Setting the service areas:
 - Facilities = intersection points
 - Generating polygons, merging the breaking values
 - Analysis Settings
 - + Impedance = Length
 - + Default Breaks = 750

With this tool we are able to calculate which areas are accessible within 750 m from the entrance of the park corresponding to a time of 15 minutes walking at 3 Km/h.

This part cannot be performed in Python.

3.4.3 Calculation of the population in served areas

Zonal Statistic as Table

Once we have obtained the polygons which represent the served areas, we perform the *Arcpy Zonal statistics as Table* on the raster input data of the population [step 19].

19. Arcpy Zonal statistics as Table

- *input tiff: population layer*
- *zone field: city blob*

3.5 The Workflow for the street indexes

This part of the study deals with two goals:

- Measuring the percentage of urban land allocate to street in the study areas;
- Measuring the number of road intersections per squared kilometre.

To measure the percentage of urban land allocated to streets, the ESM 2016 layers 35 and 45 are merged together; then the percentage over the total urban area is calculated.

In order to calculate the number of road intersections per square kilometre, the following steps are needed:

- *Arcpy tool: Intersection*
 - Input Feature: Roads
 - Output Type: Points
- Statistics – number of elements
- Calculation of the number of intersections per squared kilometre.

4. Results

The tables below (Table 2, In order to better evaluate the different levels of accessibility of different zones of the city, it is also relevant to have more information about the road network that allow to access to the urban green areas. More roads and paths are available, more intersections are in a certain area, easier will be to go from point of the city to another.

The following table show the results of the four cities for the calculation of the percentage of land allocated to street and the number of roads intersections per square kilometres.

Table 3) show the output results for the four cities in which the method has been tested: Amsterdam, Athens, Prague, and Turin.

In these cities the same method has been test not only on the ESM 2016, but also on Urban Atlas and on local datasets, when available.

Table 2 - Complete results for the four cities

	City Blob		ESM (2016) 10m		LOCAL DATASET		URBAN ATLAS 2012	
	City blob (ha)	Population	Green Areas > 0.25 ha	Served population (inhabitants)	Green Areas (ha)	Served population (inhabitants)	GREEN AREAS (ha)	Served population (inhabitants)
Amsterdam	73,422	2,328,733	12,047	1,902,970	12,751	1,513,733	5,016	672,656
	Percentage over the total		16%	82%	17%	65%	7%	29%
	Green Area per capita (smq per person)		51.73		54.75		26.36	
Athens	65,594	3,543,420	9,059	3,316,705			2,690	1,149,823
	Percentage over the total		14%	94%			4%	32%
	Green Area per capita (smq per person)		25.56				0.00	
Prague	70,058	1,667,207	12,431	1,549,621	10,747	941,021	5,655	1,100,812
	Percentage over the total		18%	93%	15%	56%	8%	66%
	Green Area per capita (smq per person)		74.56		64.46		36.49	
Turin	City blob (ha)	Population	Green Areas > 0.25 ha	Served population (inhabitants)	Green Areas (ha)	Served population (inhabitants)	GREEN AREAS (ha)	Served population (inhabitants)

	52,888	1,495,199	6,433	1,304,119	1,319	784,751	1,973	924,124
	Percentage over the total		12%	87%	2%	52%	4%	62%
	Green Area per capita (smq per person)		43.03		8.82		15.13	

In order to better evaluate the different levels of accessibility of different zones of the city, it is also relevant to have more information about the road network that allow to access to the urban green areas. More roads and paths are available, more intersections are in a certain area, easier will be to go from point of the city to another.

The following table show the results of the four cities for the calculation of the percentage of land allocated to street and the number of roads intersections per square kilometres.

Table 3 – Results of the street indexes

City	City Area (sqKm)	Streets (sqKm)	% of street	Intersections	Connectivity Index (intersections/sqKm)
Amsterdam	734	98.73	13%	307,098	418
Athens	656	121.17	18%	321,571	490
Prague	701	68.70	10%	185,378	265
Turin	529	53.43	10%	110,997	210

Figure 2 - Samples of road intersections in the four cities

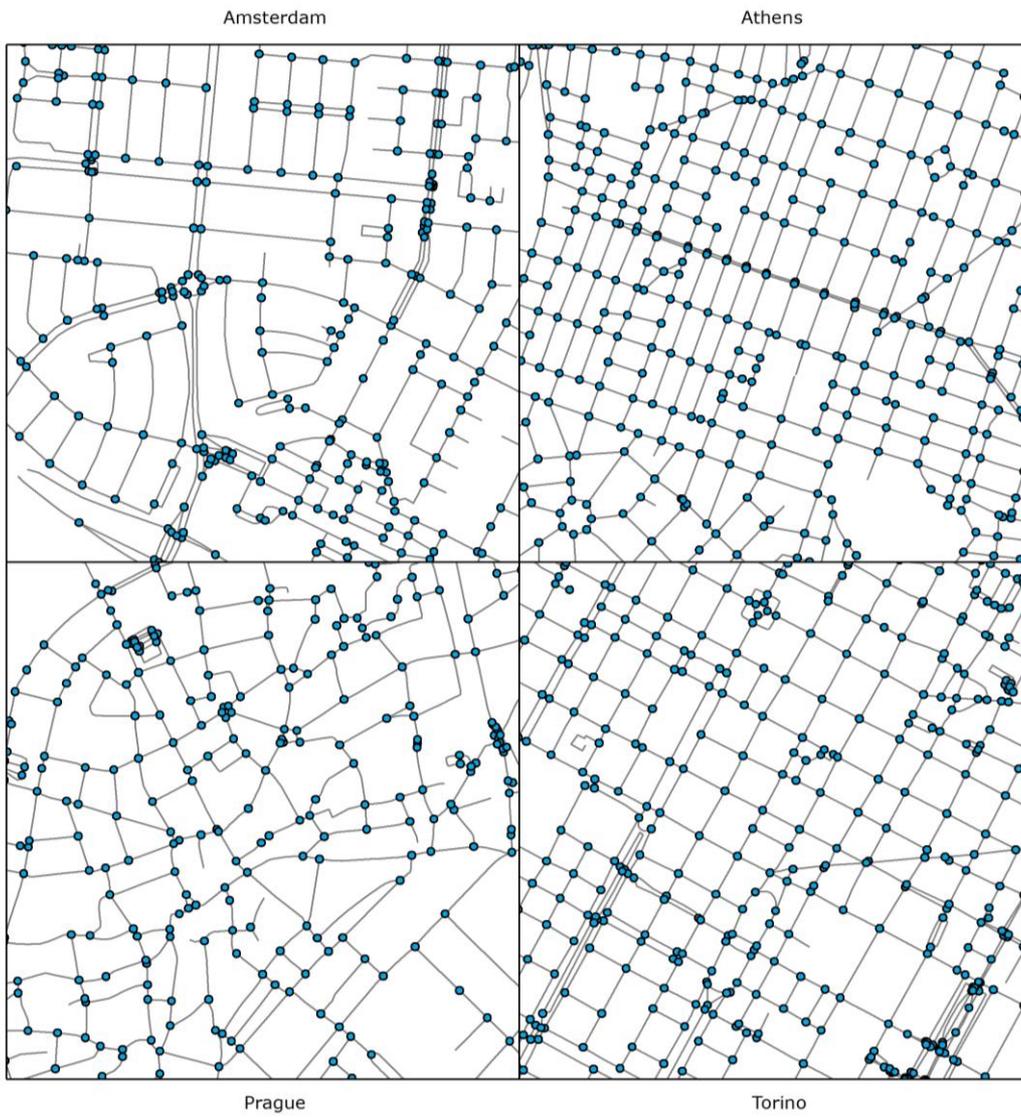


Figure 3 – Amsterdam - Green ESM 2016 – Urban Green Areas and served areas

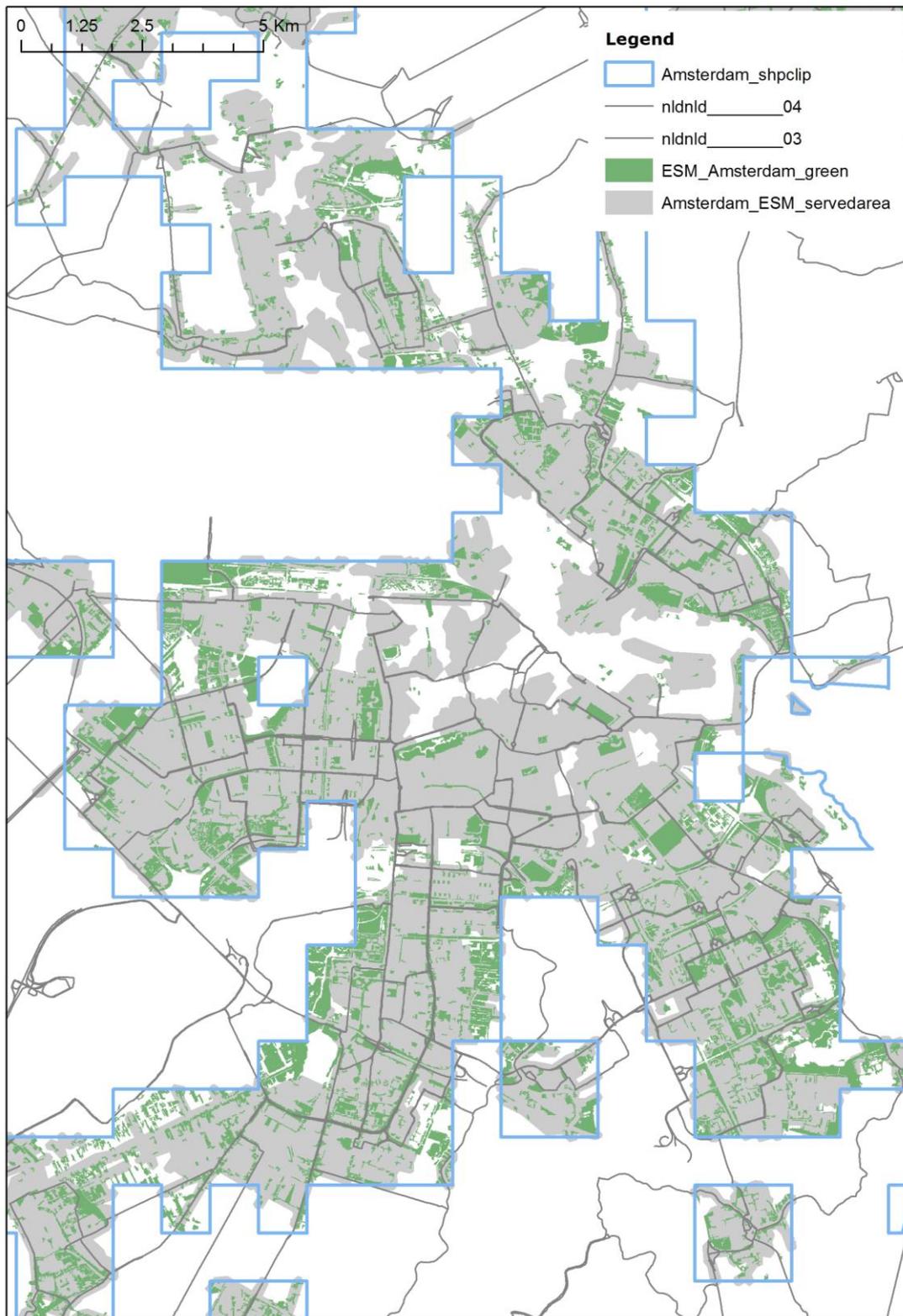


Figure 4 – Amsterdam – Urban Atlas - Green and served areas

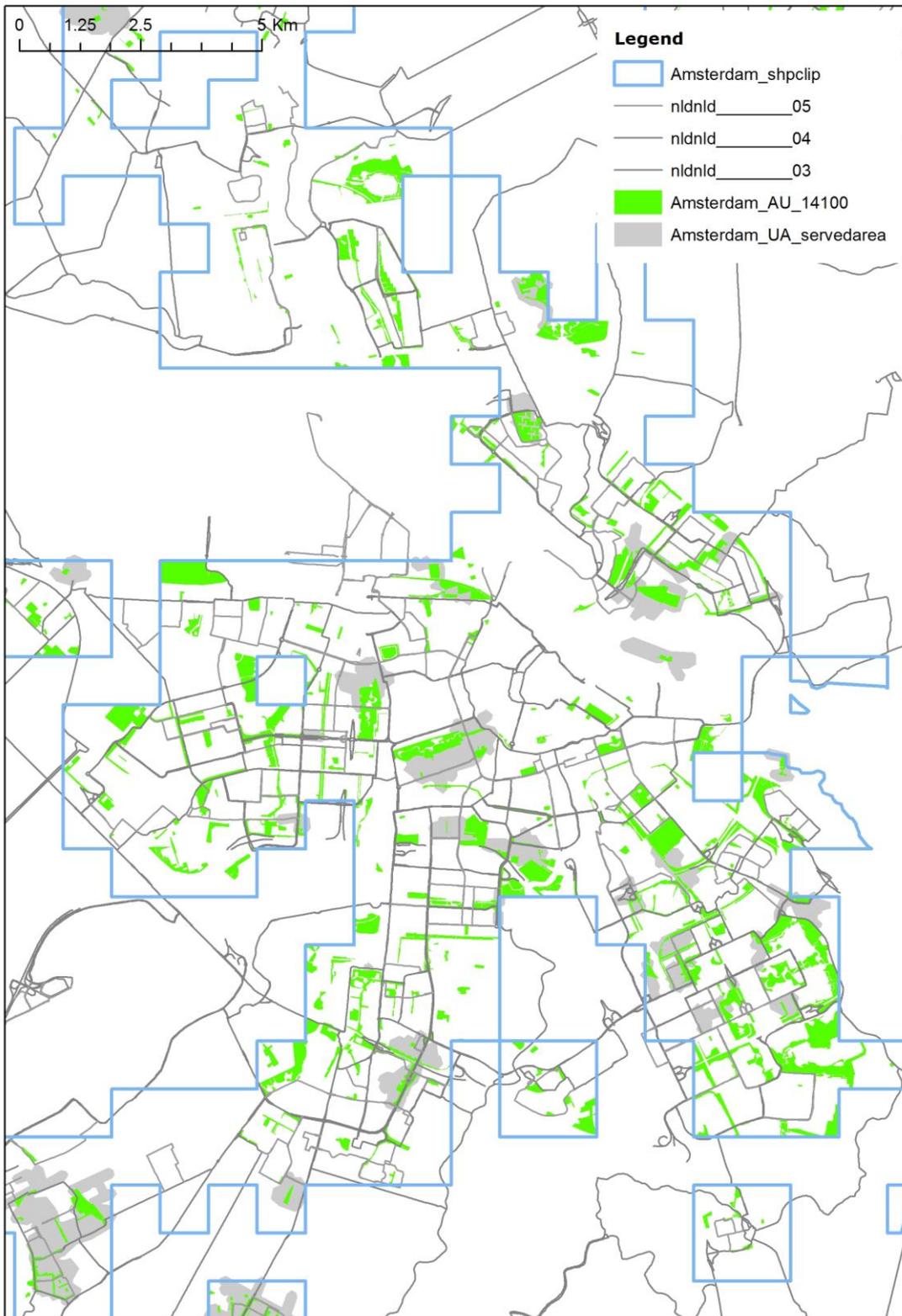


Figure 5 – Amsterdam – Local dataset - Green and served areas

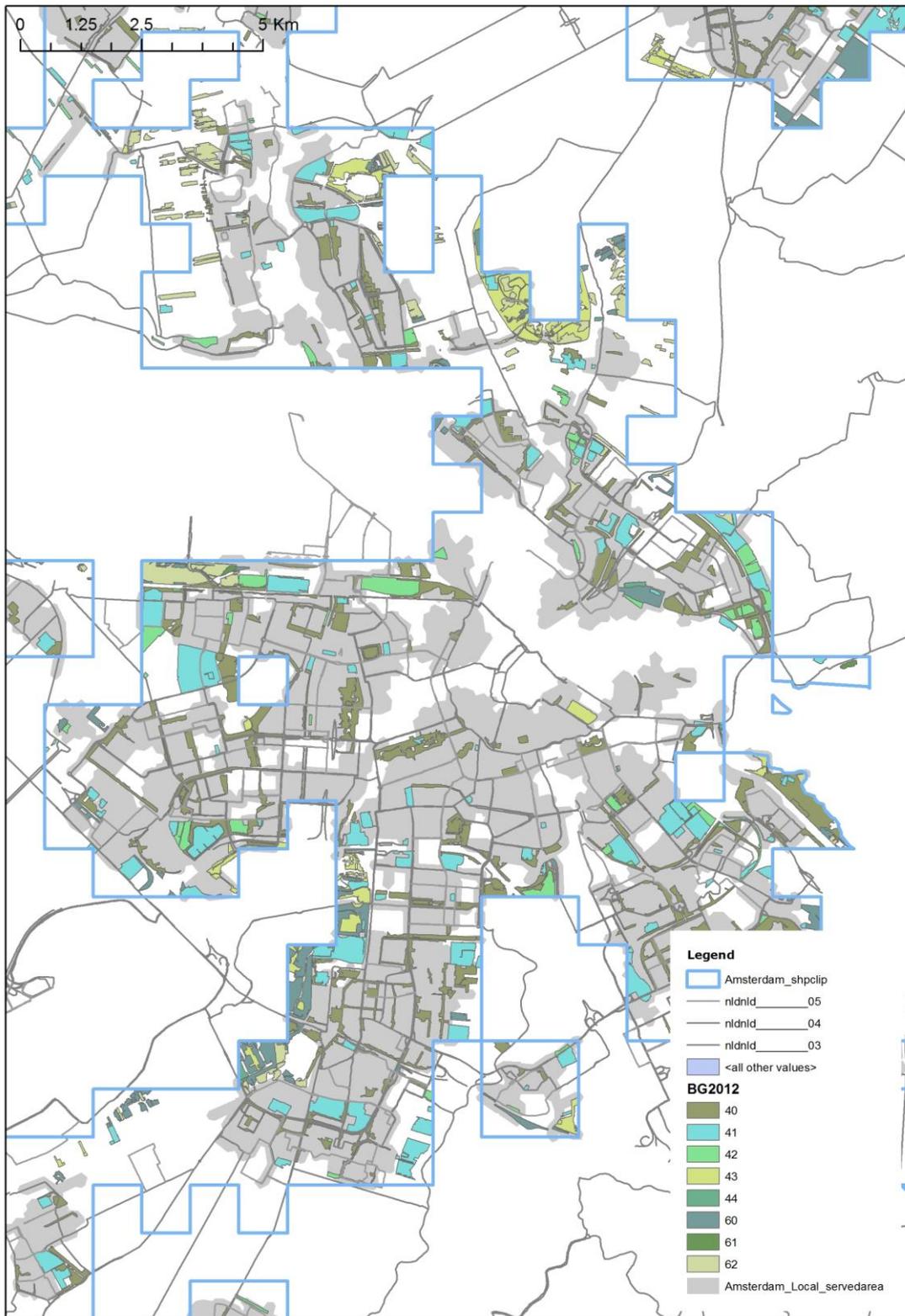


Figure 6 - Athens - Green ESM 2016 – Urban Green Areas and served areas

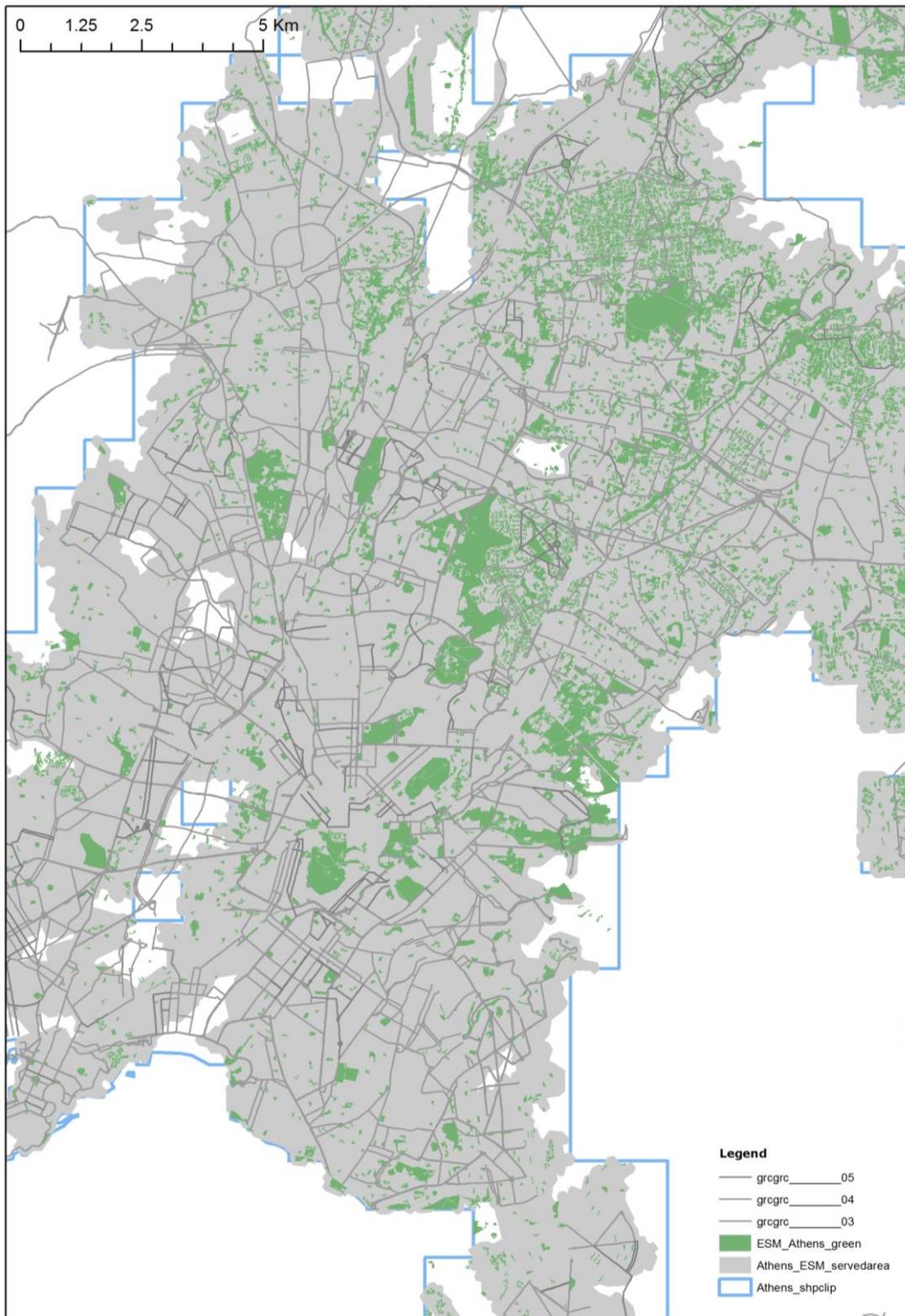


Figure 7 – Athens – Urban Atlas - Green and served areas

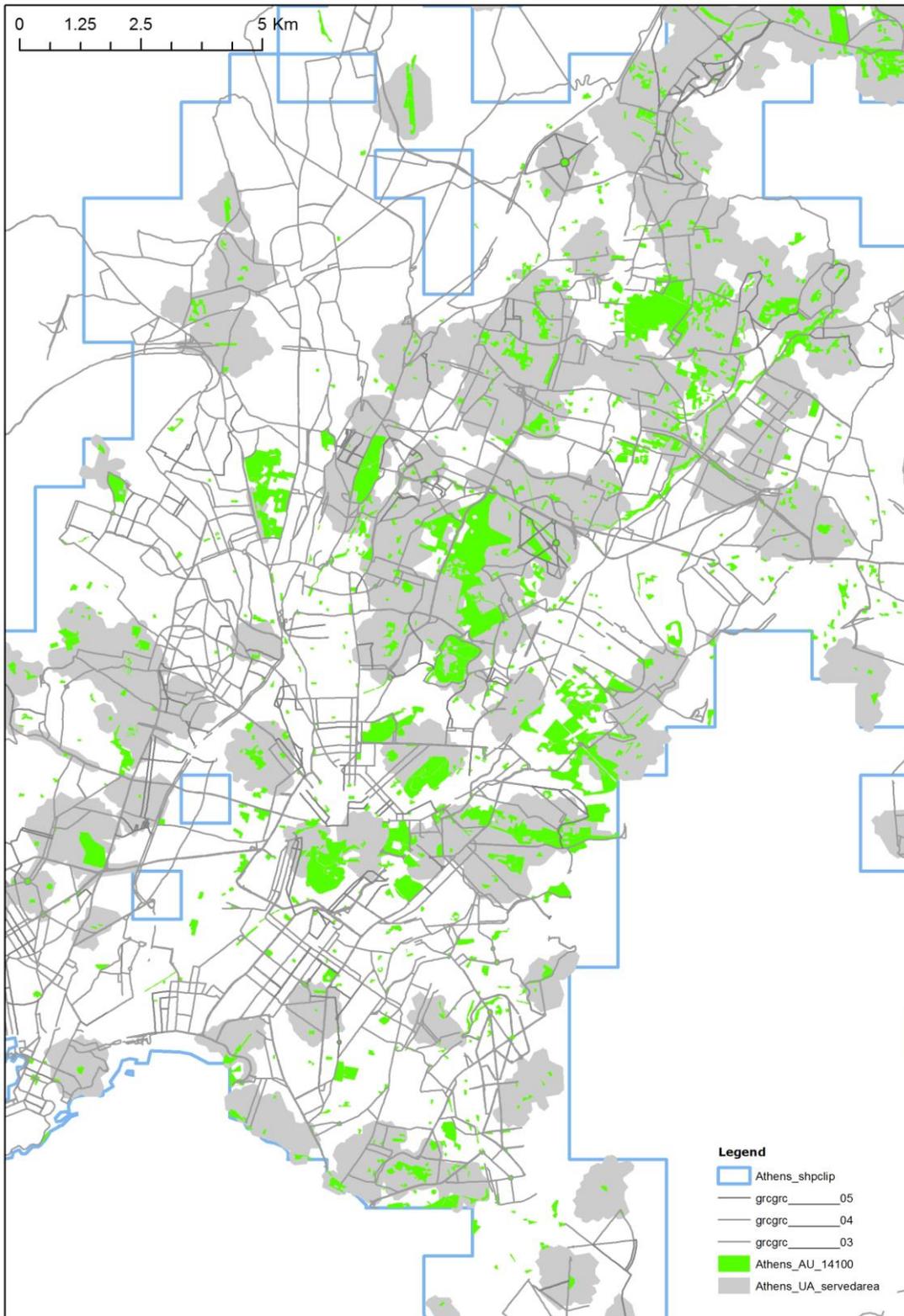


Figure 8 – Prague – Green ESM 2016 - Green and served areas

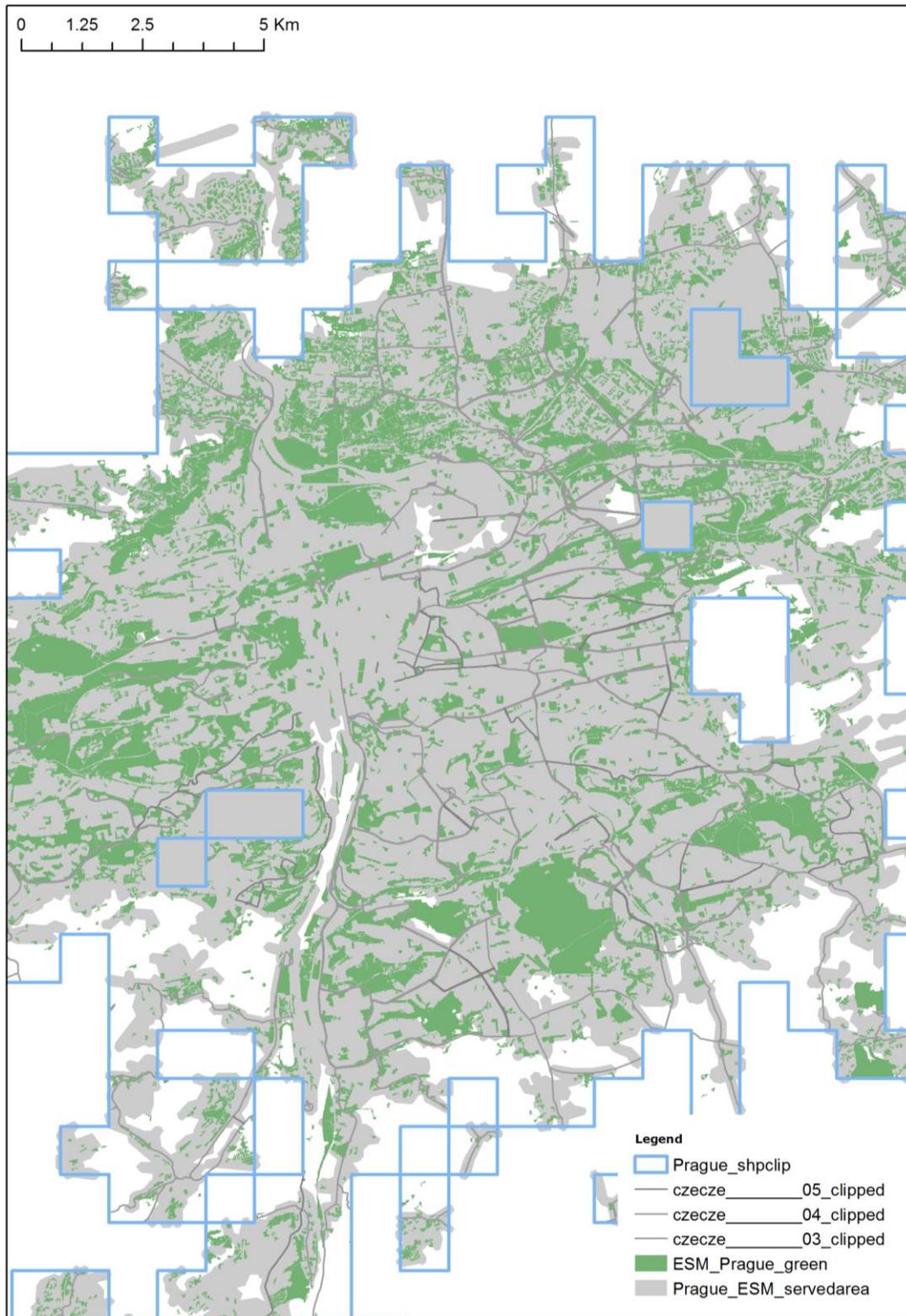


Figure 9 - Prague - Urban Atlas - Green and served areas

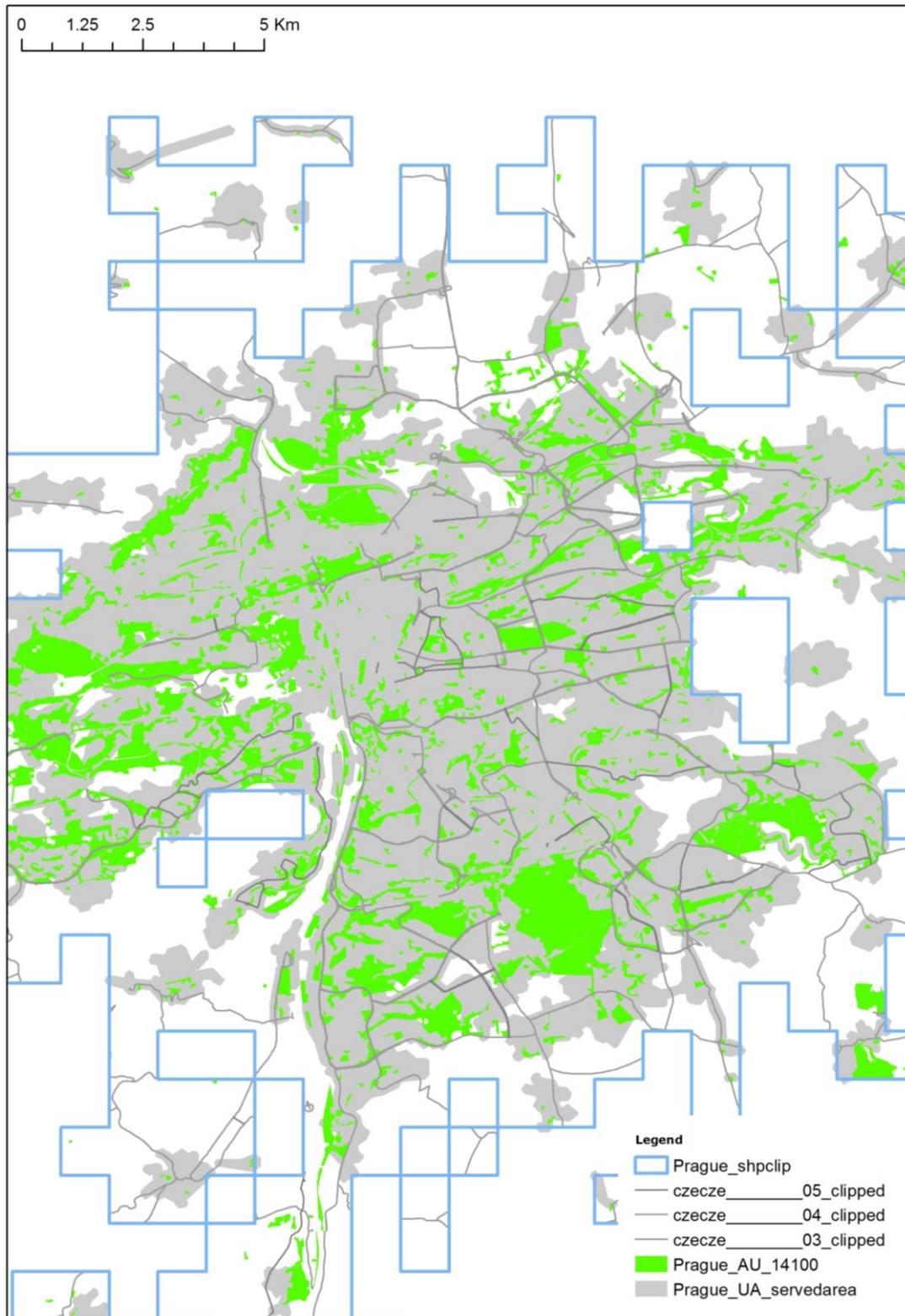


Figure 10 – Prague- Local dataset - Green and served areas

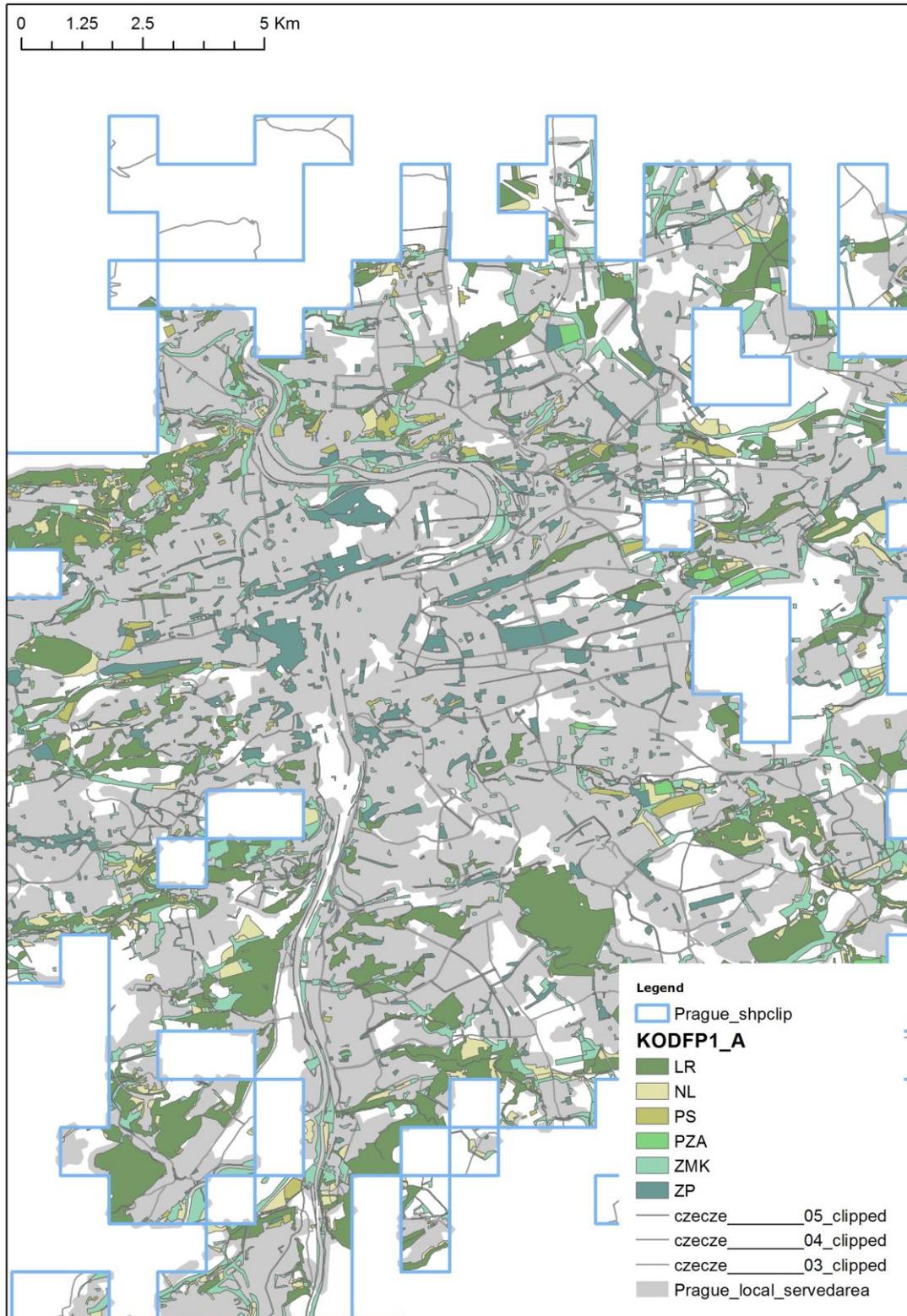


Figure 11 - Torino – Green ESM 2016 - Green and served areas

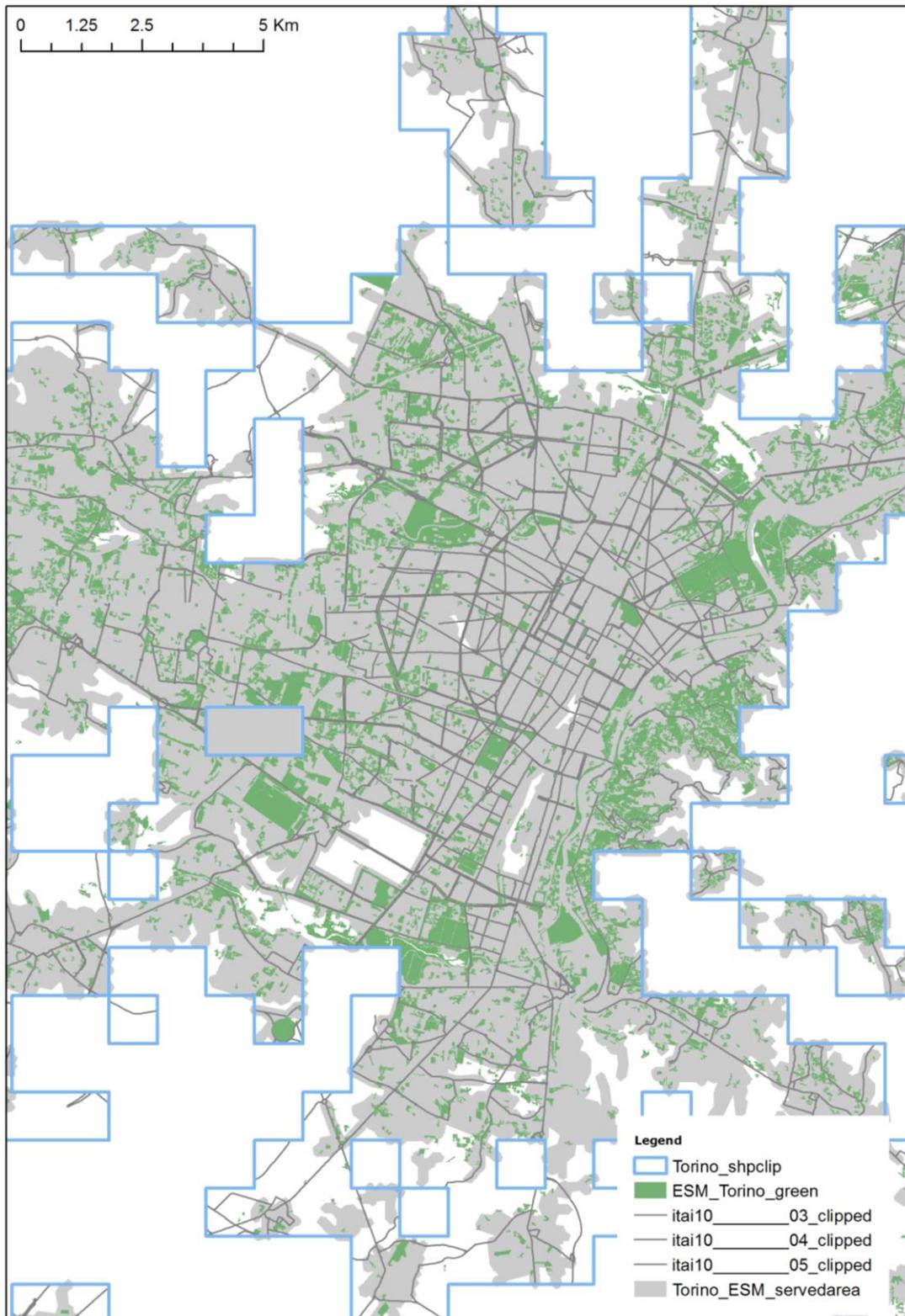


Figure 12 - Torino - Urban Atlas - Green and served areas

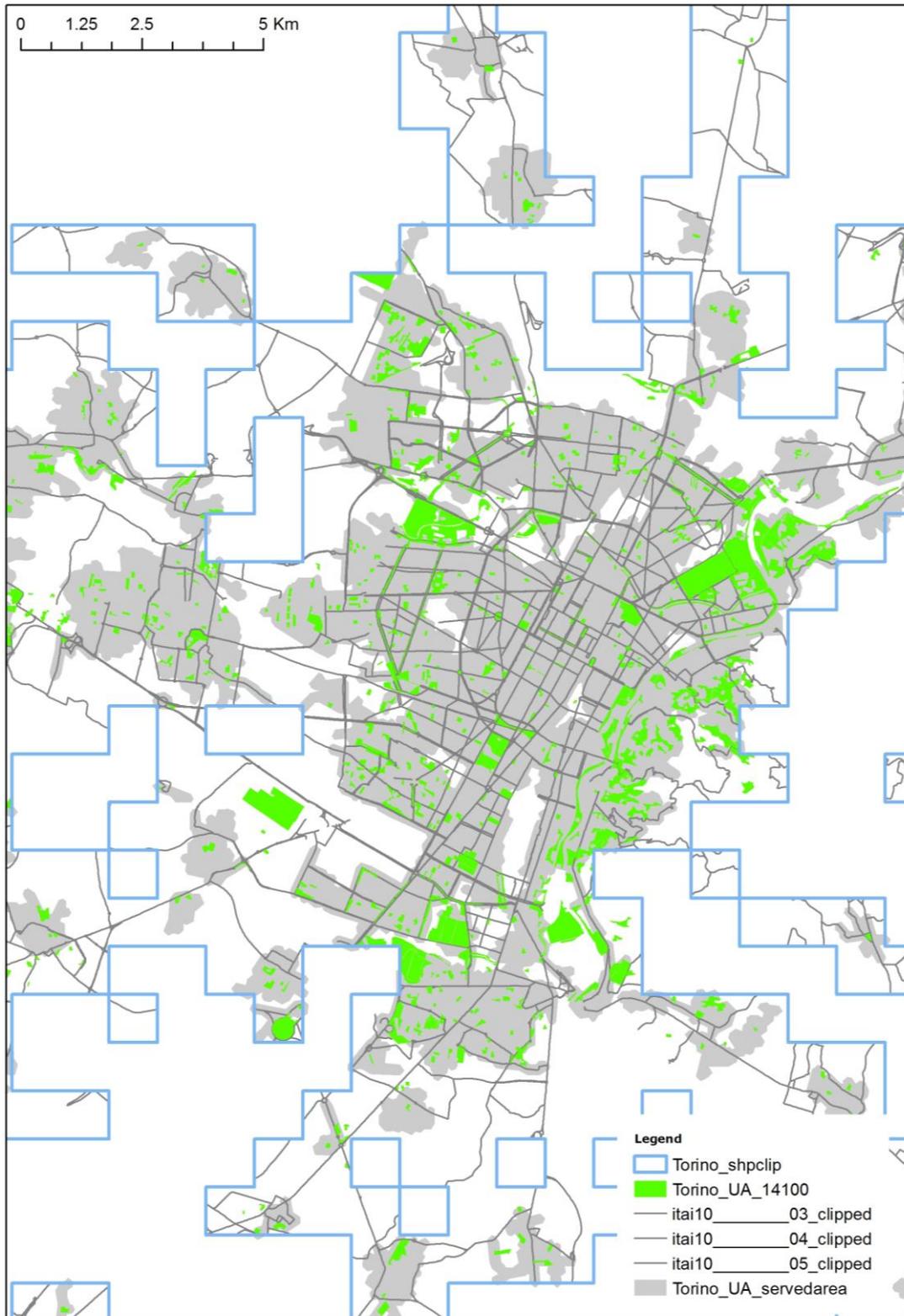
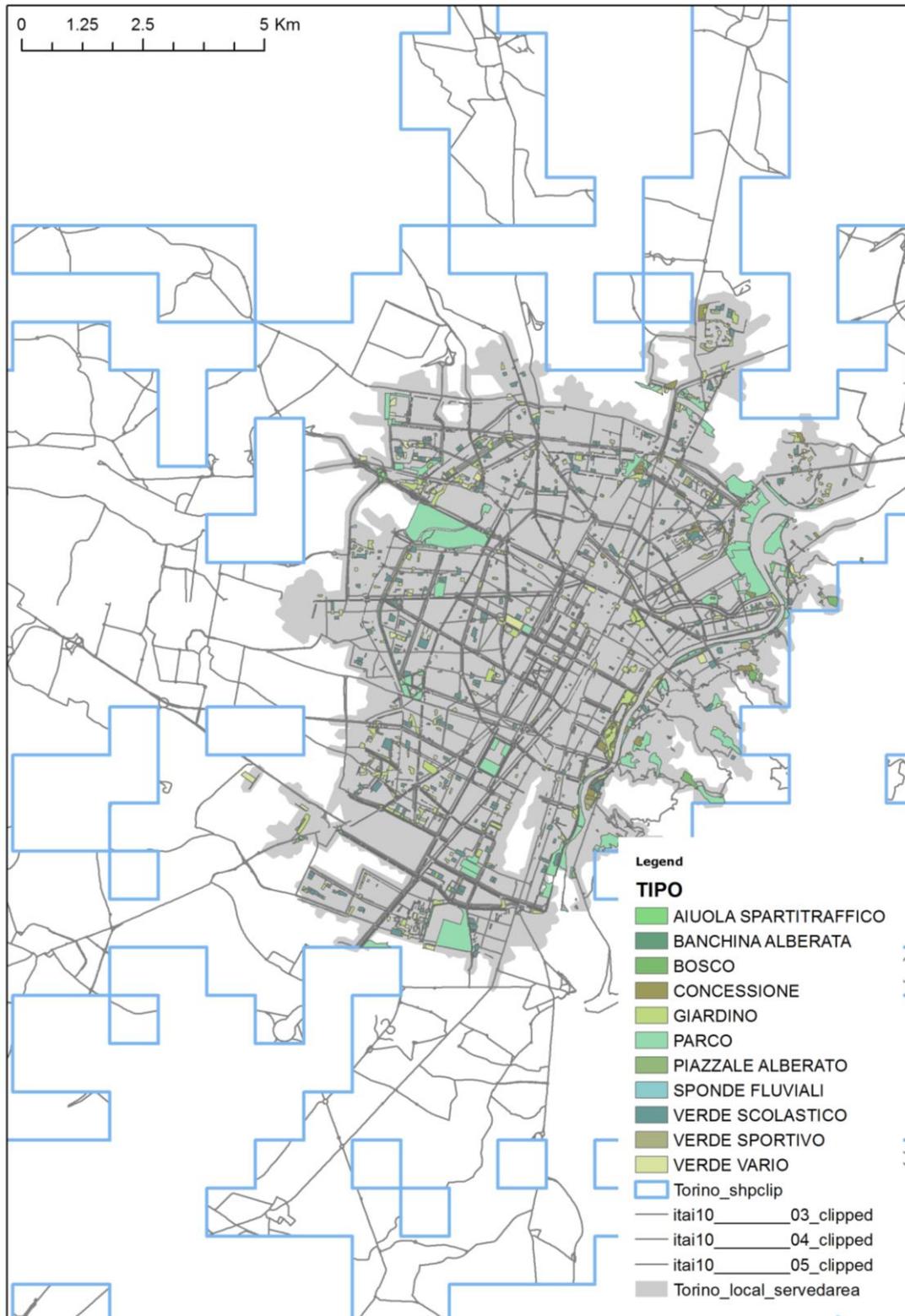


Figure 13 - Torino – Local Dataset - Green and served areas



5. Conclusion

The tests performed on the four cities demonstrate that the ESM 2016 detects more green areas than UA. If we look at the results of the ESM we see that the amount of green areas these results are closer to the local datasets than the UA.

This is due to many factors, but mostly to the definition of urban green areas that the different datasets use.

In the case shown below (a big urban green area in Prague is not included in the UA, but it is detected in ESM 2016 and in the local dataset.

Other datasets, such as the local ones, are clearly most detailed than the ESM, but often their coverage is linked to the administrative boundaries: in some cases they are bigger than the urban clusters; in others, such as Turin, they are much smaller, and consequently the urban green areas detected are less in total area.

In this method, the threshold set is 0.25ha to align the ESM with the UA minimum mapping unit: this also affects the detection of the green areas.

A limit of this methodology is that part of it has to be performed with the ESRI tool Network Analysis than cannot be done with Python: this means that for every city, it has to be performed manually. Despite that, the input data can be prepared and set.

Green ESM 2016 detects green areas, regardless the ownership status, but there are indications that some setting could help to identify the public areas. If a green area is bigger than 1 ha and it is crossed by public streets, with a high probability, this is a public green area.

In conclusion, this study demonstrates that, despite of some restrictions, the ESM can be used to measure to international targets and indicators on urban green areas.

Figure 14), a big urban green area in Prague is not included in the UA, but it is detected in ESM 2016 and in the local dataset.

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In conclusion, this study demonstrates that, despite of some restrictions, the ESM can be used to measure to international targets and indicators on urban green areas.

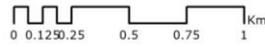
Figure 14 – Case of Olšany Cemetery – Prague

Copernicus Core_003 Seamless Mosaic

Local Dataset



- NIR
- RED
- GREEN



Legend

- PVP_fvu_p_ZMK
- PVP_fvu_p_ZP
- Parks_Prague_served_area_clipped

ESM 2016

Urban Atlas 2012



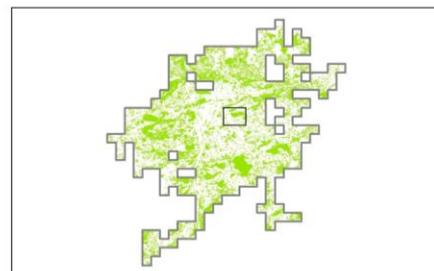
Legend

- GA_Prague_1ha
- GA_Prague_served_area

Legend

- UrbanAtlas_14100
- UrbanAtlas_14100_servedArea

The maps above aim at showing one big green area in Prague as shown in different datasets. This area is a popular cemetery, a city park where people is used to walk and surely it contributes to the reduction of air pollution and environmental aspect of the surroundings. It is detected in the ESM, it is not classified as urban green area in the Urban Atlas, while it is classified as ZP (parks, historic gardens and cemeteries) in the local dataset.



Annex

Complete workflow script

The following description illustrates the whole workflow in the Python code using the

Preparation of the data

```
#Import arcpy module
import arcpy
from arcpy import env
from arcpy.sa import *
# Check out the ArcGIS Spatial Analyst extension license
arcpy.CheckOutExtension("Spatial")
#import os
import os

1. Create File GDB
out_folder_path = "C://data/outpath/"
Accessibility_ESM = "Accessibility_ESM.gdb"
# Execute CreateFileGDB
arcpy.CreateFileGDB_management(out_folder_path, Accessibility_ESM)
```

```
2. Definition of workshop (geodatabase)
env.workspace = "C://data/outpath/ Accessibility_ESM.gdb"
```

```
3. List of layers
#creation of a list containing the different layers of the ESM needed to run the model
Index:
ESM_40 = "index10m_40.vrt"
ESM_41 = "index10m_41.vrt"
```

Definition of the city masks

```
4. Conversion of Geostat urban clusters from raster to polygons
URB_CLST_2006_GEOSTAT_tif = "C://data/URB_CLST_2006_GEOSTAT/URB_CLST_2006_GEOSTAT.tif"
URB_CLST_2006_GEOSTAT_shp = "URB_CLST_2006_GEOSTAT"
# Process: Raster to Polygon
arcpy.RasterToPolygon_conversion(URB_CLST_2006_GEOSTAT_tif, URB_CLST_2006_GEOSTAT_shp, "NO_SIMPLIFY", "VALUE")
```

```
5. Dissolve the UA shape files to obtain the UA city boarders
outroot = "C://data/outpath/ESMvsUA.gdb/"
city_UA_shapeclip = city + "_UA_shpclip"
# Process: Merge
arcpy.Dissolve_management(fullpath, city_UA_shapeclip, "", "", "SINGLE_PART", "DISSOLVE_LINES")
```

```
6. Intersection of the Urban cluster boarders with the UA city boarders
#Local variables
city_UA_shapeclip = city + "_UA_shpclip"
URB_CLST_2006_GEOSTAT_shp = "URB_CLST_2006_GEOSTAT"
City_shpclip = city + "_shpclip"
# Process: Intersect
arcpy.Intersect_analysis([city_UA_shapeclip, URB_CLST_2006_GEOSTAT_shp], City_shpclip, "ALL", "", "INPUT")
```

Clipping the datasets with the city masks

```
7. Extraction of the UA feature class 14100 – urban green
outroot = "C://data/outpath/ESMvsUA.gdb/"
UA_14100 = city + "_14100"
# Process: Feature Class to Feature Class
arcpy.FeatureClassToFeatureClass_conversion(fullpath, outroot, UA_14100, "CODE" = '\14100')
```

```
8. Arcpy Clipping of UA feature class 14100 with the city mask
UA_14100 = city + "_14100"
City_shpclip = city + "_shpclip"
UA_14100_clipped = city + "_14100_clipped"
arcpy.Clip_analysis(UA_14100, City_shpclip, UA_14100_clipped, "")
```

```
9. Arcmap Clipping of the local dataset
local_green = city + "_local_green"
City_shpclip = city + "_shpclip"
```

```
local_green_clipped = city + "_local_green_clipped"
arcpy.Clip_analysis(local_green, City_shpclip, local_green_clipped, "")
```

10. Clipping of the ESM layer 40 with the city mask

```
#Local variables
index10m_40_vrt = "C://data/index10m_40.vrt"
ESM40_clipped_tif = "C://data/ESM/" + city + "_ESM40_clipped.tif"
City_shpclip = city + "_shpclip"
# Process: Clip
arcpy.Clip_management(index10m_40_vrt, "#", ESM40_clipped_tif, City_shpclip, "#", "ClippingGeometry",
"NO_MAINTAIN_EXTENT")
rasterObj=arcpy.Raster(ESM40_clipped_tif)
arcpy.SetRasterProperties_management(rasterObj,nodata="1 255")
rasterObj.save(ESM40_clipped_tif)
```

11. Clipping of the ESM layer 40 with the city mask

```
#Local variables
index10m_40_vrt = "C://data/index10m_41.vrt"
ESM40_clipped_tif = "C://data/ESM/" + city + "_ESM41_clipped.tif"
City_shpclip = city + "_shpclip"
# Process: Clip
# Process: Clip
arcpy.Clip_management(index10m_41_vrt, "#", ESM41_clipped_tif, City_shpclip, "#", "ClippingGeometry",
"NO_MAINTAIN_EXTENT")
rasterObj=arcpy.Raster(ESM41_clipped_tif)
arcpy.SetRasterProperties_management(rasterObj,nodata="1 255")
rasterObj.save(ESM41_clipped_tif)
```

12. Raster calculator to merge the ESM layers 40 and 41

```
#Local variables
env.workspace = "C://data/ESM/"
ESM40_clipped_tif = city + "_ESM40_clipped.tif"
ESM41_clipped_tif = city + "_ESM41_clipped.tif"
ESM40_41_clipped_tif = city + "_ESM40_41_clipped.tif"
# Process: Raster Calculator
arcpy.gp.RasterCalculator_sa("Con((\'+ESM40_clipped_tif+\'+\'+\'+ESM41_clipped_tif+\')> 50,1, 0)",
ESM40_41_clipped_tif)
```

13. Conversion of ESM raster to polygons

```
#Local variables
ESM40_41_clipped_tif = "C://data/ESM/" + str(city) + "_ESM40_41_clipped.tif"
ESM_poly = "C://data/ESMvsUA.gdb/" + str(city) + "_ESM_40_41"
field = "VALUE"
# Process: Raster to Polygon
arcpy.RasterToPolygon_conversion(ESM40_41_clipped_tif, ESM_poly, "NO_SIMPLIFY", field)
```

14. Conversion of ESM from multipart to single part

```
#Local variables
ESM_poly = "C://data/ESMvsUA.gdb/" + str(city) + "_ESM_40_41"
ESM_poly_single = "C://data/ESMvsUA.gdb/" + str(city) + "_ESM_40_41_single"
# Process: multipart to single
arcpy.MultipartToSinglepart_management(ESM_poly, ESM_poly_single)
```

15. Feature Class to Feature Class

```
#Local variables
ESM_poly_single = "C://data/ESMvsUA.gdb/" + str(city) + "_ESM_40_41_single"
out_path = "C://data/ESMvsUA.gdb/"
ESM_green = str(city) + "_ESM_green"
# Process: Feature Class to Feature Class
arcpy.FeatureClassToFeatureClass_conversion(ESM_poly_single, out_path, ESM_green, "Shape_Area>2500 AND gridcode=1")
```

Preparation of the road network

16. Arcpy Clipping the road network levels (from 3 to 8) (Tool: Clip)

```
# set local variables
nldnld_03 = "C://data/ESMvsUA.gdb/roads_03.shp"
nldnld_04 = "C://data/ESMvsUA.gdb/roads_04.shp"
nldnld_05 = "C://data/ESMvsUA.gdb/roads_05.shp"
nldnld_06 = "C://data/ESMvsUA.gdb/roads_06.shp"
nldnld_07 = "C://data/ESMvsUA.gdb/roads_07.shp"
nldnld_08 = "C://data/ESMvsUA.gdb/roads_08.shp"
outLocation = "C://data/ESMvsUA.gdb/"
City_shpclip = city + "_shpclip"
# Execute Clip
```

```

arcpy.Clip_analysis(roads_03, city_shpclip, roads_03_clipped)
arcpy.Clip_analysis(roads_04, city_shpclip, roads_04_clipped)
arcpy.Clip_analysis(roads_05, city_shpclip, roads_05_clipped)
arcpy.Clip_analysis(roads_06, city_shpclip, roads_06_clipped)
arcpy.Clip_analysis(roads_07, city_shpclip, roads_07_clipped)
arcpy.Clip_analysis(roads_08, city_shpclip, roads_08_clipped)

```

17. Arcpy Merge the roads in a single feature class (arcpy.Merge_management)

```

#Merge
city_roads = "city_roads"
arcpy.Merge_management([roads_03_clipped, roads_04_clipped, roads_05_clipped, roads_06_clipped, roads_07_clipped, roads_07_clipped], city_roads)

```

Intersection of borders of the green areas with the road network

18. Arcpy Process: intersection_analysis (output type: POINTS)

```

#set local variables
city_roads = "city_roads"
ESM_city_green = "ESM_city_green"
city_inter = "city_inter"
arcpy.Intersect_analysis([city_roads, ESM_city_green], city_inter, "ALL", "", "POINT")

```

Zonal Statistic as Table

19. Arcpy Zonal statistics as Table

```

#set local variables
City_servedarea = "C://data/ESMvsUA.gdb/" + str(city) + "_servedarea"
pop_GEOSTAT_2011_V2_JRC_tif = "C://data/pop_GEOSTAT_2011_V2_JRC.tif"
output_zsta_servedpop = "C://data/ESMvsUA.gdb/" + str(city) + "_servedpop"
# Process: ZonalStatisticsAsTable
ZonalStatisticsAsTable(City_servedarea, "OBJECTID", pop_GEOSTAT_2011_V2_JRC_tif, output_zsta_servedpop, "DATA", "SUM")

```

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List of abbreviations and definitions

ESM	European Settlement Map
SDG	Sustainable Development Goal
UA	Urban Atlas
WHO	World Health Organization

List of figures

Figure 1 – Maps showing the different city borders of the NDU and Urban Atlas coverage: Amsterdam, Athens, Prague and Turin	11
Figure 2 - Samples of road intersections in the four cities.....	17
Figure 3 – Amsterdam - Green ESM 2016 – Urban Green Areas and served areas	18
Figure 4 – Amsterdam – Urban Atlas - Green and served areas.....	19
Figure 5 – Amsterdam – Local dataset - Green and served areas	20
Figure 6 - Athens - Green ESM 2016 – Urban Green Areas and served areas	21
Figure 7 – Athens – Urban Atlas - Green and served areas	22
Figure 8 – Prague – Green ESM 2016 - Green and served areas	23
Figure 9 - Prague - Urban Atlas - Green and served areas	24
Figure 10 – Prague- Local dataset - Green and served areas.....	25
Figure 11 - Torino – Green ESM 2016 - Green and served areas.....	26
Figure 12 - Torino - Urban Atlas - Green and served areas	27
Figure 13 - Torino – Local Dataset - Green and served areas	28
Figure 14 – Case of Olšany Cemetery – Prague.....	31

List of tables

Table 1 - Input datasets.....	7
Table 2 - Complete results for the four cities	15
Table 3 – Results of the street indexes.....	16

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