Urban Climate xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Urban Climate

journal homepage: www.elsevier.com/locate/uclim

Facing the heat: A systematic literature review exploring the transferability of solutions to cope with urban heat waves

Marie Josefine Hintz[a,f,*], Christopher Luederitz[b,c], Daniel J. Lang[a,c,d], Henrik von Wehrden[a,c,e]

[a] Institute of Ethics and Transdisciplinary Sustainability Research, Faculty Sustainability, Leuphana University Lüneburg, Scharnhorststr. 1, 21335 Lüneburg, Germany
[b] SPROUT Lab, Geography and Environmental Management, Faculty of Environment, University of Waterloo, 200 University Avenue West, Waterloo, ON N2L 3G1, Canada
[c] Center for Global Sustainability and Cultural Transformation at Arizona State University, Tempe, USA.
[d] FuturES Research Center, Leuphana University Lueneburg, Scharnhorststr. 1, 21335 Lueneburg, Germany
[e] Centre of Methods, Leuphana University Lüneburg, Scharnhorststr. 1, 21335 Lüneburg, Germany
[f] The Bartlett School of Planning, Faculty of Built Environment, University College London, Gower Street, London, United Kingdom

ARTICLE INFO

Keywords:
Urban heat waves
Transferability of solutions
Systematic literature review
Urban environments
Extreme heat events
Climate change

ABSTRACT

Urban heat waves are an increasing phenomenon around the world. Over the last decade the combination of climate change and the urban heat island effect have resulted in rising temperatures in cities. The related heat stress has severe impact on urban populations and infrastructure. However, it is unclear to what extent solutions to urban heat waves depend on context or if similarities can be identified that would support their adoption to different urban settings. The purpose of this study is to gain a better overview of solution characteristics and ultimately of their transferability. Based on a systematic qualitative and quantitative literature review we analysed solutions to urban heat waves with regard to geographical distribution, specific characteristics and pivotal actors. Results show that the sampled case studies concentrated on North America, Europe and Australia. The analysed solutions focus mostly on the use of green and blue infrastructure or grey infrastructure. Our review highlights city administration as pivotal actor for implementing solutions and emphasizes the importance of inhabitants as well as local governments as essential actors for adaptation to urban heat waves. We conclude by formulating recommendations to increase transferability of solutions to urban heat waves.

1. Introduction

Around the globe, the frequency and intensity of urban heat waves have increased over the last half-century impacting urban residents and the built environment. This increase is linked to trends of climate change including the warming of the atmosphere and the oceans, changes in the global water cycle, reductions in snow and ice as well as changes in local climates (IPCC, 2013). Especially, since 1950 heat waves have become more frequent in large parts of Europe, Asia and Australia (IPCC, 2013). In addition, heat waves are magnified by the urban heat island effect which increases temperature in cities as compared to their rural surroundings (NASA, 2009; IPCC, 2001). Extreme heat events have negative effects on air quality, infrastructure as well as energy supply and threaten the

* Corresponding author at: Institute of Ethics and Transdisciplinary Sustainability Research, Faculty Sustainability, Leuphana University Lüneburg, Scharnhorststr. 1, 21335 Lüneburg, Germany.
E-mail address: mariejosefinehintz@gmail.com (M.J. Hintz).

http://dx.doi.org/10.1016/j.uclim.2017.08.011
Received 15 January 2017; Received in revised form 15 May 2017; Accepted 22 August 2017

health of people, particularly of elderly, poor, disabled and very young citizens (Bicknell et al., 2009; IPCC, 2013). It is estimated that in 2050, two-thirds of the world's population will live in cities, increasing the number of people who will be affected by urban heat waves (United Nations, 2014).

For example, the European heat wave in 2003 had severe impacts on biophysical systems and human health as 35.000 excess deaths were reported (IPCC, 2007). Additionally, the risks of extreme heat events are widely underrated, for instance during the Chicago heat wave in 1995, 600 people died by insufficient recognition of the scale of heat stress (Dematte et al., 1998). This requires the provisioning of advanced heat emergency plans, that reflect especially the needs of vulnerable groups, urban green and better housing insulation (Gill et al., 2007; Lowe et al., 2011; Vandentorren et al., 2006).

Facing urban heat waves, spatial planning and urban governance play a particular role in adaptation to and mitigation of adverse effects (Bicknell et al., 2009). The term 'adaptation' can be defined as action to reduce the vulnerability of a system, such as a city in total, or specific population groups to the adverse impacts of experienced or anticipated heat waves (Bicknell et al., 2009). With regards to mitigation – i.e. the reduction of the prevalence and extend of urban heat waves - society has to "reduce global warming pollution to minimize future extreme heat waves" (National Wildlife Federation, 2009, p.13). In particular, spatial planning and urban governance are crucial in making progress towards adequate social and physical infrastructure (Garschagen et al., 2014; IPCC, 2012). Due to the complexity of cities, integrated approaches to adaptation and mitigation considering people, infrastructure, institutions and environmental processes are urgently needed (Ruth and Coelho, 2011).

A key challenge in addressing heat waves globally and coordinating solutions effectively, is the lack of a common understanding and shared definition of heat waves and solutions to cope with them. There is no commonly agreed definition of heat waves since countries define heat thresholds individually according to different climate conditions. For instance, the United Kingdom defines an urban heat wave as five consecutive days with the daily maximum temperature exceeding over 5 °C of the average maximum temperature (Met, 2015). Germany refers to the same timeframe, of at least 5 consecutive days, but with daily temperatures of 30 °C or above (Tinz et al., 2004). Following Robinson (2001) and the IPCC (2013) we define a heat wave generally as a period of abnormally and uncomfortably hot weather that has adverse effects on the lifestyle and health of populations.

Research on heat waves has gained increasing attention over the last decade, with studies focusing on adaptation such as dealing with heat related mortality or on mitigation - for example the implementation of cooling islands. Yet, many reviews look at specific aspects or areas only: for instance Stone et al. (2010) analyse the correlation of urban form and extreme heat events, but focus only on cities in the United States of America (USA). Bowler et al. (2010) reviewed the potential of urban green and as such one type of adaptive solution to urban heat waves. Other reviews highlight the risks and danger of heat waves, such as heat mortality (Kalkstein and Smoyer, 1993; Poumadère et al., 2005). Moreover, many papers compare cities or key stakeholders to each other (e.g. Castán Broto and Bulkeley, 2013). Thus, it is not clear whether solutions to urban heat waves that have been successfully applied in one urban area could be transferred and adapted in other areas. More specifically, the geographical distribution, the scale of implementation as well as the key characteristics of implemented solutions have up to now been insufficiently addressed. Furthermore it remains unknown which actors play a pivotal role in reducing the risk of urban heat waves.

The purpose of this study is to support the identification of transferable solution options. Transferability refers to the potential of a solution to be applicable to different contexts (Bos and Brown, 2012). Based on a systematic qualitative and quantitative literature review, we analysed case studies on solution options to urban heat waves examining similarities and differences with emphasis on their transferability.

In the following section, the methods used are further described (Section 2). Next the key findings are presented (Section 3) and discussed with regard to general implications (Section 4). Finally, we give some recommendations for further research, supporting the implementation of effective solution approaches to urban heat waves (Section 5).

2. Methods

2.1. Paper selection

The paper is based on a qualitative and quantitative content analysis (Mayring, 2000) reviewing existing literature. The Scopus database, was used to identify potentially relevant literature by applying a previously developed search string (Appendix 1) that resulted in 991 hits. The review procedure followed broadly the case study meta-analysis developed by Newig and Fritsch (2009) and further advanced by Luederitz et al. (2016). For each of the 991 papers the title, abstract and keywords were screened with regards to four predefined criteria to identify relevant case studies. First, the paper had to relate to the *overall topic* of urban heat waves. Second, the paper had to present research that investigated one or more *urban areas* as case study. In this context, a 'urban area' is defined as a space with urban functionalities and a high density of population compared to its surroundings. Thus, urban areas are cities, towns, urban agglomerations or metropolises, but not villages or small settlements (Pacione, 2005). Finally, the papers should give either concrete suggestions, discuss *management approaches* or refer to specific *solutions* with the aim of heat wave adaptation and mitigation. Applying the above criteria, 56 papers were identified as relevant of which two papers were not accessible as full-text. The remaining 54 papers were reviewed as full-text. Additionally, as this study aims to focus on applied solutions, approaches focusing solely on methodological advancement were excluded from the further analysis. Through this process 41 papers were considered relevant and further analysed (Appendix 2). The detailed review protocol is described in Table 1.