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Supporting local adaptation: The contribution of socio-environmental fragmentation to urban vulnerability

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ABSTRACT

Climate change and urbanization are two parallel ongoing processes that call for context-specific and overarching responses in order to tackle the complex challenges these processes involve. This article focuses specifically on the challenges associated with socio-environmental fragmentation and residential vulnerability. It is at the household, neighbourhood and municipal levels that often still lack the in-depth analysis necessary for context-specific responses. Therefore, the focus of this article is on the micro and local levels, offering an approach that theoretically combines the two concepts of fragmentation and vulnerability in order to evaluate the utility of this information regarding the development of practical, context-specific local adaptation options in response to two climate change related hazards: flooding and heat. Based on the theoretical framework a three-stage methodological approach is presented, in which each stage includes its own set of specific methodologies with particular scales and elements of analysis, utilizing both quantitative and qualitative methods. By presenting a theoretical and methodological approach that combines socio-environmental fragmentation and residential vulnerability, and discussing its application in the context of the Metropolitan Area of Santiago de Chile, benefits and constraints of the approach are also explored.

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Local adaptation needs based on socio-environmental fragmentation and vulnerability

Urbanization and climate change are among the great challenges of on-going global change, especially due to the complex and intricately interwoven processes implied by these phenomena. In continuously growing megacities (here defined as cities with five million inhabitants or more), processes of urban expansion result in increasing population, an extension of built-up land, and the corresponding effects on diminishing natural and agricultural land. This often causes new hazard-prone areas subject to phenomena such as flood and heat events, and increases the number of people exposed to these hazards. In this context, exposure is seen as one component of vulnerability, together with susceptibility and coping capacities (Kuhlicke, Kabisch, Krellenberg, & Steinführer, 2012; Watts & Bohle, 1993; Wisner, Blaikie, Cannon, & Davis, 2004). Climate change is considered as an additional pressure that adds to the "bundles" of stress cities are already facing, and it is expected that an increase in the frequency and intensity of extreme weather events is likely to aggravate hazards such as flooding and heat.

Simultaneously, megacities are also highly fragmented places (Bähr & Mertins, 1995; Coy, 2006; Gilbert, 1998). Most often, this fragmentation relates to processes of socio-spatial differentiation, the spatial structure of the urban area as well as governance issues. The underlying fragmentation approach of this article goes beyond these traditional considerations as ongoing urban expansion and vulnerability to hazards in the context of climate change opens up new perspectives with regards to socio-environmental conditions. This article poses the question of whether the socio-environmental fragmentation of urban areas is a precondition for an unequal distribution of the impacts with regards to climate change related hazards.

In order to analyse this nexus between urbanization, fragmentation, climate change, and related vulnerabilities, Latin American megacities present a compelling example. Their development is often driven by private capital interests, real estate companies, and/

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or the urban elite as a result of neo-liberal principles. Newly urbanized fragments, such as gated communities, shopping and entertainment centres, business parks and revitalized areas, interfere with traditional patterns of socio-spatial differentiation and deepen the overall fragmentation of the urban structure (Coy, 2006).

The research approach presented in this article seeks to fill in some of the gaps regarding the availability of local, context-specific information regarding climate change impacts. It is innovative as it takes both the concepts of fragmentation and vulnerability into account, combining them theoretically and methodologically in an urban setting. In doing so, the article discusses to what extent and in what ways the two concepts are capable of providing a useful framework in order to assist cities in developing local responses to climate change related hazards, with a focus on adaptation options. This approach integrates the dimension of fragmentation into the discussion and analysis of urban vulnerability in a way that is not yet reflected in the literature on either of these issues. It is argued that the resulting analysis allows for more context-specific conclusions on the role that fragmentation plays in the context of residents' vulnerabilities, and therefore provides an enhanced database for the formation of more adequate response measures. In addition, this approach adds further insight into the still nascent concept of urban vulnerability and recognizes that adaptation involves not only adapting to changing climate conditions, but also adapting to other changes such as urbanization (O'Brien, 2012).

In order to test the feasibility and applicability of the combined approach, this article tests its application to the Metropolitan Area of Santiago de Chile (MAS), a megacity located in Latin America. In previous research the city has been shown to be subject to both current and future impacts of heat and flood related hazards (Krellenberg, Müller, Schwarz, Höfer, & Welz, 2013; Müller & Höfer, 2014). This investigation was part of an international research project aimed at developing adaptation measures based on exposure and vulnerabilities to climate change at the urban-regional level (Metropolitan Region of Santiago de Chile) (Krellenberg, 2012; Krellenberg & Hansjürgens, 2014). Taking these prior results as a basis, new insights are achieved by conceptualizing and analysing urban vulnerability at the household, neighbourhood and municipal levels.

Thus, the approach presented in this article focuses on residents' vulnerability to two selected hazards, flooding and heat, in a socio-environmentally fragmented urban space. Flood hazard is defined as the likelihood of a potentially damaging flood event of a certain magnitude occurring within a certain period of time, whereas heat hazard is understood as surface temperature rising one or more standard deviations above the mean surface temperature in the urban built-up area. These hazards were selected because their impacts are already felt today, and because both the occurrence of these hazards as well as their related impacts are very likely to increase in the future due to ongoing urban expansion and climate change (Krellenberg & Hansjürgens, 2014; Krellenberg et al., 2013). Accordingly, the article aims to respond to the following three research questions:

1. How can theoretical considerations of socio-environmental fragmentation help to construct a better understanding of vulnerabilities to climate change related hazards?
2. What kinds of methodological issues need to be taken into account when considering socio-environmental fragmentation as a precondition for vulnerability?
3. In what way can the application of this novel approach combining socio-environmental fragmentation and vulnerability facilitate the generation of information for local climate change adaptation options?

In order to theoretically combine socio-environmental fragmentation and vulnerability, the two concepts are first presented separately, before discussing the linkages between them (Section Combining socio-environmental fragmentation and vulnerability theoretically). 'Section Climate change, socio-environmental fragmentation and vulnerability in Santiago de Chile' focuses on the applicability of the concepts to the Metropolitan Area of Santiago de Chile. The developed methodologically approach is presented and applied to the MAS in 'Section The socio-environmental fragmentation and vulnerability methodological approach'. 'Section Discussion of the applicability of the approach according to benefits and challenges' presents an initial evaluation of the approach, including both its benefits and limitations.

Combining socio-environmental fragmentation and vulnerability theoretically

The concept of fragmentation is often used to describe socio-spatial processes associated with urban development. In social science, the concept refers, for example, to the dynamics of the interdependence and division between social groups, or between their relations within a homogeneousness or heterogeneousness composition of an urban area (Janoschka, 2002; Low, 2006; Prévot-Schapira, 2001), as well as to cultural patterns and processes that affect urban areas (Hamnett, 2003; Wacquant, 2001; Watt, 2000). Environmental issues are more prevalent among approaches developed in landscape ecology and urban planning (Angel, Parent, & Civco, 2012; Schneider & Woodcock, 2008; Schwarz, 2010) that consider morphological (often also the spatial or structural) properties of patches of an urban area (Inostroza, Baur, & Csaplovics, 2013). Accordingly, the concept of fragmentation offers an interesting analytical framework for systematizing socio-spatial-structural processes and differentiates between a 'city of fragments' and a 'fragmented city' (e.g. Borsdorf, 2003). This is of particular interest in the case of Latin American cities, which are traditionally characterized by socio-spatial inequalities (Janoschka, 2002; Jordan, Rehner, & Samaniego, 2012). A fragmented city, like the MAS, is characterized by varying spatial-structural forms of isolation and segmentation which may nevertheless also open up new opportunities for adjacent areas.

Fragmentation refers to the various levels of connection between different parts of the city as well as certain isolated/connected fragments and is also related to different scales of analysis (Low, 2006). Hence, the concept of fragmentation is understood as a form of organizing socio-spatial elements or entities in an urban area that are internally homogenous, while also heterogeneous to one another, separated by borders that can be generated in any particular way (Link, 2010). This gives an overview of the structure of the urban area but does not allow for conclusions on whether high or low levels of socio-environmental fragmentation are positive or negative. In the literature, six complementary dimensions of urban fragmentation are distinguished: morphological (e.g. Salingaros, 2005; Tella, 2005), economic (e.g. Janoschka, 2002), socio-cultural (e.g. Link, 2008; Prévót-Schapira, 2001), political-administrative (e.g. Rodríguez & Winchester, 2001; Salinas, 2010; Sánchez, 2007), and environmental (e.g. Bizama et al., 2011). In the context of urban studies, the idea of fragmentation has often been put forward in at least one of these dimensions (c.f. Borsdorf, 2003; Link, 2008; Vidal, 1999). The consideration of a combined socio-environmental dimension as suggested in this article is thus innovative and opens up new research opportunities.

In other words, criteria such as the accessibility of basic services, physical housing conditions, population density, existing vegetation cover, or varying degrees of impermeability characterize and define a certain urban area, which can be understood as

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