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A socio-spatial analysis of vulnerability to climate change

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Summary

In urban areas, climate change effects are often associated with increasing risks of flood, heat waves, and sagging. Increasing climate risks exacerbate existing urban inequalities, poverty levels, and environmental degradation. Global urban policy is reacting to these urban issues by calling for making cities more inclusive, safe, resilient, and sustainable. In this paper, social impact assessment is used in combination with spatial analysis in a framework to support the operationalisation of urban polices. The framework is employed to investigate how climate change effects are distributed across the city and to identify which social groups are more vulnerable to climate risks.

KEYWORDS: climate change, social impact assessment, cities, vulnerability, spatial analysis.

1. Introduction

Urban regions around the world are being affected by climate change at a growing pace (Bulkeley, 2013). In addressing the growing challenges of rising sea levels, increasing flooding frequency, as well as more intense and longer heat waves (Hunt & Watkiss, 2011), cities have become sites not only of mitigation but also of adaptation strategies (Hunt & Watkiss, 2011). Decision makers have the constant challenge (Rosenzweig et al., 2010) and the legal mandate (Spier, 2020) to transition city-wide systems into sustainable forms of infrastructure, services, and resources. Moreover, the effects of climate change occur in a larger context of persistent poverty, growing inequalities, and environmental degradation. In fact, the adverse effects of climate change have intensified these urban issues (Rosenzweig et al., 2010). At the same time, global policy is calling for making cities more inclusive, safe, resilient, and sustainable (United Nations, 2015). However, local actors face multiple challenges to operationalise and contextualise these global policy calls (Díaz-Pont, 2021).

In this context, social impact assessment (SIA) provides a framework to support the development and implementation of local urban polices. SIA is a process of identifying and managing social impacts from a current or proposed (policy) intervention (Vanclay, 2002). Social impacts vary in both time and space and are often cumulative: They are the result of incremental changes to the (urban) environment caused by multiple (urban) interventions, as well as by human activities and natural processes. SIA literature has highlighted the need to focus on the most vulnerable groups to improve the management of socio-environmental risk (Climent-Gil et al., 2018). The vulnerability focus is important because climate change effects as well as urban processes, such as inequality and segregation, have a strong spatial component. Communities become vulnerable to climate change when climate risks intersect with (physical, economic, institutional, etc.) inability to cope with them. Therefore, acknowledging the importance and role of space in the causes and differentiation of climate change effects and identifying the communities' capability to cope with climate change can provide insights to manage climate risks across the city.

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In this research, we apply the framework of SIA to carry out a socio-spatial analysis of vulnerability to climate change in cities. Our case study is The Hague, The Netherlands. We investigate how climate change effects are distributed across the city and identify which social groups are more vulnerable to these effects. While SIA provides the theoretical grounding for the assessment of impacts caused by climate change effects on the livelihoods of people and communities, spatial data analysis enables the quantification and visualisation of the studied data. Many cities around the world maintain large databases containing information on several aspects of the urban environment, using such data our goal is to gain insights into people's livelihoods and how they are affected by climate change risks.

2. Methodology

Figure 1 shows an overview of the SIA framework applied to climate vulnerability. The first step in a social impact assessment is building the social profile of the impacted area - a comprehensive picture of the livelihoods of people and communities. The social profile considers basic demographic data, trends affecting the community, context analysis, stakeholder analysis, and a vulnerability analysis. In this paper, we use demographic data and climate trends affecting the community to perform a climate vulnerability analysis and identify climate risks for each social profile (Figure 1A). The step illustrated in Figure 1B is focus of ongoing work.

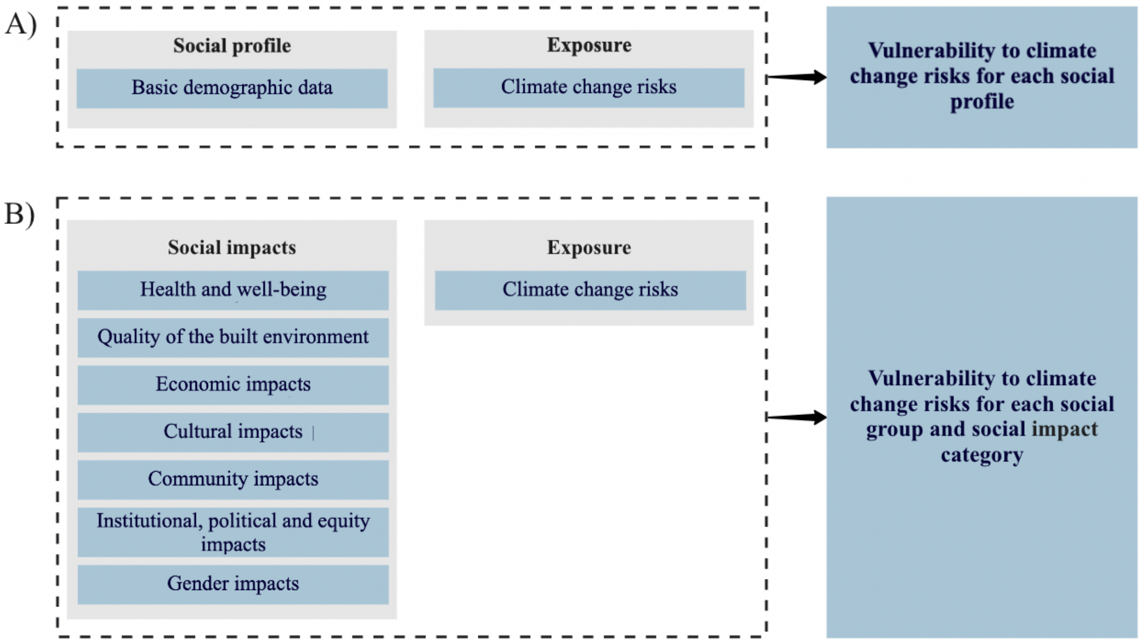

Figure 1 SIA framework applied to understand vulnerability to climate risks

The specific case study of this research is the Dutch city, The Hague. The municipality of The Hague maintains a large database with multiple indicators (denhaag.incijfers.nl). The Hague is the third largest city in the Netherlands with a population of 550,000 inhabitants in 2021 (Gemeente Den Haag, n.d.).

3. Preliminary results

3.1 Social profile

We choose five socio-economic indicators to describe the social profile of the city. These indicators are income, average age, migration background, percentage of men, and percentage of children. Figure 2A shows how these indicators are spatially clustered across the city, revealing that the city is segregated by both income and ethnicity (see Table 1 for the average values of the indicators). Social groups 1 and 3 present low income and are concentrated on the south and southwest while groups 0 and 2 have high income and are concentrated in the North and close to the coast. Social group 3 is characterised by a relatively high percentage of migrants (on average 75%), while the other groups have a relatively low percentage of migrants (average from 36% to 42%).

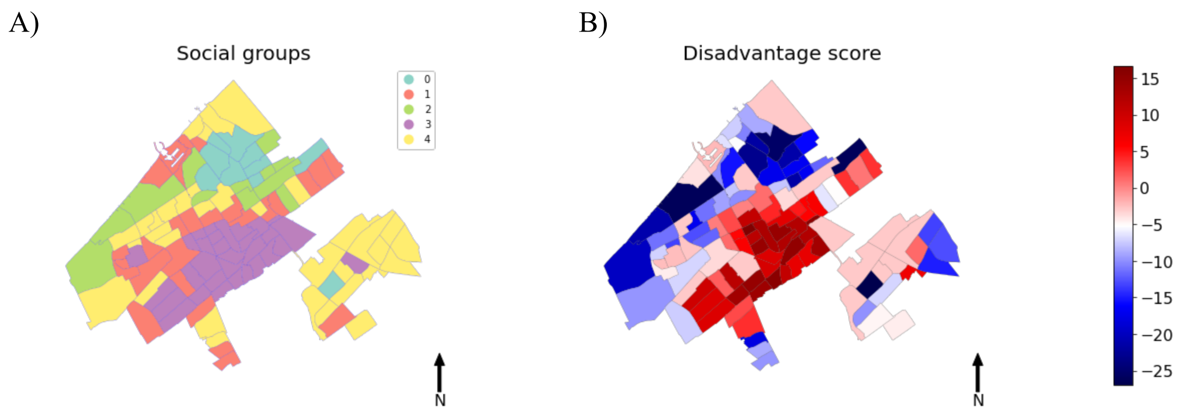

Figure 2 (A) Social groups based on income, average age, migration background, percentage of men, and percentage of children; (B) Disadvantage score

The municipality of The Hague also provides a *disadvantage score* based on the following factors: percentage of ethnic-cultural groups, income, real estate valuation of residential properties, percentage of relocations and percentage of the long-term unemployed in each area (Gemeente Den Haag, n.d.). A score of 0 is average, a negative score (-) means less disadvantage and a positive score means more disadvantage. Figure 2B shows that the disadvantaged score has a similar distribution and represents well the social groups identified in Figure 2A. Since the disadvantage score is an indicator used by the municipality of The Hague and it matches the social profile in Figure 1A, for the remained of this paper we will use the disadvantage score to represent the social groups.

Table 1 Characteristics of the five social groups obtained via spatial clustering

Social Group	0	1	2	3	4
Income [€/year]	73430.00	31425.93	55700.00	22829.03	39904.51
Average Age	44.70	41.52	43.75	35.74	39.82
% Migration Background	39.50	42.46	40.48	75.37	36.49
% Men	48.14	48.40	48.83	52.94	50.63
% Children	26.05	23.29	19.93	28.04	27.50

3.2. Exposure to climate change risks

This section analyses the exposure to climate risks with respect to the disadvantage score. We consider the following three climate risks (available for The Hague):

1. Heat risk: Percentage of the area within the area boundary that is very sensitive to heat stress on summer days.
2. Flood risk: Percentage of the area within the area boundary that will be more than 10 cm under water in one hour after extreme showers of 70 millimeters.
3. Sagging risk: Percentage of total area with 'extra sag' greater than 30 cm. Based on "stress scenario with two dry years" within the district.

Figure 3 shows that climate change risks are also distributed unevenly across the city. The risk of heat is higher in the central regions of the city (Figure 3A), while the risk of sagging is higher in the neighbourhoods closer to the coast (Figure 3C), which host relatively advantaged neighbourhoods (low disadvantage score in Figure 2B). Figure 3B shows that most neighbourhoods in The Hague are at some risk of flood, but the risk is higher in the central region.

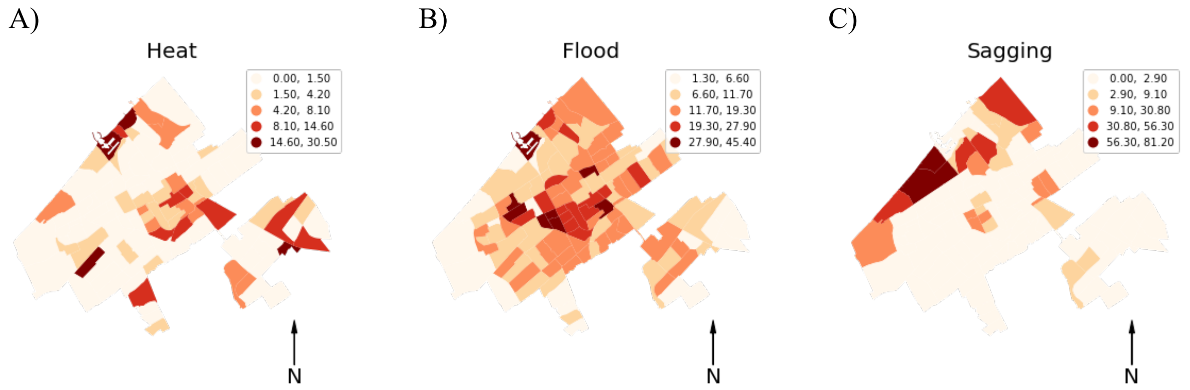

Figure 3 Climate risks: (A) Heat risk, (B) Flood risk, (C) Sagging risk (in quantiles, each risk is represented by the percentage of total area within the boundary area that is exposed to the corresponding risk).

Next, Figure 4 combines the distribution of climate risks with the distribution of the disadvantage score (from Figure 2B). Clustering is performed using K-means method. This figure reveals that groups that are relatively more disadvantaged are also groups that are under relatively high risk of flood (exposure groups 1, 2 and 3 in Table 2). In other areas, high risk intersects with low disadvantage scores: Exposure group 4 is under relatively high risk of flood but presents a low disadvantage score, and group 0 is under high risk of sagging but presents a low disadvantage score.

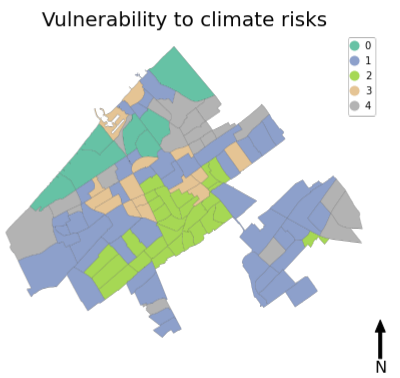

Figure 4 Vulnerability to climate change

Table 2 Climate vulnerability groups

Exposure group	**0**	**1**	**2**	**3**	**4**
Heat risk [%]	1.37	2.77	3.66	5.90	1.53
Flood risk [%]	8.87	10.54	15.67	31.30	9.93
Sagging risk [%]	51.83	1.04	3.08	2.67	3.73
Disadvantage Score	-13.55	-3.46	11.53	-2.21	-17.28

4. Preliminary conclusions

In this paper, we combine social impact assessment with spatial data analysis to investigate how climate change effects are distributed across space and which social groups are more vulnerable to climate risks. Our case study is The Hague, The Netherlands. Through the lens of SIA, we build a social profile of the city based on basic demographic data and data on climate trends affecting the communities. These data are used to perform a climate vulnerability analysis. We identify areas in the city that have high risks to climate effects. The results reveal that groups that are relatively more disadvantaged are also groups that are under relatively high risk of flood. In other areas, high risk intersects with low disadvantage scores, particularly the risk of sagging in the coastal areas. This information can help the municipality to allocate resources in space according to the vulnerability framework. Ongoing work focuses on (1) extending the social profile to include additional demographic data and provide a more comprehensive picture of the social groups, and (2) extending the framework to consider the seven social impact categories, such as gender relations and the quality of the built environment (as shown in Figure 1B).

5. Acknowledgements

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Biographies

Juliana Goncalves is a postdoc researcher at the Centre for Urban Science and Policy (CUSP) and the TPM AI Lab, within the Faculty of Technology, Management and Policy at TU Delft. Her research seeks to understand the socio-spatial dimension of the urban environment to support integrated decision-making in cities.

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Trivik Verma is an Assistant Professor at Delft University of Technology. His research focusses on tackling challenges of urbanisation in an equitable and just manner. Specifically, he is using methods in spatial data science, complex network analyses and participatory mapping to develop computational tools for advancing the theories and practices of urban science.