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GREENEST CAPITAL OF THE BALTIC STATES – A SPATIAL COMPARISON OF GREENERY

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Abstract. The meaning of the term "green city" today is more related to sustainability rather than to vegetation or greenery. Therefore, the aim of this research is not to develop another complex green index, but simply to calculate and compare a share of greenery among functional urban areas of three Baltic capitals. Comparison was done using GIS tools and analysing Urban Atlas, CORINE and degree of soil sealing datasets. Although the results of Urban Atlas and CORINE datasets showed slight disagreement, it has been discovered that Tallinn has the highest share of greenery, Vilnius is in the middle and Riga is the last. Analysis of 1990, 2000, 2006 and 2012 CORINE datasets showed the highest relative decrease of greenery in Riga (2.53 %) over time, Tallinn was the second (1.44 %) and the smallest decrease (0.53 %) was in Vilnius. The analysis of degree of soil sealing demonstrated the highest relative share of pervious surfaces in Tallinn (95.5 %) and the smallest share in Vilnius (92.1 %), therefore this research nominates Tallinn as the greenest (literally) capital of the Baltic States.

Keywords*: Baltic States, CORINE, degree of soil sealing, greenery, Urban Atlas, vegetation.*

INTRODUCTION

Although there is a number of "green city" initiatives, most of them focus on sustainability, use complex indices and often have subjective judgment. Meanwhile, the aim of this research is to employ simple methods by calculating and comparing greenery (areas dominated by coverage of vegetation, water and pervious surfaces) and the share of pervious surfaces among functional urban areas of the Baltic States. The first objective, i.e. analysis of greenery, was reached using land use and land cover classes of CORINE and Urban Atlas datasets. The second objective, namely, the analysis of the share of pervious surfaces used the degree of soil sealing, which is ground covering by impermeable/impervious material. The results were compared between the functional urban areas of the capitals of the Baltic States.

Tallinn, Riga and Vilnius – three capitals of the Baltic States, which due to rapid economic development in the 2000's were called "Baltic Tigers" became the Baltic equivalent of four Asian Tigers: Hong Kong, Taiwan, Singapore and South Korea (Hübner, 2011; Kattel, 2009). But before and after the economic boom in 2006–2007, the Baltic States were simply called "Baltic sisters", because they share common features and similar history – outer EU border with Russia, regained independence from the Soviet Union, joined EU, NATO and euro area, have major similarities in geography, size, development, demography and economic structure (Poissonnier, 2017). Although the Baltic States like real sisters tend to do many things together, in order to keep together they have to catch each other up. Thus they cannot avoid sisterly competition, even in such fields as natural environment.

Environmental issues are topical in contemporary societies. That is why assurance of environmental sustainability was identified as one of the Millennium Development Goals (Parry et al., 2007), which was redefined in 2015 and covers a few of the Sustainable Development Goals today (UN, 2015). Countries seek to achieve these goals in order to make a better world, especially for the future generations. One of the motivating initiatives was started in Tallinn, Estonia, by 15 European cities (Tallinn, Helsinki, Riga, Vilnius, Berlin, Warsaw, Madrid, Ljubljana, Prague, Vienna, Kiel, Kotka, Dartford, Tartu and Glasgow) and the Association of Estonian cities (EEA, 2017a). Later on it was transformed into a joint Memorandum supported by the European Commission and established as a competition for designation of the Green Capital City in 2008, and, starting from 2010, each year a European city is selected as the European Green Capital (EEA, 2017a). Criteria for selection include a consistent record of achieving high environmental standards, commitment to ongoing and ambitious goals for further sustainable development and environmental improvements, ability to inspire other cities and promote best practices to other European cities (Beatley, 2012; EEA, 2017a). The Green Capital City award was won so far by the following cities: Stockholm in 2010, Hamburg in 2011, Vitoria-Gastiez in 2012, Nantes in 2013 and Copenhagen in 2014, Bristol in 2015, Ljubljana in 2016, Essen in 2017 and Nijmegen in 2018 (EEA, 2017a), and, for instance, Hamburg was chosen because of planned massive energy savings and reduction of CO_2 emissions by 80 % in year 2050, also almost all citizens have access to public transport within 300 meters away from their homes. While Copenhagen intended to be carbon neutral by 2025 and defined the goal that at least 50 % of the population would use bikes regularly. Another German city, Essen, invested a lot into green infrastructure and enhanced biodiversity in the city, also invested a lot in wastewater treatment, air quality and implemented integrated environmental management system (EEA, 2017a). Unfortunately, none of the Baltic cities has achieved or plans to achieve such goals soon, but they might win a prize in another "contest".

Another European competition was initiated by the Economist Intelligence Unit (2009), which developed the European Green City index in 2009. This index addresses 30 indicators from the categories of CO_2, energy, buildings, transport, water, waste and land use, air quality and environmental governance. According to this index, Vilnius, the capital of Lithuania, got the highest score for the air quality among 30 leading European cities from 30 European countries. Overall, Vilnius was ranked in the 13th place among east European cities (also among low-income cities), while Riga was ranked 15th and Tallinn was 23rd (Economist Intelligence Unit, 2009). Unfortunately, this index was not updated after 2009. Moreover, it was criticized by Venkatesh (2014). He concluded that each city faces different challenges which form different list of indicators defining sustainability. It is a very complicated task to define a generic set of indicators which would be relevant, credible and valid for all cities.

Except these two competitions, no other well known initiatives of “green city” have been initiated. As (Venkatesh, 2014) has stated, such competitions can be very subjective. Although the term “green city” is commonly used, it is fuzzy and unspecific. Often it is not strongly related to green color or vegetation. The term “green city” was developed by Green movement which believe in “four pillars” of ecology, grassroots democracy, social responsibility and non-violence (Capra and Spretnak, 1984; Roseland, 1997). Therefore today this term means more a sustainable, climate- and eco-friendly (Birch, 2015) city with clean air and water, high resilience to natural disasters, enhanced public transport and reduced traffic (Kahn, 2007) rather than a city with higher proportion of urban green and vegetation.

That is why this research is not another development study of a complex index addressing sustainability but rather a simple spatial comparison identifying which Baltic capital has the greatest share of greenery. But first it is important to identify what the case study areas and the measures for greenery are.

1. STUDY AREAS

Capitals of three Baltic States have similar and at the same time different geographical features. All three capitals are located in the same time zone, between 24th – 26th meridians (east), Tallinn being the northernmost, Riga – in the middle and Vilnius – the southernmost city. All three cities are quite flat and lie at low altitudes (200 meters and lower). Tallinn and Riga are adjacent to the Baltic Sea while Vilnius is far in the mainland. Vilnius has the river Neris and Riga has the Daugava. Climate of all three capitals is more or less similar – humid continental. Because Vilnius is far inland, it has a little bit colder and drier winters and hotter summers. According to UN demographic report in 2015 (United Nations, 2017), the city of Tallinn covered about 158 square kilometers and had more than 413 thousand population. Riga covered almost twice as much – 304 square kilometers and had less than double of Tallinn’s population – over 642 thousand, while Vilnius covered the largest area – 400 square kilometers, but had population of only 541 thousand people. However, it is important to note that the city area does not always present the functional city area.

Each country has its own way to define a city. The criteria include population size and density, urban functionality and historical value. For instance, in the UK the city status is defined by the Monarch since the 16th century and this procedure is still in force today. That is why such city as St Davids in Wales has less than 2,000 inhabitants (European Commission, 2011). Nowadays, city boundaries are not some kind of physical barrier as they used to be in medieval or ancient times, when cities or city-states in Greece were surrounded by huge concrete or stone walls. Today thanks to the developed road and public transport network many people daily commute back and forth to the city. Although these people officially work, but do not live in the city, they are a part of it. Therefore, talking about the cities, it might be a better solution to consider not only the city, but also its commuting zone also known as metropolitan area or functional urban area (FUA), previously known as larger urban zone (European Commission, 2017a). The definition of commuting zones (FUA or metropolitan areas) was developed jointly by the European Commission (EC) and Organization for Economic Cooperation and Development (OECD) in order to allow comparing different cities, especially on the cross-country basis across Europe (European Commission, 2017a). The definition does not account for city's function and history, but rather the population size and density. The EC and OECD identify commuting zone based on the following commuting patterns: 15 % of the employed persons live in one city and work in another, both cities are assigned to one commuting zone; municipalities with at least 15 % of population working in a city are assigned to the city's commuting zone and all municipalities surrounded by a single functional area are assigned to the commuting zone as well (European Commission, 2011). In other words, all surrounding and further municipalities with at least 15 % of population working in that city are assigned to the city's FUA or metropolitan area. The example of FUA area is illustrated in Figure 1. It shows the area of the city, the greater Dublin City and its FUA. It means that within the FUA more than 15 % people work in Dublin. Today in Europe 40 % of population lives in the city with a centre of 50,000 inhabitants, and other 20 % lives within the commuting zone. Together, the city and FUA areas account for 60 % of the whole EU population (European Commission, 2011). That is why today the functions of the cities go far beyond city boundaries and that is why for this research I decided to address FUA instead of city boundaries.

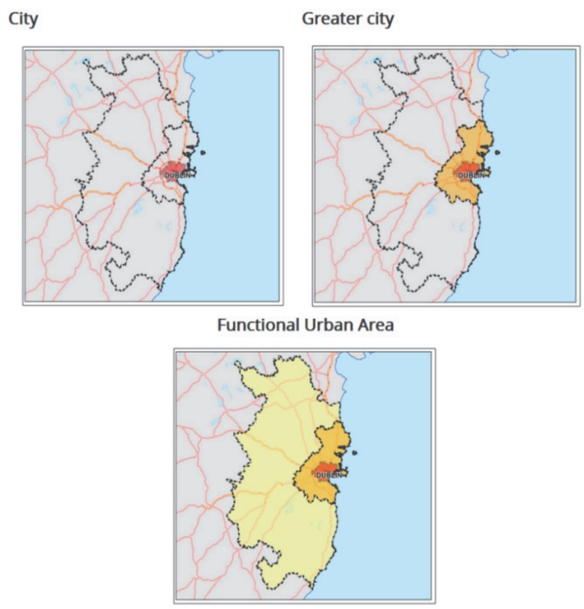

Fig. 1. Spatial levels of Dublin (European Commission, 2017a).

Based on the Eurostat database (European Commission, 2017b), the FUA regions of Tallinn, Riga and Vilnius cover 4,333, 247 and 9,424 square kilometers, respectively. It is surprising that Riga's metropolitan area is smaller than the area of Riga City, but that could be a simple data error. Alternatively, the metropolitan areas of the Baltic capitals can be calculated using GIS assessing Urban Atlas data, which covers FUA. According to Urban Atlas data, the FUA of Tallinn is 4,339 km^2, of Riga – 5,392 km^2 and of Vilnius – 4,245 km^2 (Figure 2).

Fig. 2. FUA zones of the Baltic States (down from the top: Tallinn, Riga, Vilnius) (data source: European Comission, 2017d).

Greenery criteria and used datasets are analyzed in the next subchapter.

2. GREENERY CRITERIA AND USED DATASETS

In order to perform quantitative spatial comparison, the criteria, which will be used to measure the greenery, should be explained. Greenery in this research means the areas with vegetation, water and pervious surfaces – areas like meadows, agricultural areas, forests, wetlands, waters, etc. in contrast to pervious are impervious surfaces, which cover most of the built areas, parking lots, streets, buildings' roofs, etc. Additionally, this research considers green urban areas, sport and leisure facilities, agricultural areas and water bodies as greenery, but does not address urban fabric, industrial, commercial and transport areas, mines, construction and dump sites and areas like beaches, dunes, sands, bare rocks, sparsely vegetated or burnt areas. Sport and leisure facilities might be covered by impervious surfaces, but most of them in the Baltic States have green fields and can be defined as greenery. Because planted plants are considered vegetation, agricultural areas can be considered greenery as well. Although artificial and natural water bodies usually do not have much vegetation, they are part of the eco-system and often are strongly related with greenery and are addressed in this research as well.

Previously described greenery can be identified in many ways. Because the case study within this research covers multiple cities with large areas, the most appropriate way would be to use satellite produced data. The number of satellite datasets is available on the market. These datasets cover large study areas, have good resolution and part of them is available in free access. Additionally, in order to achieve better quality of the comparison analysis, all data preferably should be supplied by the same data source. Plenty of European environmental data are supplied by the European Environmental Agency (EEA). It is an agency of the European Union. Its task is to provide independent information, which could be used to adapt, develop, implement and evaluate environmental policy (European Commission, 2017c). The EEA defines its data portal (eea.europa.eu) as one of the most comprehensive public environmental information services on the internet (European Commission, 2017c). The EEA data portal provides access to everyone in the form of maps, interactive maps, indicators, graphs and datasets in raster, vector and attribute data format. This research uses three EEA datasets: Urban Atlas, CORINE and degree of soil sealing.

Urban Atlas is one of the examples of the EEA environmental data. Urban Atlas is a part of GMES/Copernicus land monitoring services, which is coordinated by the EEA. Urban Atlas provides inter-comparable and high-resolution vector-based land use maps for 305 urban zones with more than 100,000 inhabitants. Urban Atlas contains 19 land use classes, five of them are associated with greenery. The aim of Urban Atlas is to provide information on the land use in the European cities. Urban Atlas allows comparing land use patterns among major European cities using high-resolution maps developed by satellites in a cost-efficient manner. Such comparison can be relevant for transport, environmental or land use related analysis. The Urban Atlas data were produced from 2.5-meter resolution earth observation – multispectral merged with panchromatic satellite data, topographic maps and degree of soil sealing data. Additionally, it used ancillary data like local city maps and navigation data provided by commercial orbital transportation services: points of interest, land use/cover, water sources. In certain cases, the local zoning map (i.e. cadastral maps), on-site visits and very high-resolution imagery were used. The EEA states that Urban Atlas has 100 times higher resolution than CORINE dataset. High resolution data with accurate street network allow performing detailed analysis such as, for example, proximity to green areas or transport infrastructure analysis (European Commission, 2017d). However, although Urban Atlas has higher resolution than CORINE, its data classes are far more aggregated and Urban Atlas does not always cover the entire FUA of the larger cities. Thus it can be stated that the data of Urban Atlas is more suitable for local city-based analysis with the focus on land use, while the regional land cover studies might prefer to use CORINE datasets. The Urban Atlas dataset was used in a similar research, addressing greenery, by Kabisch et al. (2016). Kabisch et al. (2016) evaluated Urban Atlas in order to identify greenery in multiple cities, but instead of three datasets, scientists used only Urban Atlas data. Additionally, the Urban Atlas data can be used in a number of applications, from mapping eco-system services (Larondelle et al., 2014), analyzing urban growth (Barranco et al., 2014) to planning urban green infrastructures (Madureira and Andresen, 2014) and monitoring changes in the urban landscape (Pazúr et al., 2017).

CORINE (Coordination of Information on the Environment) is another frequently used EEA dataset. The CORINE Land Cover (CLC) program was initiated in 1985 by the European Commission and since 1994 the EEA is responsible for CLC and its work program (EEA, 2017b). The CLC dataset is raster grid-based and consists of 44 classes of land cover (30 of them are associated with greenery) covering the whole of Europe by 100 × 100 meter resolution cells. Land cover classes vary from continuous urban fabric, construction and airport zones to green areas, coastal lagoons, annual and permanent crops, coniferous forests and many other (Kosztra and Arnold, 2014). The initial dataset of CLC was produced in 1990 with following updates in 2000, 2006 and 2012, which can be used for historical analysis. Although the classes of CLC from initial dataset produced in 1990 did not change as compared to the latest dataset in 2012, different methods, data, accuracy requirements and spatial coverage were used. For instance, the CLC 1990 used Landsat-5 MSS/TM data with geometric accuracy lower than 50 meters, whereas the CLC 2012 dataset was produced using advanced IRS P6 LISS III and Rapid Eye satellite data with geometric accuracy lower than 25 meters. CLC is mainly used for environmental analysis, but it also can be used for spatial planning, transport agriculture and other fields (EEA, 2017b), like population mapping (Gallego et al., 2011), watershed analysis (Teixeira et al., 2016), assessment of airport catchment areas (Suau-Sanchez et al., 2014) and even can help analyze Golden Eagle's breeding performance (Vittorio and López-López, 2014).

The last EEA dataset used in this research is the degree of soil sealing. The soil sealing is known as "loss of soil resources due to the covering of land for housing, roads or other construction work" (European Commission, 2017e). It defines a degree of imperviousness (or perviousness) and characterizes human impact on the environment. The higher degree of soil sealing shows higher density of man built-areas – impervious surfaces, while the lower degree of soil sealing presents areas with higher proportion of vegetated or water covered surfaces. For instance, about 6.5 % of the European territory more or less is sealed and 1.8% of soil in Europe is totally sealed (Maucha et al., 2010). The EEA degree of soil sealing dataset is a raster grid, which covers 38 countries (27 EU countries and their neighbors). The raster grid contains raster cells with the degree of soil sealing ranging from 0 % to 100 %, where 0 % is non-built areas and water bodies, while 1-100% are the sealing values for built-up areas. Food and Agriculture Organization (FAO, 2005) identified four ranges of the degree of soil sealing: scattered (15 %–30 %), low density (30 %–50 %), medium density (50 %–75 %) and high density (>75 %). The degree of soil sealing raster grid is available in two spatial resolutions: 20 × 20 meters and 100 × 100 meters. (FAO, 2005) The degree of soil sealing can be very helpful in monitoring land consumption (Behnisch et al., 2016; Salvati and Carlucci, 2016), analyzing urban-rural gradient (Salvati, 2014) or even mapping population (Steinnocher et al., 2010).

Three different datasets (Urban Atlas, CORINE and the degree of soil sealing) captured using similar technologies, but supported by different auxiliary information, will allow comparing greenery among the capitals of the Baltic States from different perspectives. As these datasets vary in formats, spatial and temporal coverage, qualitative attributes, it is important to explain the methodology in detail, in order to perform quantitative comparison.

3. METHODOLOGY

The methodology is based on the idea to compare spatial data (degree of soil sealing, CORINE and Urban Atlas) covering FUAs of three Baltic capitals. Although the FUAs of the Baltic States cover similar areas in terms of size, it is appropriate to ignore the size of the FUAs and compare not only the absolute, but also the relative greenery (or the share of greenery). Moreover, historical CORINE datasets allow identifying how the greenery have changed over the years to monitor whether the coverage of greenery reduced or expanded. Also identifying the trend in the past and assuming that the pattern of urban development will not change, the potential trends of greenery development in the future can be identified. However, in order to compare spatial data, plenty of other methodological tasks have to be completed.

Area match is one of the initial steps in order to compare different datasets. This operation is necessary because datasets often have different projections, resolutions and coverage, even when they are provided by same data source. For instance, CORINE and the degree of soil sealing datasets are raster grid datasets covering the whole of Europe, while the Urban Atlas is vector dataset covering only a limited number of FAU in Europe. That is why clarification of the case study area was required. Therefore, in order to compare these datasets, only the data within FUA of Tallinn, Riga and Vilnius has to be assessed. For that reason, the CORINE and degree of soil sealing raster datasets were masked out by vector Urban Atlas data, representing the FUAs. This operation was done using GIS tools. The reduced number of cells allows not only comparing the data between specific locations, but also reducing the size of datasets and required computational resources.

Temporal coverage is another important factor. For instance, if two datasets have to be compared, they should be captured at the same time. Even with the advanced remote sensing technology, it would be hard to achieve. The time difference of the data capture depends on the application and can vary considerably. Because data capture and validation campaign of these datasets usually takes more than one year and the land use does not change so fast, maximum difference of five years is acceptable. However, this issue does not apply for this research, because all datasets, except the historical CORINE datasets, were developed for the same year of 2006. Another application where the temporal coverage can be used is the comparison of the same dataset over the years. One of the aims is to compare how CORINE data changed from 1990 to 2000, 2006 and 2012. Such comparison allows observing how greenery have changed over the years.

Qualitative comparison is one of the most important steps of the present methodology. The first issue is that all three datasets have different meaning: the degree of soil sealing indicates the proportion of pervious and impervious surfaces, CORINE represents land cover and land use classes, while the Urban Atlas addresses land use classes with higher aggregation degree. For instance, in Urban Atlas, agricultural lands, semi-natural areas and wetlands are aggregated into one class, while in CORINE these qualities are distributed among 25 classes.

Moreover, the public areas such as cemeteries or squares with little vegetation are defined in Urban Atlas as one class containing properties of industrial, commercial, public, private and military areas. Therefore, the classes defining greenery in Urban Atlas might be different from the classes in CORINE datasets. Despite these differences, the following classes in Urban Atlas dataset were identified as containing greenery: forests, green urban areas, sport and leisure facilities, water bodies and composition of agricultural, semi-natural areas and wetlands. At the same time, in CORINE the classes containing greenery were green urban areas, sport and leisure facilities, water bodies, agricultural areas, wetlands and semi-natural areas. Instead of selecting all semi-natural areas, only scrub and herbaceous vegetation covered areas were selected. Open spaces with little or no vegetation, such as beaches, bare rocks, sparsely vegetated or burnt areas, were not considered. Such different selection of classes between two datasets due to different aggregation degree shows that there might be an issue in comparing these datasets because in order to compare the data, it should have the same or nearly the same meaning. However, it should be noted that the aim of this research is not to compare and make a judgment, but rather to compare and to explore how two different datasets correlate. Another issue is whether the greenery can really be defined using the above-mentioned classes. It can happen that the CORINE's and Urban Atlas class of discontinuous urban areas (which were not considered as greenery in this research) would contain more greenery than arable land with permanent crops, or airport land would have more meadows than pastures. This problem of land use and land cover discretization is not new, especially in the field of remote sensing (Anderson, 1976). But the selection of classes in this research was made assuming that urban fabric, but not vegetation, should dominate in the discontinuous urban fabric class. The degree of vegetation, or more precisely the perviousness or imperviousness of all classes can be identified based on the degree of soil sealing, but not according to CORINE or Urban Atlas classification.

Quantitative comparison of spatial data was made by calculating the areas covered by the data with specific qualities. In CORINE and Urban Atlas these qualities are different land use and land cover classes, while considering the degree of soil sealing it is the percentage of sealed surface. The spatial data within the raster CORINE dataset were calculated by summing cells of the previously mentioned classes. Areas associated with greenery of polygons in Urban Atlas vector layer were simply calculated using GIS tools. Because the degree of soil sealing does not characterized by any classes, but is rather a percentage expression, percentage calculation is a more appropriate way to represent the area covered by different degree of soil sealing. Such calculation shows how many cells (percentage) of different degree of soil sealing can be found within a specific area.

All these methods were implemented using various GIS techniques and approaches, which allows quickly and precisely collect, process, analyze and visualize spatial information. The methods mentioned above are not the only ones used in the quantitative spatial comparison. They were selected due to simplicity, robustness and clarity.

4. RESULTS

Within this research, four spatial analyses between FUA of three Baltic States were conducted: area calculation of Urban Atlas and CORINE datasets, degree of soil sealing coverage analysis and historical CORINE analysis for each FUA. This chapter illustrates the results with a number of figures and tables.

Table 1. Greenery in the FUAs of the Baltic States by Urban Atlas classes (2006 data) (data source: European Comission, 2017d)

	Tallinn		Riga		Vilnius	
	Area (sq.km)	%	Area (sq.km)	%	Area (sq.km)	%
Forests	2,436	56	2,915	54	1,829	43
Green urban areas	19	0	33	1	35	1
Sports and leisure facilities	8	0	28	1	6	0
Water bodies	51	1	205	4	115	3
Agricultural + semi-natural areas + wetlands	1,522	35	1,739	32	1,916	45
Total greenery	4,036	93	4,920	91	3,901	92

The first result is the calculation of the area with greenery based on Urban Atlas data. As mentioned in the chapter dedicated to methodology, the specific classes of datasets were selected to represent the greenery. Table 1 shows total and relative area covered by greenery in each FUA of the Baltic capitals by Urban Atlas classes. Riga has the largest area of forests, but relatively Tallinn's FUA has slightly higher coverage (more than a half of the whole area), while Vilnius is ranked in the 3rd place with 43 %. However, Vilnius is the leader regarding the green urban areas (urban parks) among all Baltic capitals. In general, all capitals have relatively small areas covered by urban green – under 35 square kilometers, which is about 0 %–1 % of the entire FUA area. Very similar situation is observed with the areas housing sports and leisure facilities. This class covers less than 2 % of the entire FUA in all capitals. Riga takes the lead with 28 square kilometers and Vilnius has only 6 square kilometers of land class associated with sports and leisure. Also only 1 % (51 square kilometer) of Tallinn's FUA is covered by water bodies, while Riga has 4 times more and Vilnius about 2.5 times more (the regional waters of Tallinn and Riga were excluded). Large area in Vilnius is covered by agricultural land, semi-natural areas and wetlands – almost 2,000 square kilometers, which is about 45 % of the entire FUA. Riga has less – 1,739 square kilometers, but proportionally 32 % of its FUA is covered by these classes. Tallinn has the smallest covered areas among the Baltic sisters, but by relative coverage scores the second place. All of these classes have higher or lower degree of vegetation. The sum of the area covered shows total greenery in the FUA. The relative and absolute numbers of the total greenery in the capitals of the Baltic States are quite different, but by absolute numbers the largest area of greenery is observed in Riga with less than 5,000 square kilometers. The second place is taken by Tallinn with 4,036 square kilometers and Vilnius is the last with 3,901 square kilometers. Considering the relative area covered by greenery Tallinn is the first with 93 %, Vilnius is the second (92 %) and Riga is in the last place (91 %).

Another output of the current research is similar spatial analysis of CORINE. Instead of calculating the vector data as it was done using Urban Atlas data, raster cells were analyzed. Comparing to Urban Atlas, CORINE contains the same qualitative information – same classes of land use and land cover, but with different aggregation level. For instance, Urban Atlas dataset unites beaches, bare rocks, sparsely vegetated or burnt areas within one class together with agricultural, semi-natural areas and wetlands, while CORINE has these classes separated. Therefore, Urban Atlas can overestimate the total greenery, while CORINE might provide more accurate estimation of certain classes. It is also important to note that because the vector data is spatially more precise than the raster of grid cells in terms of geographical features, the total area by raster and vector data differs – according to raster data, the FUA in Tallinn is by one, in Riga and Vilnius by two square kilometers larger. This issue can cause slight differences in the calculation of the relative area, but it does have a significant effect due to larger FUAs. Table 2 presents the total and relative areas covered by greenery in each FUA of the Baltic States by the aggregated CORINE classes. It can be clearly seen that absolute and relative areas for all Baltic States have increased in agricultural, semi-natural areas and wetlands, but decreased in forest class. This shows that classes in CORINE and Urban Atlas might have different qualitative properties, although the names of the classes are the same. This issue is not a problem, because in the end all considered classes are aggregated into a single greenery's coverage value. Concerning the forest coverage, Riga has the largest absolute area, but the largest relative area is observed in Tallinn. The least absolute and relative coverage by forests is recorded in Vilnius. Riga also has the largest coverage by green urban areas, while Vilnius is the second and Tallinn is the last. The largest area of sports and leisure facilities can be found in Riga. Tallinn has four times less and Vilnius – more than six times less. Riga is also leading by water bodies, second place taken by Vilnius and the smallest coverage of water bodies is recorded in Tallinn. Although CORINE does not include beaches, bare rocks, sparsely vegetated and burnt areas in contrast to Urban Atlas, the difference cannot be identified because of the mixed classification of forest, agricultural, semi-natural areas and wetlands in both datasets. Despite this issue, Tallinn has largest coverage by agricultural, semi-natural areas and wetlands. Relatively, Riga has slightly smaller coverage and Vilnius has the smallest coverage among all Baltic capitals. Considering total greenery, Riga with 93 % (5,013 square kilometers) of the entire FUA scores the last place, Tallinn with lower greenery coverage of 94 % (4,069 square kilometers) is in the middle and Vilnius got the first place with 95 % (4,031 square kilometer) of greenery.

Table 2. Greenery in the FUAs of the Baltic States by CORINE classes (2006 data) (beaches, bare rocks, sparsely vegetated and burnt areas excluded) (data source: EEA)

	Tallinn		Riga		Vilnius	
	Area (sq.km)	%	Area (sq.km)	%	Area (sq.km)	%
Forests	2,096	48	2,412	45	1,617	38
Green urban areas	15	0	42	1	23	1
Sports and leisure facilities	8	0	32	1	5	0
Water bodies	45	1	187	3	108	3
Agricultural + semi-natural areas + wetlands	1,905	44	2,339	43	2,277	54
Total greenery	4,069	94	5,013	93	4,031	95

The absolute area of greenery in both datasets maintains the same ranking: Riga has the most, Tallinn is in the middle and Vilnius has the smallest absolute area of greenery. Meanwhile, relative area of greenery is the largest in Tallinn according to Urban Atlas and, according to CORINE, it is the largest in Vilnius. Riga in both datasets has the smallest relative area of greenery. Despite this fact, the relative numbers in both datasets are very close to each other.

The next output is the historical CORINE dataset analysis. In order to make the results more understandable and clear, the historical changes in the total greenery instead of aggregated CORINE classes will be shown. The EEA contains historical CORINE raster datasets for 1990, 2000, 2006 and 2012. The comparison of historical data allows observing how certain land use and land cover classes have changed within the case study area. Figure 3 shows the relative changes of greenery (coupled CORINE classes with higher vegetation and water coverage) from 1990 to 2006 in the FUAs of three Baltic capitals. In all Baltic capitals, the proportion of greenery has decreased, especially in Riga, where the proportion decreased from 1990 to 2012 by 2.53 %, while in Vilnius the relative decrease was five times slower (only 0.53 %). Tallinn was in the middle and relative decrease was about 1.44 % in 22 years.

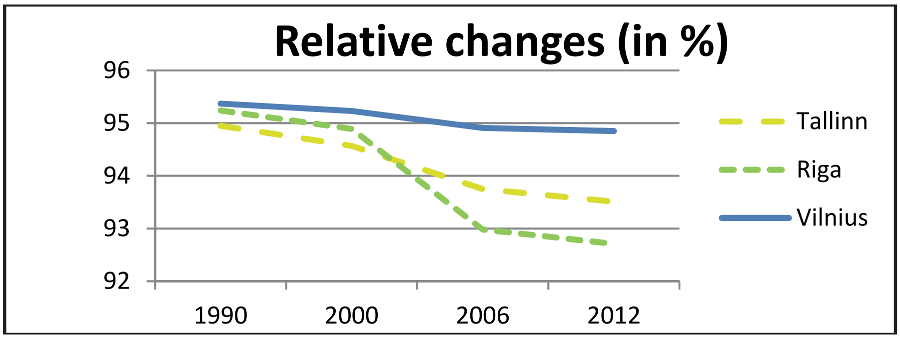

Fig. 3. Relative changes of greenery in the FUAs of Tallinn, Riga and Vilnius according to CORINE datasets (data source: EEA).

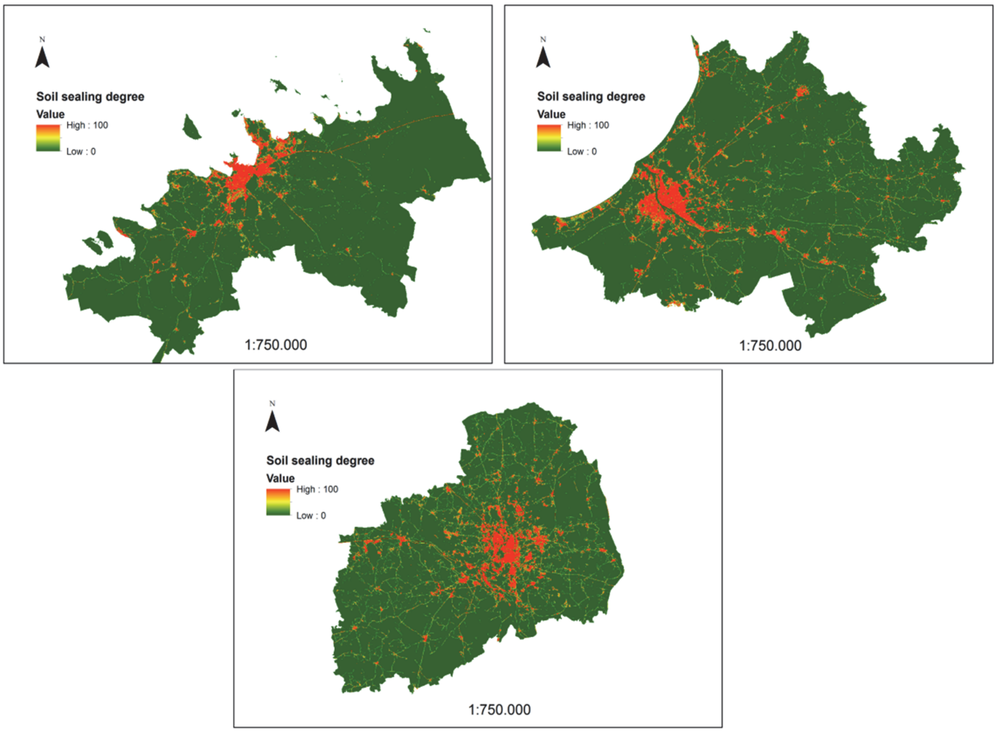

Fig. 4. Degree of soil sealing of Tallinn (top left), Riga (top right) and Vilnius (bottom) FUAs (data source: EEA).

The last result of this research is the comparison of the degree of soil sealing. In contrast to the matching qualitative classes of CORINE and Urban Atlas datasets, the analysis of degree of soil sealing calculates the total share of cells with specific degree of soil sealing – share of pervious and impervious surfaces. This allows accounting for other lower vegetation areas, which were not addressed through the other classes in CORINE and Urban Atlas datasets. Figure 4 shows the degree of soil sealing for three Baltic States. The high degree of soil sealing maps urban areas and webbed road network of FUAs. Low degree of soil sealing shows more vegetated and less urbanized areas. The following table (Table 3) shows the relative area with the sealed soil among the Baltic States' FUAs. I assigned the entire range of degrees of soil sealing from 0–100 to five classes with certain ranges and properties: 0–20 with very high greenery and very low urbanization, 20–40 with high greenery and low urbanization, 40–60 with average greenery and average urbanization, 60–80 with low greenery and high urbanization, and 80–100 with very low greenery and very high urbanization. In all Baltic capitals, the majority of the areas have very high greenery and very low urbanization (ranging degree of soil sealing from 0 to 20). However, Tallinn is the leader with 95.6 % of such areas within its FUA, Riga is the second with 93.8 % and Vilnius is the last with 92.1 %.

Table 3. Relative coverage of the degree of soil sealing values within FUAs (data source: European Comission 2017e)

SSD	Tallinn	Riga	Vilnius
0–20	95.6	93.8	92.1
20–40	1.8	2.7	3.5
40–60	1.1	1.6	2.0
60–80	0.7	1.0	1.3
80–100	0.9	1.1	1.3

The spatial comparison of greenery and soil sealing degree summarizes this research and leads toward following conclusions and discussion.

CONCLUSION

This research presented spatial comparison of greenery between FUAs of Tallinn, Riga and Vilnius. The comparison was done by analyzing the EEA datasets: vector-based Urban Atlas, raster grid-based CORINE and the degree of soil sealing. Comparison between Urban Atlas and CORINE datasets showed slight disagreement, especially between forest, agricultural, semi-natural and wetlands classes. Although CORINE did not address beaches, rocks, sparsely vegetated and burnt areas, the differences were obviously too high. This may be explained by different qualitative interpretation of remote sensing data and assignation to different land use and land cover classes. Another reason could be the differences in calculating the area in raster and vector datasets. These two issues might have caused disagreement in the input data and affected the ranking of the greenest Baltic capital. In general, all three Baltic capitals have very similar greenery coverage and the differences are very minor, 1–2 % of the relative area. According to both Urban Atlas and CORINE datasets, Riga had the largest greenery coverage, Tallinn was second and Vilnius was the last. But Riga was first only because it has the largest FUA. If the FUA of Riga were smaller, the total greenery coverage in Riga might be considerably smaller. Considering the relative greenery coverage, Tallinn was leading according to Urban Atlas, and based on CORINE data, Vilnius was in the lead. Additionally, CORINE datasets showed historical development of greenery in 1990–2012. Historical analysis showed a pattern of decreasing greenery in all Baltic capitals, however, in Vilnius the decrease was only 0.53 %, while in Riga it was 2.53 %. Because country capitals in general have higher potential for new urban development than the rest of the country, the decrease of greenery might be related to increased urbanization, but according to World Bank, the population living within urban areas have slightly decreased in all three Baltic States (The World Bank, 2016). From another point of view, the decrease in urban population but increase in urban land could be an effect of urban sprawl. If the decrease of greenery follows the same pattern, it is possible that based on Urban Atlas data Vilnius will outrun Tallinn in the future and. according to CORINE, Vilnius will lead even more. If Riga does not act fast by increasing the greenery, it might be very difficult to catch up other Baltic sisters in the future. Considering the degree of soil sealing data, which additionally takes into account urban fabric, commercial, industrial and other less vegetated areas, Tallinn is the leader with most of its FUA covered (95.5 %) by areas with 0 %–20 % of sealed soil (the majority of the area covered by pervious surfaces), while Vilnius has 92.1 % of its FUA covered. From land use and land cover class-based perspective, Tallinn and Vilnius share the title of the greenest capital but evaluating all data-driven approaches it can be stated that Tallinn is the winner and can be titled the greenest capital of the Baltic States. Notwithstanding, the differences in greenery and the degree of soil sealing are so minor, therefore it can be concluded that all three Baltic States are the winners as they have been throughout all these years of independence.

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