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# The similar size of slums

John Friesen[a], Hannes Taubenböck[b], Michael Wurm[b], Peter F. Pelz[a,*]

[a] Chair of Fluid Systems, TU Darmstadt, Otto-Berndt-Straße 2, 64287 Darmstadt, Germany
[b] Deutsches Zentrum für Luft- und Raumfahrt, Earth Observation Center, 82234 Wessling, Germany

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ABSTRACT

More than half of the world's population currently resides in urban areas. In the majority of developing countries slums are a defining part of the urban scape. Their supply with energy, basic infrastructure, among others is one of the main challenges of modern civilizations. To provide an optimal supply, the spatial patterns of slums in cities have to be explored. While most of current literature is focused on inter-urban dynamics, this paper is focused on intra-urban pattern (i.e. the spatial pattern of morphological slums within a city) and its link to the inter-urban ones. Therefore, census and remote sensing data are analyzed to create rank size distributions of morphological slums in different cities of developing countries. The observations were compared to rank size distributions of cities in a respective developing country. It is found that typical inter-urban pattern can be transferred to intra-urban pattern. Surprisingly is the fact that the size of slums is independent from city and global region in the analyzed cities. The slums in Mumbai, Manila, Rio de Janeiro and Cape Town have an average area of 0.016 $km^2$ with a standard deviation of only 0.004 $km^2$.

## 1. Introduction

In 2014, more than 54% of the world's population lived in cities. It is expected that this proportion will rise to a level of 66% by the year 2050 (United Nations, 2014). While the urban population increases per se, the number of very large agglomerations (megacities) with a significant proportion of slums is also increasing (United Nations, 2016). The rapid urbanization and growth of megacities can be observed especially in developing countries, which are mainly located in Africa, South America and Asia (Taubenböck et al., 2015a). The capital of Bangladesh (Dhaka) for example grows every hour by an estimated 50 people (Taubenböck et al., 2015a). This fact leads to a massive strain on the infrastructure of these cities and to underdeveloped water or energy supply systems (Jain, Knieling, & Taubenböck, 2015; Van der Bruggen, Borghgraef, & Vinckier, 2010). Furthermore, these megacities are characterized by a typical polar structure (Hoerning, 2016): a complex arrangement of slum areas form a complex pattern within the formal city where social gradients are present: poor people reside in close spatial vicinity next to rich ones (Marques & Saraiva, 2017). In most of the above mentioned cities, a big amount of these poor inhabitants live in areas outside of municipal planning efforts, called slums or informal settlements (Hofmann, Taubenböck, & Werthmann, 2015). These informal settlements are often characterized by the poor living conditions of their inhabitants, which are strongly related to the often poorly developed infrastructure, having a negative impact on different areas of life, such as health or education (Martnez, Mboup, Sliuzas, & Stein, 2008).

These slums are a significant part of urban regions and they form a highly complex pattern within the agglomeration. In cities such as Mumbai populations in slums feature 55% of the entire population and have become a defining part of the urban landscape (Taubenböck et al., 2015a). Political, social and economic mechanisms coupled with geographical constraints lead to different spatial patterns. Obviously, optimal supply systems for these topologies of slums depend on the observed urban pattern. To create holistic solution strategies to improve the bad living conditions of the urban poor (Martnez et al., 2008), it is important to understand these different urban patterns and their spatial distribution (Friesen, Rausch, & Pelz, 2017; Rausch, Friesen, Altherr, Meck, & Pelz, 2018; Hachmann, Jokar Arsanjani, & Vaz, ).

There are many approaches describing urban systems and their spatial configurations. A common used tool are rank size distributions. In this method, the different elements of a system are ordered by size and the emerged distribution is analyzed. While there are many studies of describing inter-urban patterns (cities in a region or a country), rank-size distributions were rarely used in an intra-urban context. In this paper we will focus on the rank size distributions of a specific urban structural type within the city - namely morphological slums. We understand morphological slums as a characteristic physical appearance of the built environment, i.e. organic, complex spatial layouts of very high building density featuring very small and predominantly low

* Corresponding author. Chair for Fluid Systems, Otto-Berndt-Straße 2, 64287 Darmstadt, Germany.
*E-mail address:* peter.pelz@fst.tu-darmstadt.de (P.F. Pelz).

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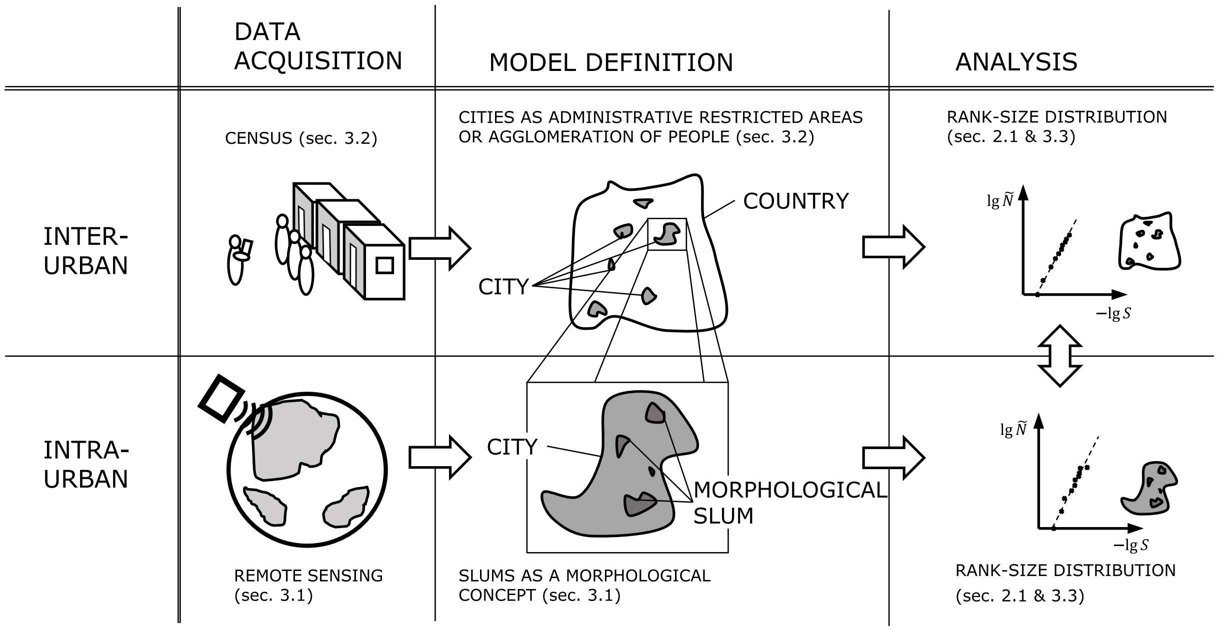


**Fig. 1.** Framework of this work.

buildings (Wurm and Taubenböck, 2018; Taubenböck, Kraff, & Wurm, 2018.). In addition, we also integrate for comparison census based slums (i.e. areas classified as slums based on household income) to allow for analyzing different measurement methods.

To do so, we analyze histograms, where the relative frequency of morphological slums sizes is plotted versus a size parameter. For identifying the morphological slums we deploy remote sensing data and classify slums as morphological objects using characteristic physical parameters of their settlement appearance. After presenting our conceptual background and a brief overview of the history of rank size distributions in the following section, we show the methods and data we used in section 3 before we present our results in section 4, discuss them in section 5 and finally conclude the paper with section 6.

## 2. Conceptual background

The aim of this paper is the analysis whether size distributions of morphological slums in different cities show similarities. To do so, we first present the method of rank size distributions in the following subsection (Fig. 1, right column). It was introduced in the last century and points out that most of the cities in different countries follow the so-called Zipf's law (Nitsch, 2005). In the main part of this paper, we investigate the intra-urban size distribution of morphological slums in four different cities (Fig. 1, lower row).

Beyond the analysis of size distributions of morphological slums, the analysis of census data allows in parallel an investigation on the influence of measurement methods as well as the question whether similarities between inter-urban and intra-urban size distributions exist.

### 2.1. Rank size distributions

Before applying the concept of rank size distributions to morphological slums, we present an overview of their use in the description of urban systems in general. Therefore, the following review is divided in two sections. The first section presents the use of distributions for analyzing and pointing out characteristics of cities within a region (e.g. country, state) while the second one presents the research of size distributions in intra-urban systems, i.e within a city.

#### 2.1.1. City distributions within a region

In 1913, Felix Auerbach looked at the relation between rank $\widetilde{N}$ of a city belonging to a specific country and its size $S$ measured in number of citizen: $\widetilde{N} = \widetilde{N}(S)$ (Auerbach, 1913). The rank represents the position of a city when ordering the cities by their size. He observed that the rank is proportional to the reciprocal size of the city. For the largest Brazilian cities this relation is plotted in Fig. 2 with census data from 2005 (de Geografia e Estatstica, 2017a).

This dependency was investigated in the following years for cities in different regions and countries (Jefferson, 1939; Singer, 1936). The most popular research was done by George Kingsley Zipf (Zipf, 1941; Zipf, 1949). The power law relation

$$\widetilde{N} \propto \left(\frac{1}{S}\right)^{\alpha} \tag{1}$$

sketched in Fig. 2 is known as Zipf's law. The empirical gained power coefficient is according to Zipf approximate one, $\alpha \approx 1$. This result was confirmed by different investigations in the following decades (e.g. (Nitsch, 2005; Rosen & Resnick, 1980; Soo, 2005, 2007)). In a distribution of this kind, also known as Pareto distribution, there is no typical rank and no typical size, i.e. there is no inherent scale. Such systems are therefore called scale-free.

Further empirical studies from Reed and Eeckhout have shown that Zipf's law only describes the largest elements of a distribution (Eeckhout, 2004; Reed, 2002). If one considers a larger number of cities, it can be observed that the rank of smaller cities can no longer be

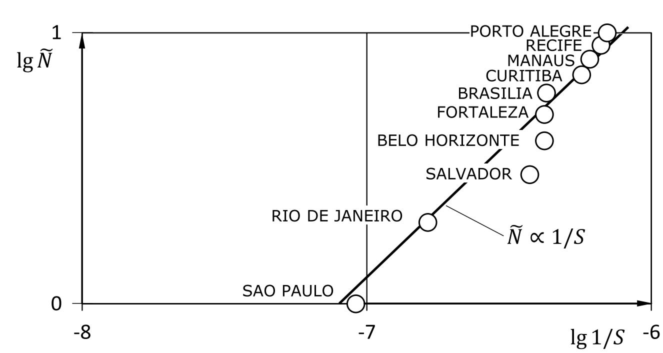


**Fig. 2.** Rank logarithm of $\widetilde{N}$ of a city vs. the logarithm of the reciprocal size $1/S$ measured in citizen for the ten largest Brazilian cities. The census data from 2005 (de Geografia e Estatstica, 2017a) confirm the known Zipf relation: the rank is proportional to the reciprocal size.