Change in Artificial Land Use over time across European Cities: A rescaled radial perspective

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Summary

This paper presents the first evidence, using radial analysis of 292 European cities that artificial land use within a rescaled distance of ~ 20km (using London as a reference) to the city centre is decreasing on average across Europe. This is contrasted with further expansion and increase in artificial land use in the suburbs and periphery areas. This finding has important implications relating to the sustainability of our cities as the evidence is pointing to increasing urban sprawl and lower urban centre living. A rescaling component is utilised in the analysis, along with radial profiles to enable comparisons between cities of different populations.

KEYWORDS: Spatial analysis, radial analysis, land use, scaling laws, urban sprawl

1. Introduction

This research focuses on the change in artificial land use in European cites across both time and space. Land use is not only compared between cities but the internal structure of cities is also examined at a detailed level of spatial disaggregation. The EU Copernicus Urban Atlas (Copernicus, 2016), which is available at a 5m resolution, is combined with the Eurostat GEOSTAT 1km population grid (Eurostat, 2012) to produce radial profiles of 292 cities for the years 2006 and 2012. Population density and land use can be examined across both time and space (between and within).

Soil sealing as a result of artificial land use has several associated negative impacts such as; loss of water retention, loss of biodiversity and unsustainable living patterns (Prokop et al., 2011). It is one of the main factors threatening the state of soil in Europe (Jones et al., 2012). Given the amount of GHG produced by cities, through transport in particular (OECD, 2010), sustainable development is required in order to minimise the negative impact of growing cities on the environment. The need for environmentally sustainable development is recognised in the UN's 'New Urban Agenda' (UN, 2017). Sustainable development requires analysis of the changing internal structures of cities. This research outlines a methodology and presents results provided by radial analysis to help inform policy debate.

Previous literature has examined socio-economic aspects of cities and their; scaling laws using population as a measure of city size (Bettencourt, 2013; Bettencourt et al., 2007). Cities are often analysed following the concept that distance to the central business district (CBD) is an important determinant of their internal structure (Alonso, 1964; Henderson, 1974; Thünen, 1826). The Alonso model is found to be compatible with such rescaling of population procedures (Delloye et al., 2018). The research presented here bridges the gap between these two strands of research, namely the scaling of cities to allow for comparisons between cities and analysis of the internal structure of cities as determined by distance to CBD.

2. Methodology

Using the rescaling methodology developed by Lemoy and Caruso, (2018) the change in artificial land

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use of 292 cities for the years 2006 and 2012 is calculated. This methodology and definition of an urban area enables comparisons between cities of varying size while also considering the internal structure of cities. **Figure 1** shows the spatial extent of the large urban zone (LUZ) for Newcastle combined with the Geostat population grid and 100m radial profiles.

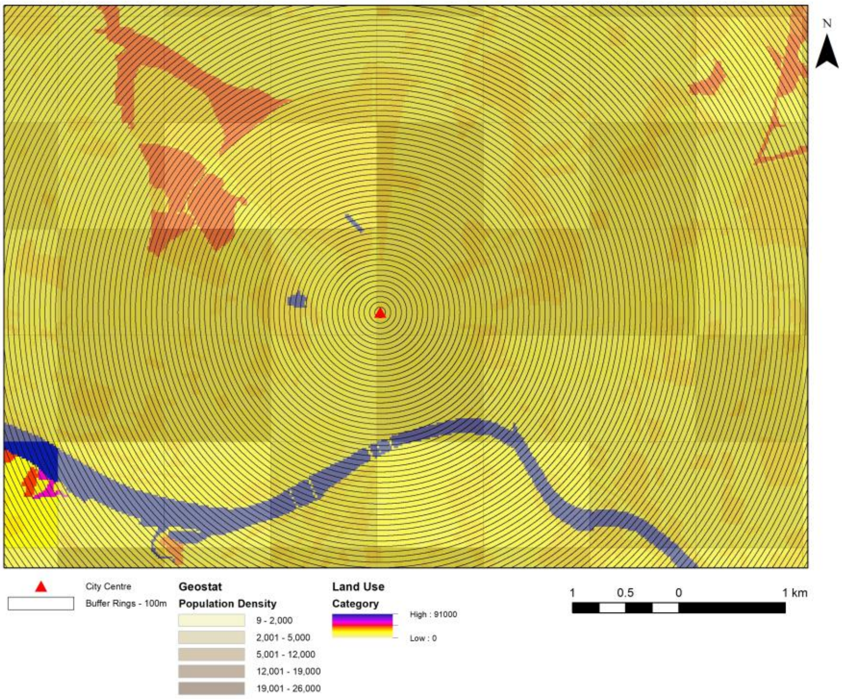

Figure 1 Land Use, Population Density and radial rings around Newcastle city centre

A radial analysis of land use for each of the 292 cities in the database is conducted using distance to the central business district (CBD) as a function of its population, **equation (1)**.

$$s(r') = s\left(\frac{r}{\sqrt{\frac{N}{N_{London}}}}\right) \tag{1}$$

Where s(r') is the artificial share of land at radius r, r' and r the rescaled and non-rescaled radius respectively, N the population of the considered city (N_{London} is taken as reference) and ½ is the exponent used, corresponding to the square root. This rescaling exponent is shown to be robust and close to optimal after conducting sensitivity analysis (Lemoy and Caruso, 2018).

$$r' = \frac{r}{\sqrt{\frac{N}{N_{London}}}} \tag{2}$$

3. Results

Results for the 2006 Urban Atlas data show that the artificial area around city centres scales linearly with city population. The land use profiles of cities are therefore homothetic, and the scaling with population is linear. This highlights the similarity of European cities when city size is controlled for (Lemoy and Caruso, 2018). Recalculating the rescaled artificial land use profiles using 2012 Urban

Atlas data yields a similar outcome to 2006 results reported in Lemoy and Caruso (2018). **Figure 2** shows the share of artificial land across all 292 cities without rescaling, while **Figure 3** shows the rescaled profiles of **equation 1**. Rescaling cities allows for comparisons between cities of varying degrees of population: controlling for population, makes the internal structure of cities the main focus.

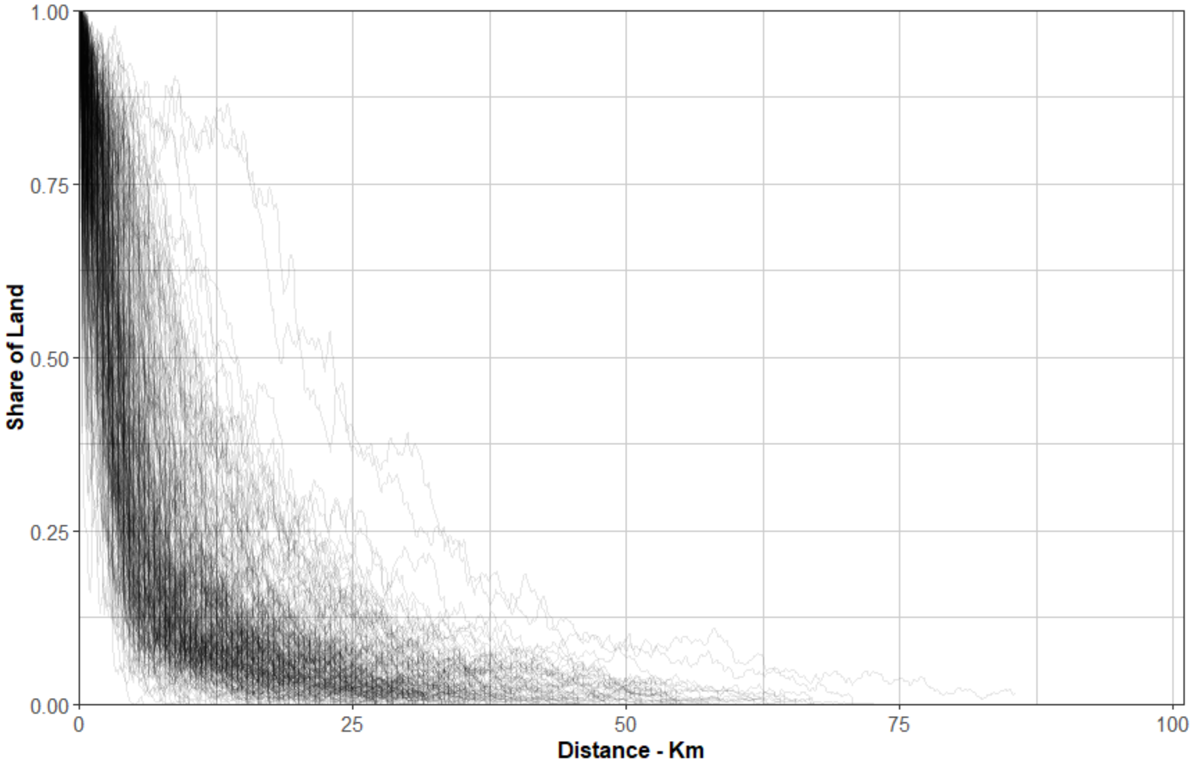

Figure 2 Share of Artificial Land use across 292 cities using Urban Atlas 2012 data. No scaling.

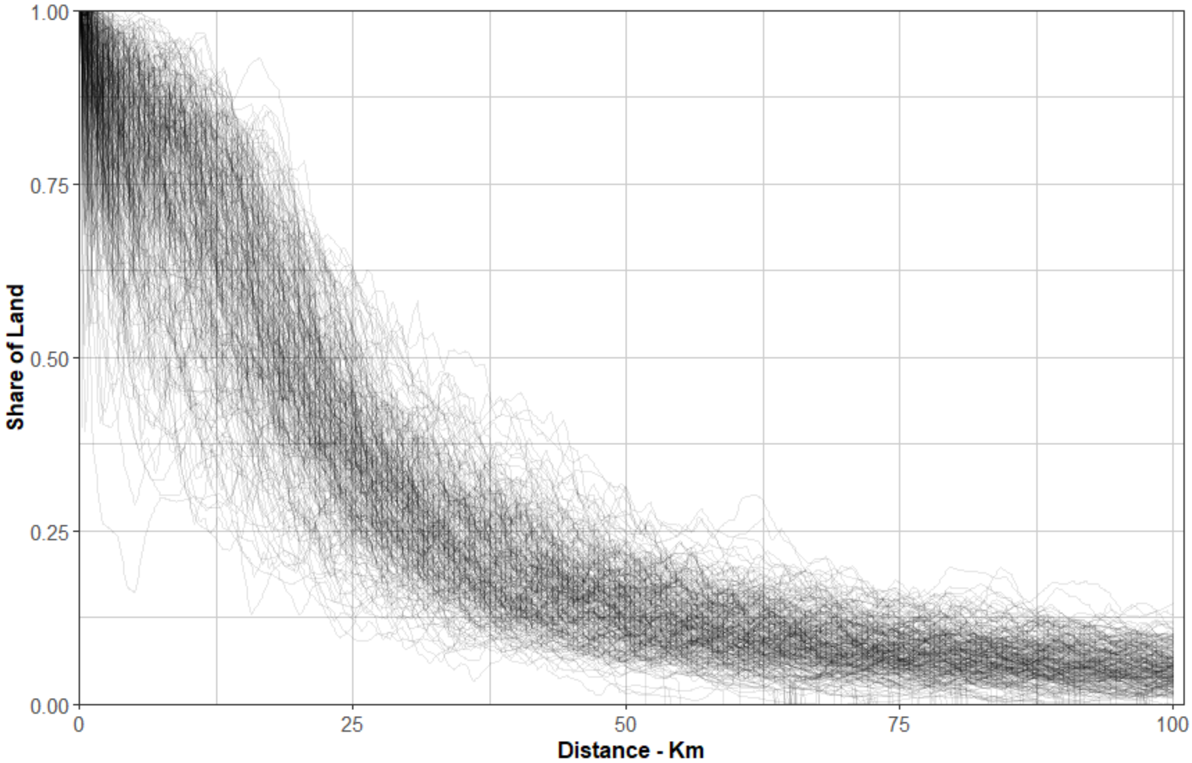

Figure 3 Rescaled to London, share of artificial land use across 292 cities using Urban Atlas 2012 data.

Table 1 shows the reduction in variation around the mean after rescaling. Rescaling is particularly useful when analysing distances closer to the CBD as this is where the greatest variation occurs. From **Figure 2** it is clear that there are large differences in levels of artificial land use across cities at distances of 5-10km from the CBD, with city population a large determinant of the rank.

Table 1 Mean and Standard deviation of non-rescaled and rescaled shares of artificial land use of cities by distance

	Non-rescaled		Rescaled	
Distance	Mean	StdDev	Mean	StdDev
Origin - CBD	1	0	1	0
1km	0.779	0.144	0.904	0.099
5km	0.351	0.214	0.791	0.140
10km	0.168	0.147	0.714	0.150
25km	0.038	0.056	0.362	0.105

Using the rescaled shares of artificial land use for Urban Atlas cities in 2006 and 2012, allows us to compute the change in artificial land use share across these 292 cities. **Figure 4** shows that overall there has been a decrease in artificial land use within a rescaled distance of 20km from the CBD. Stagnant or decreasing artificial land use share in the city centre and increasing artificial land use in the suburbs is observed. This is supported by the trend of soil sealing increasing at a greater rate than the population of Europe (Artmann, 2015). This is some of the first such empirical evidence of decreasing city centre artificial land use across Europe using radial analysis and scaling. This raises important challenges for policymakers and planners.

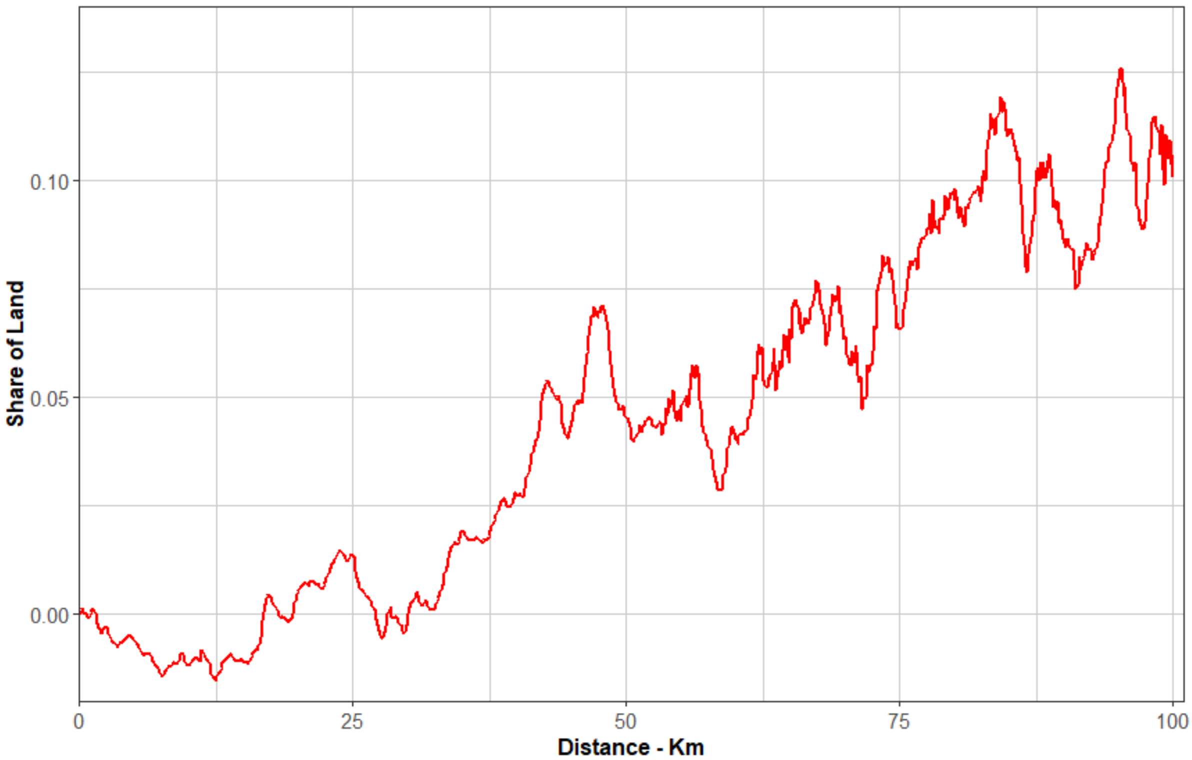

Figure 4 Change in Average Artificial Land Use 2006 to 2012 by Rescaled distance as a percentage of 2006 Artificial Land Use

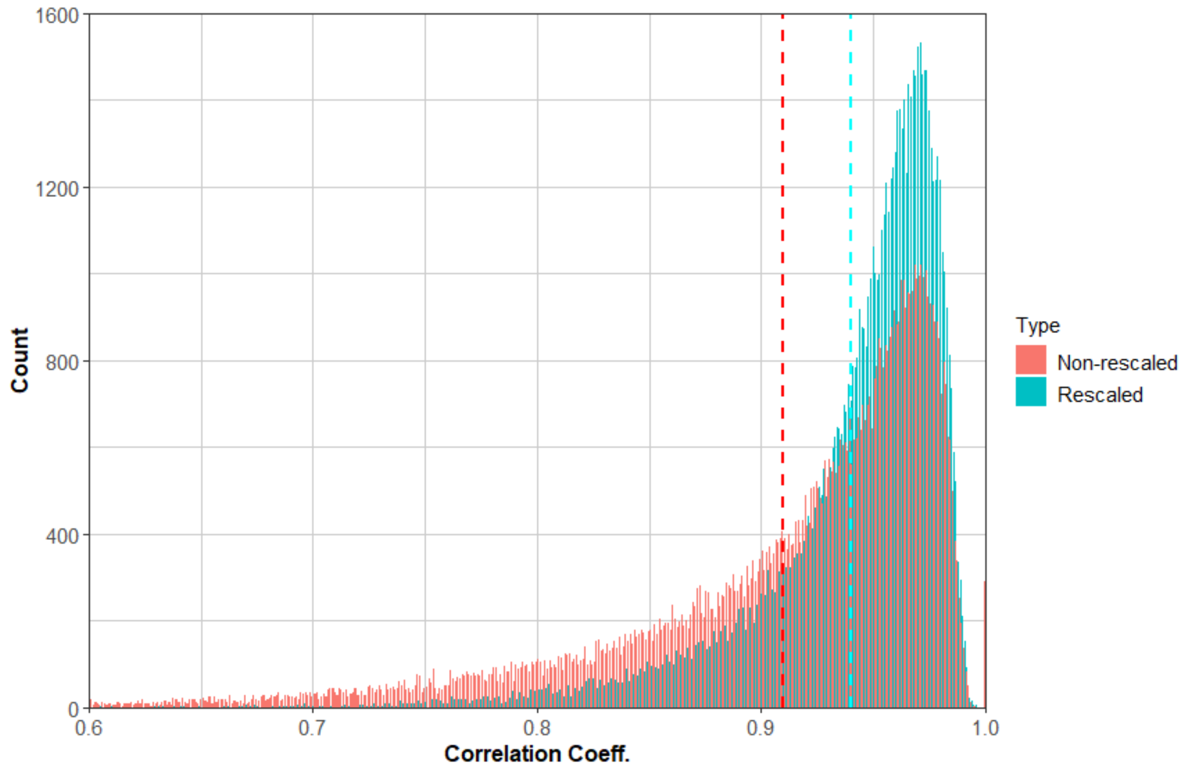

Figure 5 Pairwise correlation coefficients – 2012 cities – Rescaled and Non-rescaled

Figure 5 shows the pairwise correlation coefficients across the 292 artificial land use profiles using rescaled and non-rescaled data. The figure shows that the correlation coefficients of the rescaled profiles are more concentrated around the (higher) mean, compared to the non-rescaled cities. Before rescaling the mean correlation coefficient across all cities was 0.91, the new mean after rescaling is 0.94.

4. Acknowledgements

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Biographies

Geoffrey Caruso – Geoffrey is Professor for Urban Analysis and Modelling at the University of Luxembourg (UL) and at the Luxembourg Institute of Socio-Economic Research (LISER). His research is devoted to understanding spatial patterns and dynamics with specific foci on urban forms and residential choice, their impact on transport and the environment, the role of green space, and the integration of geosimulation and urban economics.

Rémi Lemoy – Rémi is an associate professor in the Department of Geography at the Université de Rouen (France). With a background in physics and a PhD in economics, he studies cities and systems of cities in the face of current environmental and social challenges.

Paul Kilgarriff – Paul is a Post-Doctoral Researcher at LISER working on the SCALE-IT-UP project. His previous research projects have examined the spatial impact of commuting and housing on income and the improvement of water quality using farm level models.