



A GIS-based framework to identify priority areas for urban environmental inequity mitigation and its application in Santiago de Chile

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ABSTRACT

Environmental inequity is a common phenomenon of modern cities, particularly in the developing world where the high rates of urbanization often surpass the capacity of local governments to develop proper urban planning. In these cities the spatial distribution of environmental quality is frequently associated with socioeconomic characteristics, with vulnerable sectors often having a disproportionately larger share of environmental problems. While reducing environmental inequity is widely recognized as an important step towards more sustainable cities, decision-makers usually lack the tools and information for designing effective and efficient intervention strategies. A challenging decision is to resolve on where, among all the areas having environmental problems, efforts should be allocated first. Here we present a GIS-based framework that can help decision-makers to prioritize the spatial allocation of policy interventions at different spatial scales or administrative levels. The framework focuses on (1) identifying areas having the highest levels of environmental problems, (2) identifying areas having the highest levels of social relevance, and (3) prioritizing the allocation of resources within the areas concurrently having the highest levels of environmental problems and social relevance. To show the potential use of the framework we apply it to the city of Santiago de Chile at three different scales. Our assessment focuses on three main environmental problems currently affecting this city: urban heat, lack of green infrastructure, and air pollution. Based on the results from Santiago, we discuss how the framework can be used to help policy-makers to identify priority areas for policy intervention at their respective administrative level.

1. Introduction

Global urban population exceeded rural population for the first time in human history in 2007. Since then, the proportion of people living in urban areas has continued growing and it is expected that by 2050 almost two thirds of global population will be urban (UNDESA, 2014). The large proportion of this urban population increase is taking place in the developing world, with millions of people migrating from rural to urban areas searching for better living conditions and development opportunities (Henderson, 2010). The urbanization process experienced by developing regions is happening very quickly, often faster than the capability of governments to develop and apply proper urban planning strategies (Cohen, 2006). While cities are hubs for innovation, economic growth and sociocultural development, they are also becoming places of severe environmental problems, growing economic and social inequalities, and political and social instabilities (Nassauer, Wu, & Xiang, 2014; Pickett et al., 2011; Wolch, Byrne, & Newell, 2014; Wu, 2014; Wu, He, Huang, & Yu, 2013).

Latin America has the highest urbanization level among developing regions, with almost 80% of its population currently living in urban areas (UNDESA, 2014). This region has undergone an explosive urbanization process since the middle of the past century. While in 1950 urban areas in Latin America were home to 70 million people, this number increased to nearly 400 million in 2000, and is expected to go over 600 million by 2030 (Cohen, 2006). The urbanization processes associated with this increase in urban population has been seldom coupled with appropriate urban planning policies, often resulting in spatially segregated cities with high levels of socioeconomic and environmental inequalities (Angotti, 1996; Carruthers, 2008; Fernández, Manuel-Navarrete, & Torres-Salinas, 2016). Whereas socioeconomic inequality has been widely covered in the literature and increasingly included in governmental political agendas (Roberts, 2012), environmental inequality is still a scarcely addressed topic in Latin America.

Environmental inequality refers to the “unequal social distribution of environmental risks and hazards and access to environmental goods and services” (Sustainable Development Research Network, 2007). A

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related but different concept is environmental inequity, which implies that the observed environmental inequality is judged as socially unfair (Kawachi, Subramanian, & Almeida-Filho, 2002). Thus, the concept of inequality emphasizes the spatial distribution of environmental resources and risks without a normative judgment, whereas the concept of inequity focuses on the social fairness of that environmental distribution (Pope, Wu, & Boone, 2016). In this work we focus on environmental inequity, as this plays a key role for bridging environmental inequalities with the broader concept of environmental justice. In this regard, environmental justice goes beyond the unfair spatial distribution of environmental resources (i.e. inequities), by covering other dimensions such as power relations, politics and social movements (Schlosberg, 2013).

Urban environmental inequity has negative impacts on the well-being of urban residents. This is not only because of the direct effects of environmental hazards on people's health (e.g. air pollution causing respiratory diseases), but also because the psychological impacts on disadvantaged people due to the unfair distribution of environmental quality (van Kamp, Van, Leidelmeijer, Marsman, & de Hollander, 2003). For example, people in environmental disadvantaged neighborhoods could be more prone to experience feelings of personal powerlessness and develop depression (Downey & Van Willigen, 2005). These negative effects on perceived well-being could be a common phenomenon operating in Latin American cities, because people in the upper socioeconomic sectors usually have disproportionately greater access to areas of better environmental quality, whereas people in lower socioeconomic sectors are relegated to areas of lower environmental quality (Escobedo et al., 2006; Fernández & Wu, 2016; Pedlowski, Silva, Adell, & Heynen, 2002; Romero et al., 2012; UN-Habitat, 2014; Wright Wendel, Zarger, & Mihelcic, 2012).

As the future of humanity lies in urban areas (UNDESA, 2014), reducing urban environmental inequity is a major objective to move towards more sustainable cities (UN-Habitat, 2014). This will require to prevent inequities by better understanding their underlying factors, but also to develop urban planning strategies to mitigate inequities once they have been generated. Whereas reducing intra-urban inequities in developing countries has been noted as of primary concern by the United Nations (UN-Habitat, 2012), methods and indicators that can inform decision-makers on where to prioritize their actions for mitigating environmental problems and inequities are still in their infancy (Benmarhnia, Laurian, & Deguen, 2013; Martínez, 2009; Norton et al., 2015; Ribeiro, de Fátima Pina, & Mitchell, 2015; Sadd, Pastor, Morello-Frosch, Scoggins, & Jesdale, 2011).

A challenging question that decision-makers may face when attempting to reduce urban environmental inequities, is where to allocate available resources first. This entails a spatial prioritization problem, highlighting that environmental inequity is inherently a spatial issue (Ringquist, 2005). Difficulties to solve this problem arise because (1) environmental problems are seldom evenly distributed within cities, (2) their spatial patterns may not be easily identifiable, and (3) the effects of these problems on people's quality of life may greatly differ based on the socioeconomic resources at their disposal (Jenerette, Harlan, Stefanov, & Martin, 2011). Furthermore, the severity and spatial patterns of environmental inequities are scale-dependent (Fernández & Wu, 2016), meaning that multiple scales need to be considered simultaneously for both research and mitigation policies. Therefore, a prioritization approach to identifying target areas for mitigating urban environmental inequities would require multiscale spatially explicit methods, first aiming to identify the areas with severe environmental problems, and then to prioritize these areas based on socioeconomic factors accounting for the unfair social distribution of these problems.

Although quantitative data on the spatial distribution of socioeconomic factors are often available at relatively fine spatial resolutions through census databases (e.g. census block data), environmental data are usually available at coarser resolutions (e.g. county, city, municipality or other administrative levels), limiting our ability to assess the

spatial relationship between socioeconomic and environmental variables at finer scales. This is a key limitation for addressing intra-urban environmental inequities, because cities are highly spatially heterogeneous systems, and therefore environmental, economic, and social issues often present high spatial variability within administrative boundaries (Cadenasso & Pickett, 2008; Pickett et al., 2011). An alternative to overcome the spatial resolution limitation of environmental data is to take advantage of the increasing availability of remote sensing data and spatial software. Remote sensing data could provide high-resolution environmental information that otherwise would be infeasible to collect at the intra-urban level (e.g. vegetation, temperature), whereas spatial software could transform point-based information into spatially continuous data (e.g. air pollution interpolation from monitoring stations), increasing our availability to assess the spatial variability of environmental issues in urban areas.

Integration of environmental and demographic information into a spatially explicit framework is a helpful approach to identify the areas concentrating environmental problems, and to prioritize efforts among the areas with higher social relevance (i.e. pertinence to society). Based on such an approach, we present a GIS-based indicator framework that integrates environmental and demographic data into an “Environmental Improvement Priority Index (EIPI)”, which can be used by policy-makers to identify priority areas for reducing environmental inequities at different spatial scales and administrative levels. This framework aims to help: (1) identifying intra-urban areas having the highest levels of environmental problems, (2) identifying intra-urban areas having the highest levels of social relevance, and (3) prioritizing the allocation of resources within the areas concurrently having the highest levels of environmental problems and social relevance. To show the potential use of this framework for identifying priority areas to be targeted with environmental inequity mitigation interventions, we apply the framework to the city of Santiago de Chile at three different scales, focusing our study on three main environmental inequity problems currently affecting this city: urban heat, low vegetation coverage, air pollution (Fernández & Wu, 2016). Based on the results from our case study, we further discuss how results from the EIPI framework can be used by policy-makers for addressing intra-urban environmental inequities.

2. The Environmental Improvement Priority Index (EIPI) framework

The EIPI framework (Fig. 1) is intended to be a relatively simple and flexible spatial prioritization tool that can be applied at different spatial scales and administrative levels. To use the framework in a particular urban area, relevant environmental inequity problems need to be first identified through scientific research, literature review, stakeholder workshops, political decisions, or combinations of the above. Thus, the goal of the EIPI is not to identify the particular environmental inequities to be targeted, as these need to be identified in a previous stage. The goal of EIPI is to provide a step-by-step procedural framework to help researchers and policy-makers identify priority areas or administrative units (e.g. districts, municipalities) to be targeted with environmental interventions to reduce environmental inequities. These areas are prioritized based on the assumption that from an environmental inequity perspective, policy interventions ought to be focused in areas or administrative units where more vulnerable people are facing severe environmental problems (e.g. Norton et al., 2015). Whereas the structure of the framework allows for simultaneously addressing multiple environmental inequity problems, it is preferable to assess a set of problems that can be tackled with similar environmental interventions, otherwise potential interventions to be implemented on priority areas can be difficult to identify.

Operationally, the EIPI index works through constructing and integrating two spatial indicators: (1) an environmental stress indicator (ESI) accounting for the spatial distribution and level of assessed

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