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URBAN SPRAWL FROM URBAN ATLAS DATA: ROMANIAN CASE STUDY

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Abstract
The main purpose of the paper is to provide an easy-to-use and simple instrument, accessible to non-expert users interested in urban sprawl analysis. Thus, answers to the following questions are proposed: Is it possible to measure urban sprawl using Urban Atlas data exclusively? If so, how such a measure looks like? How easy is to compute urban sprawl by means of the proposed measure? How can be applied to Romanian cities?
Keywords:urban sprawl, Urban Atlas, urban development, urban expansion, land use

1. INTRODUCTION

United Nations Department of Economic and Social Affairs, Population Division states (UN, 2018) that, in 2018, 55% of the world's population lives in urban areas, while the prospects indicate that 68% of the world's population will do the same by 2050. In absolute terms it means that the world urban population is supposed to increase from 4,2 billion in 2018 to 6,7 billion by 2050. Thus, the world urbanization will continue at a high pace. At the same time, according to Food and Agricultural Organization of the United Nations (FAO, 2011) the global food production demand will increase up to 70% by 2050, relative to 2009 levels.

From the above paragraph it obviously follows that land, and fertile land especially, is subject to a global competition between urbanization and food demand. Consequently, measures, actions, and instruments must be implemented for achieving a sustainable urbanization process. At this stage, actions and instruments for monitoring and control of urbanization process, through all its main dimensions, are currently needed. Urbanization involves three main processes (EEA-FOEN, 2016): urban development, urban growth and urban sprawl.

Following (EEA-FOEN, 2016) urban development includes the other two processes, namely both urban growth and urban sprawl, which are distinct but overlapping entities. Thus, according to the above-mentioned EEA-FOEN report, besides including increase in spatial extent, urban development also refers the "removal of built-up areas and changes in land uptake per person"; urban growth, as a particular form of urban development, "simply indicates an expansion of built-up areas, irrespective of their spatial distribution and the change in land uptake per person". In this context, urban growth and urban expansion are synonymous and, due to the fact that only the spatial dimension is considered, its monitoring is almost straightforward. One of the most effective research programs dedicated exclusively to urban expansion/growth is the New York University Urban Expansion Program (NYU, 2018).

Urban sprawl is a major concern in Europe and the European Environment Agency published two reports on this topic, namely (EEA, 2006) and (EEA-FOEN, 2016), recognizing in this way the importance of this process. Thus, (EEA-FOEN, 2016) defines urban sprawl as a kind of urban development, denoting "an increase in the extent of built-up areas, an increase in dispersion of built-up areas or an increase in land uptake per person, or a combination of changes in these three dimensions". As a process, it can be considered from many distinct points of view because it depends on a large diversity of often interdependent factors, such as spatial, demographical, geographical, environmental, socio-economical, legislative, psycho-social, resolution, scale of study, data availability and traditional factors, which may vary from country to country, and from region to region. Therefore, it is not surprising that there is no consensus regarding the urban sprawl definition, the literature providing a large variety of definitions.

The present paper is not intended to be an exhaustive overview of urban sprawl approaches and ascertains that the two EEA reports mentioned above, namely Urban Sprawl in Europe – The Ignored Challenge (EEA, 2006) and Urban Sprawl in Europe (EEA-FOEN, 2016) provides a comprehensive study of urban sprawl issues in Europe, including an extensive bibliography that will not be reproduced here. Urban sprawl was studied also in Romanian context and the following two papers are approaching important aspects of this process (Suditu et al., 2010) and (Grigorescu et al., 2012). At the same time, the study dedicated to the habitat in the periurban areas should be also mentioned (Sârbu, 2005)

Nevertheless, there are two features generally encountered when considering urban sprawl: the first one is related to the spatial discontinuity and low density of built-up areas, and the second notes usually an increase of built-up areas significantly greater than the population growth.

One of the most important key issues when analysing urban sprawl is the resolution of study, both in time and space. For instance, urban sprawl analysis undertaken within (EEA-FOEN, 2016) considers this process for 32 countries in Europe at national, regional (NUTS-2) and 1-km2 cell (LEAC grid) levels, at two different moments in time, namely 2006 and 2009. On another hand, Urban Atlas provides data at the city level, but the spatial extent of data is not the administrative limit. More precisely, it considers the Functional Urban Area (FUA) that can be shortly defined as the area that consists of a city plus its commuting zone (EUROSTAT, 2017). FUA was formerly known as Larger Urban Zone (LUZ), its definition being given in (OECD, 2013) and was used for the 2012 version of the dataset, while the 2006 version used LUZ. (European Union, 2011) and (European Union, 2016)

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include more comprehensive information about FUA and LUZ.Finally, in the case of Urban Atlas, the temporal resolution of urban sprawl analysis is defined by the dataset updating pace.

There is no urban sprawl indicator published by EEA but the constant interest in monitoring the processes related to land use is proved by promoting the following four indicators (EEA, 2018): land recycling and densification (published since July27, 2018), landscape fragmentation pressure from urban and transport infrastructure expansion (April 26, 2018), imperviousness and imperviousness change (December 4, 2017), land take (April 21, 2017).

Why propose a new urban sprawl measure?The question is legitimate because, as remarked earlier, there are already so many proposals to define and measure urban sprawl process, following a large diversity of perspectives. At the same time, in recent years new datasets were made openly available, intensively integrating a lot of information from a large variety of sources. For instance, according to (European Union, 2016) the Urban Atlas 2012 dataset integrates remote sensing data (e.g. VHR2 available from ESA Data Ware House, namely DWH_MG2b_CORE_03), statistical data, topographic maps, thematic maps, local city maps, local zoning data (e.g. cadastral data), COTS data (e.g. Google Earth), navigation data network (Open Street Map), VHR - Very High Resolution imagery (e.g. aerial photography), other relevant datasets (e.g. HRL Imperviousness layer), field check (e.g. on-site visits).In this context, proposing a new urban sprawl measure that is based exclusively on Urban Atlas data makes sense, mainly because using this dataset gives the possibility to avoid complex and often costly operations/processing involving, besides various data sources, a lot of expertise during data processing.One might say that using Urban Atlas data is just like driving 100km to the destination by a state-of-the-art car versus barefoot walking the same distance on the same road.

The paper has four main sections. The second section deals with the data used in the applications presented in the paper, describing also the methodology of the data processing procedure.The case study within the third section consists in applying the methodology from the previous section to four cities in Romania, selected from the Urban Atlas dataset.Conclusions and further developments are presented in the fourth section of the paper.

2. DATA AND METHODOLOGY

The data used within the present paper are exclusively Urban Atlas data. Urban Atlas is an European Union project involving European Commission, European Space Agency and European Environment Agency. The main result of the project is the Urban Atlas dataset, which is published on Copernicus Land Monitoring Service website (UA-CLMS, 2018), and which is also accessible through an access point from EEA website EEA (UA-EEA, 2018). The first version, Urban Atlas 2006, covered 305 urban areas from EU-27 countries (UA2006, 2018). The second version, Urban Atlas 2012, extended the coverage to 800 urban areas from EEA-39 countries (UA2012, 2018)

Besides extending the geographical coverage, the second version has a more detailed legend. Thus, the number of classes increased from the 20 classes of Urban Atlas 2006 to the 29 classes of Urban Atlas 2012, each class having assigned a unique code, as illustrated in Table 1.

TABLE 1 - LEGENDS OF URBAN ATLAS 2006 AND URBAN ATLAS 2012 DATASETS

Urban Atlas 2006			Urban Atlas 2012	
Code	Nomenclature		Code	Nomenclature
11100	Continuous urban fabric		11100	Continuous urban fabric
11210	Discontinuous dense urban fabric		11210	Discontinuous dense urban fabric
11220	Discontinuous medium density urban fabric		11220	Discontinuous medium density urban fabric
11230	Discontinuous low density urban fabric		11230	Discontinuous low density urban fabric
11240	Discontinuous very low density urban fabric		11240	Discontinuous very low density urban fabric
11300	Isolated structures		11300	Isolated structures
12100	Industrial, commercial, public, military and private units		12100	Industrial, commercial, public, military and private units
12210	Fast transit roads and associated land		12210	Fast transit roads and associated land
12220	Other roads and associated land		12220	Other roads and associated land
12230	Railways and associated land		12230	Railways and associated land
12300	Port areas		12300	Port areas
12400	Airports		12400	Airports
13100	Mineral extraction and dump sites		13100	Mineral extraction and dump sites
13300	Construction sites		13300	Construction sites
13400	Land without current use		13400	Land without current use
14100	Green urban areas		14100	Green urban areas
14200	Sports and leisure facilities		14200	Sports and leisure facilities
20000	Agricultural areas, semi-natural areas and wetlands			
			21000	Arable land (annual crops)
			22000	Permanent crops
			23000	Pastures
			24000	Complex and mixed cultivation
			25000	Orchards
30000	Forests			
			31000	Forests
			32000	Herbaceous vegetation associations
			33000	Open space with little or no vegetation
			40000	Wetlands
50000	Water		50000	Water
			91000	No data (clouds and shadows)
			92000	No data (missing imagery)

Due to their characteristics as described in Table 4.1, Urban Atlas data can be used in various applications related to land use in European cities, including urban sprawl analysis. The method used in the present paper to perform urban sprawl analysis consists in computing an urban sprawl indicator based exclusively on Urban Atlas data at city level. There are 14 classes used for the computation of the indicator; they are grouped in three categories as presented in Table 2.

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TABLE 2 - THE 14 CLASSES FROM THE LEGEND OF THE URBAN ATLAS DATASET, WHICH ARE GROUPED INTO THREE CATEGORIES: C1 (CONTINUOUS URBAN FABRIC), C2 (NON-CONTINUOUS URBAN FABRIC), ANDC3 (OTHER TYPES OF ARTIFICIAL SURFACES)

Item	Class code	Description	Category
1.	11100	Continuous urban fabric	C1
2.	11210	Discontinuous dense urban fabric	C2
3.	11220	Discontinuous medium density urban fabric	
4.	11230	Discontinuous low density urban fabric	
5.	11240	Discontinuous very low density urban fabric	
6.	11300	Isolated structures	
7.	12100	Industrial, commercial, public, military and private units	C3
8.	12210	Fast transit roads and associated land	
9.	12220	Other roads and associated land	
10.	12230	Railways and associated land	
11.	12300	Port areas	
12.	12400	Airports	
13.	13100	Mineral extraction and dump sites	
14.	13300	Construction sites	

The three categories described in Table 4.2 can be characterized in a more detailed manner as follows:

C1 - Continuous urban fabric

C2 - Non-continuous urban fabric, i.e. discontinuous urban fabric and isolated structures

C3 - Other types of artificial surfaces, excluding artificial non-agricultural vegetated areas.

Thus, it is worth mentioning that the urban sprawl definition used within the present paper is focused on non-continuous urban fabric and quantifies the relation between this type of urban fabric and any other type of artificial surfaces, excluding artificial non-agricultural vegetated areas, as follows:

Normalized Urban Atlas Sprawl Indicator (NUASI) is the ratio between the area corresponding to C2, and the sum of areas corresponding to C1, C2 and C3:

NUASI = area(C2) / [area(C1) + area(C2) + area(C3)]

Roughly speaking, NUASI says how much of the total built-up area of the city is covered by non-continuous built-up zones. Obviously, its value is always less than 1. Also, the comparison between cities with respect to NUASI is enabled because the indicator does not depend on the absolute values of the built-up areas.

The idea of introducing NUASI was generated by the urban sprawl analysis performed in (Kukuk, 2013), where the indicator used was defined as the ratio between the non-continuous built-up area and all the other artificial surfaces in the city. Thus, the urban sprawl indicator could take values greater than 1, namely in those cases where the non-continuous built-up area overcame the total of all the other types of built-up areas, leading to a more difficult comparability of the urban sprawl process between different cities.

It follows that the methodology of measuring the urban sprawl corresponding to a city consists in computing the NUASI indicator for the associated FUA of that city.

3. CASE STUDY

The case study included the following three steps: choice of the cities, computation of the areas corresponding to the three categories (C1, C2 and C3), computation of NUASI indicator accompanied by a comparative presentation of the tabular results and, finally, urban sprawl trend illustrated as a bar chart.

In order to make a relevant choice several criteria were taken into account. First of all, the 14 cities included in both 2006 and 2012 versions of the Urban Atlas dataset were selected. The second criterion aimed at identifying the most important cities from the 14 already selected and consisted in choosing those that have at least 300.000 inhabitants and are listed as Rank 0 and I according to the Law 351/2001 (Romanian Parliament, 2001). Thus, the following 4 cities were nominated: Bucharest, Cluj-Napoca, Craiova and Timişoara.

In Figure 1 and Figure 2 the data corresponding to Cluj-Napoca are illustrated using the pdf format files downloaded from Urban Atlas 2006 and 2012 datasets, respectively.

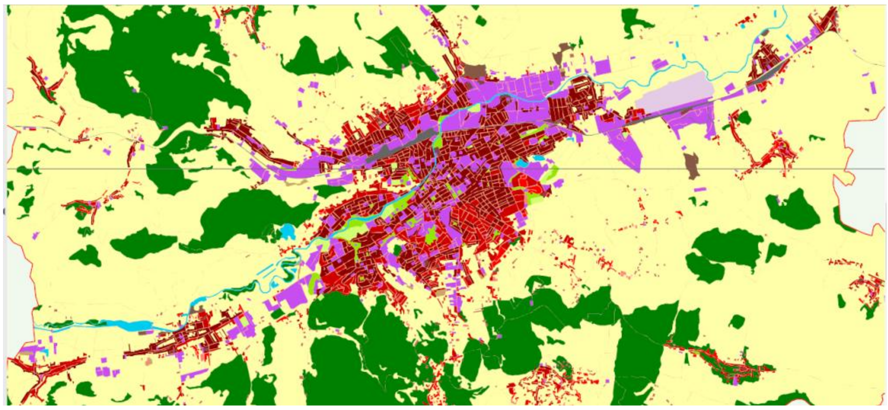

FIGURE 1 - CLUJ-NAPOCA DATA (DETAIL) AS ILLUSTRATED BY RO002L_CLUJ_NAPOCA.PDF FILE THAT IS INCLUDED IN THE DATASET DEDICATED TO THE CITY WITHIN URBAN ATLAS 2006

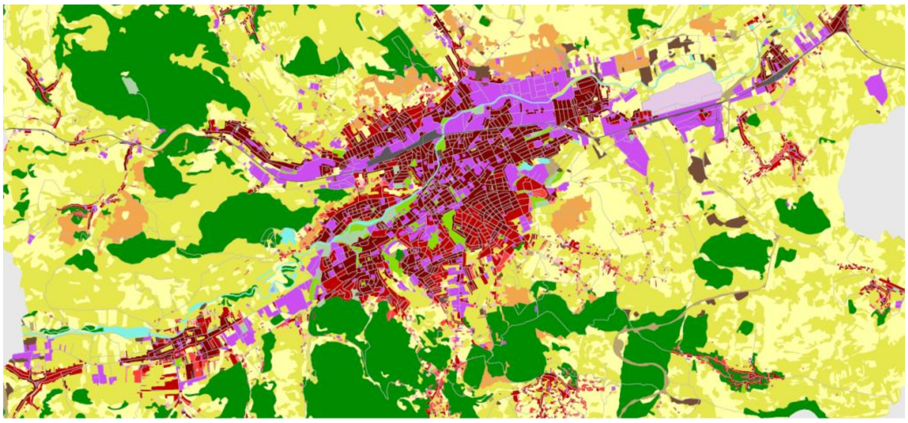

FIGURE 2 - CLUJ-NAPOCA DATA (DETAIL) AS ILLUSTRATED BY RO002L1_CLUJ-NAPOCA_UA2012.PDF FILE THAT IS INCLUDED IN THE DATASET DEDICATED TO THE CITY WITHIN URBAN ATLAS 2012

The next step consisted in computing the areas corresponding to the three categories C1, C2 and C3. Within both 2006 and 2012 versions, for each class-code of the Urban Atlas legend, the area is provided in square meters.

Thus, the following three tables, namely Table 3, 4 and 5 centralize the Urban Atlas 2006 data for C1, C2, and C3 categories, for all the four nominated cities.

TABLE 3 - COMPUTATION OF THE AREA CORRESPONDING TO CATEGORY C1 FOR URBAN ATLAS 2006 DATA

Code	Bucharest	Cluj-Napoca	Craiova	Timişoara
11100	132577216,79	18207242,96	18615652,13	13941545,77
Total (m^2)	132577216,79	18207242,96	18615652,13	13941545,77
Total (ha)	13257,72	1820,72	1861,57	1394,15

TABLE 4 - COMPUTATION OF THE AREA CORRESPONDING TO CATEGORY C2 FOR URBAN ATLAS 2006 DATA

Code	Bucharest	Cluj-Napoca	Craiova	Timişoara
11210	25862777,44	13841786,65	13166696,84	21117987,71
11220	298618,07	2895656,32	422588,25	1007766,98
11230	20084,81	820594,75	16292,39	40469,16
11240	0,00	58281,99	0,00	0,00
11300	1531954,83	2425471,17	572737,01	839888,49
Total (m^2)	27713435,15	20041790,88	14178314,49	23006112,33
Total (ha)	2771,34	2004,18	1417,83	2300,61

TABLE 5 - COMPUTATION OF THE AREA CORRESPONDING TO CATEGORY C3 FOR URBAN ATLAS 2006 DATA

Code	Bucharest	Cluj-Napoca	Craiova	Timişoara
12100	86553670,41	16357524,49	14073215,94	18544687,28
12210	899025,75	0,00	0,00	0,00
12220	21686873,02	8570048,64	6765646,91	6262256,04
12230	6694307,23	1168816,06	1715461,08	1834755,19
12300	0,00	0,00	46737,47	0,00
12400	9364507,87	1392586,15	1761672,97	2302331,85
13100	2746785,18	900260,99	6926,96	395049,57
13300	6686973,70	269019,98	982523,65	743677,35
Total (m^2)	134632143,16	28658256,31	25352184,98	30082757,28
Total (ha)	13463,21	2865,83	2535,22	3008,28

The next three tables, namely Table 6, 7 and 8 provide the Urban Atlas 2012 data for C1, C2, and C3 categories, for all the four nominated cities.

TABLE 6 - COMPUTATION OF THE AREA CORRESPONDING TO CATEGORY C1 FOR URBAN ATLAS 2012 DATA

Code	Bucharest	Cluj-Napoca	Craiova	Timişoara
11100	133077627,70	18554629,43	18646958,53	13906342,83
Total (m^2)	133077627,70	18554629,43	18646958,53	13906342,83
Total (ha)	13307,76	1855,46	1864,70	1390,63

TABLE 7 - COMPUTATION OF THE AREA CORRESPONDING TO CATEGORY C2 FOR URBAN ATLAS 2012 DATA

Code	Bucharest	Cluj-Napoca	Craiova	Timişoara
11210	27856666,16	14879804,27	13330774,45	21209841,95
11220	1602245,84	3477290,09	663645,08	1060425,17
11230	2762380,87	1459751,40	337383,08	314895,92
11240	7934455,29	2145213,86	2790933,19	1040916,49
11300	2675487,75	2987263,54	855436,40	957868,70
Total (m^2)	42831235,91	24949323,16	17978172,21	24583948,24
Total (ha)	4283,12	2494,93	1797,82	2458,39

TABLE 8 - COMPUTATION OF THE AREA CORRESPONDING TO CATEGORY C3 FOR URBAN ATLAS 2012 DATA

Code	Bucharest	Cluj-Napoca	Craiova	Timişoara
12100	92239243,09	17324353,79	15418721,92	19257253,06
12210	842965,27	0,00	0,00	0,00
12220	22107822,19	8548591,95	6773464,35	6599628,42
12230	6667556,18	1163126,67	1793165,08	1877328,29
12300	0,00	0,00	0,00	0,00
12400	9358784,25	1392259,16	1966854,78	2045104,76
13100	3341665,03	2829875,35	2965184,52	332715,16
13300	5779455,31	3301147,01	218381,37	507774,82
Total (m^2)	140337491,32	34559353,92	29135772,02	30619804,51
Total (ha)	14033,75	3455,94	2913,58	3061,98

Finally, Table 9 presents the values of NUASI indicator for 2006 and 2012 Urban Atlas versions. The bottom line includes the value of the urban sprawl trend since 2006 till 2012, computed as the difference between 2012 and 2006 indicator values.

TABLE 9 - THE VALUES OF NUASI ACCOMPANIED BY THE URBAN SPRAWL TREND SINCE 2006 TILL 2012.

	Bucharest		Cluj-Napoca	Craiova	Timişoara
NUASI 2012	13,54 %		31,96 %	27,34 %	35,57 %
NUASI 2006	9,40 %		29,95 %	24,38 %	34,32 %
Trend	**4,14**%		**2,01**%	**2,96**%	**1,25**%

Finally, a more intuitive representation of the urban sprawl trend expressed using NUASI (see the bold values in Table 9) is illustrated in Figure 3.

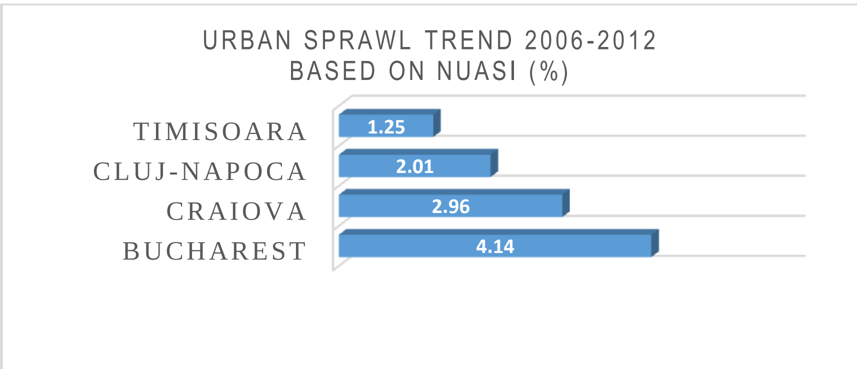

FIGURE 3 - THE URBAN SPRAWL TREND ILLUSTRATED AS A BAR CHART

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4. CONCLUSIONS

The urban sprawl quantification instrument proposed in this paper uses exclusively Urban Atlas data. There is no restriction imposed on the software to be used because Urban Atlas dataset is open data, that is no constraint applies for accessing and processing of data. NUASI indicator is easy to compute and, therefore, it enables non-expert users to perform urban sprawl analysis. Thus, the main purpose of the paper was reached: provide the non-expert user an easy-to-use and simple tool in order to analyse urban sprawl.

As shown in Table 5.7, the indicator proposed in the paper can be used: a) to measure the urban sprawl corresponding to a city at a certain moment in time as well as b) to measure the urban sprawl trend based on a series of measurements.

It follows that the proposed instrument becomes a valuable investigation and management tool for the end-user, mainly public administration at city level, while there is no need for any external assistance because the indicator can be computed by the end-user itself.

It is important to note that due to the spatial resolution of Urban Atlas data, the corresponding urban sprawl analysis is performed at city level, using its FUA. Considering different spatial extent will lead to different values for the indicators. Therefore, NUASI can be reasonably compared with other ones, only if they are also spatially based on FUA.

The relevance of the NUASI indicator still needs confirmation. This is due in the first place to the fact that Urban Atlas dataset is very young if we consider the urbanization process pace. Also, further application of NUASI for cities in other countries should be taken into account. Comparison with other methods dedicated to urban sprawl analysis should also be undertaken.

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