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Urban Adaptation to Climate Change

The Role of Urban Form in Mediating Rising Temperatures

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Vivek Shandas
Toulan School of Urban Studies and Planning
Portland State University
Portland, OR, USA

Cynthia Skelhorn
Qatar University
Doha, Qatar

Salim Ferwati
Qatar University
Doha, Qatar

ISSN 2191-5547 ISSN 2191-5555 (electronic)
SpringerBriefs in Environmental Science
ISBN 978-3-030-26585-4 ISBN 978-3-030-26586-1 (eBook)
https://doi.org/10.1007/978-3-030-26586-1

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Acknowledgement

The authors are grateful for several organizations and individuals who helped provide feedback, guidance, support, and encouragement for the completion of this book. We acknowledge NPRP grant # NPRP 5-074-5-015 from the Qatar National Research Fund (a member of Qatar Foundation), which helped to provide financial support for hiring the students, post-docs, and other staff, who conducted much of the research herein. Portland State University – specifically the Institute for Sustainable Solutions and the Toulan School of Urban Studies and Planning – was also instrumental in providing financial, logistical, and additional research support for the studies presented in this book. The authors would like to acknowledge Paul Pawlowski, David Sailor, and Greg Acker, all of whom provided insights and guidance for working across continents, disciplines, and the research and practice divide. We also drew deep inspiration from the many students and staff at our respective universities and workplaces who reminded us that future generations will inherit today's infrastructure decisions, and without considering the amplification of heat (and the myriad other climate-induced hazards), we will face fewer options for adapting to a dysfunctional climate system.

Introduction: Why Urban Adaptation and Why Now?

Vivek Shandas

Upon the writing of this book, organizations, country representatives, scientists, and policymakers are meeting to revisit the "Paris Agreement", a voluntary agreement signed by 184 parties that agree to keep the increase in global average temperatures to well below 2 degrees Celsius above preindustrial levels, and to limit the increase to 1.5 degrees Celsius. Like its predecessor, the Kyoto Protocol, which sets commitment targets that have legal force, the Paris Agreement emphasizes consensus building, allowing countries to voluntarily determine targets. The politically driven agendas of many countries, such as the United States, China, Qatar, and Brazil, have made such international agendas idiosyncratic and subject to changes in political power. As a result, greenhouse gases are on a trajectory to surpass the 2 degree Celsius by the end of the century, if not sooner, and scientific papers[1] suggest that society has less than a 5% chance to achieve the targets set forth in the Paris Agreement. By all measures, the ongoing negotiations, whether maintaining momentum for the current Paris Accord or future events, seem all but impossible.

This book aims to understand the intersection of two central concepts that emerge to define the future of cities: *adaptation and livability*. While we examine the concept of livability in the next chapter, here, we argue that the well-documented changes in our climate system, and the breakdown of global agreement on capping emissions, will require monumental preparation for the unprecedented changes already occurring to the systems that define the modern society. While literature on the grave impacts of climate change is mounting, few studies offer empirical evidence about the role that our built environmental plays in amplifying planetary warming. By conducting empirical assessment of one of the cities on the brink of extreme temperature inhabitability—Doha, Qatar—we examine the relationship between adaptation and livability by addressing several questions that help to define the emerging field of urban climate adaptation studies. Some of these questions include, how do increasing temperatures interact with land use change to amplify experiences of urban heat? To what extent can interventions

[1]Raftery, AE, A Zimmer, DMW Frierson, R Startz, and P Liu 2017. Less than 2 °C Warming by 2100 Unlikely, Nature Climate Change Vol. 7: 637–641.

to the current urban form help to temper extreme heat in neighborhoods? How might future changes in land use mediate opportunities for adaptations? Each chapter provides a glimpse into these questions, and we begin by providing a broader frame of the potential challenges facing cities in the face of a warming planet.

Towards Adaptation

Researchers around the world are beginning to grapple with changes in weather, ecosystems, agriculture, disease patterns, and physical infrastructure that are predicted under a scenario of 2 °C warming by 2100. Relying on paleoclimate records, the science boils down to ten climate-relevant impacts, and a few social ones. The most notable for the purposes of this book is the implication that of a 2 °C warming will result in increases in frequency of extreme weather events, such as hurricanes, flooding, heatwaves, drought, large and rapidly spreading wildfires, rising sea levels, and changes to environmental conditions and ecosystems, which are leading to changing conditions for plant and animal life. Additional implications include the destabilizing of social and economic systems, crop failures, and the expansion of diseases for which many communities have little experience. These implications will occur with widely varying frequency, though current climate models suggest increasing intensity and duration of extreme weather events. At the local scale, communities that are mal-adapted to withstand the change in conditions will likely experience the greatest impact, while those that are not preparing at all will face grave consequences from which they may never recover.

We argue that the effects of these extreme climate events are especially acute in urban areas, where society, ecosystems, and technology come together as interconnected systems. Failures to major infrastructure systems such as transportation (e.g., airplanes, roads, railroads), energy (e.g., transmission lines, power generation, overload demand), water (e.g., pipe integrity, supply shortages, distribution capacity), and others can generate a cascading series of impacts that ultimately befall the most vulnerable communities and ecosystems (Kim et al. 2016). In particular, extreme climate-induced events reduce the capacity to accommodate acute and additional pressures for which many urban systems were not designed. Impacts on community health and well-being alone, for example, during a heatwave take the lives of more people than all other natural disasters combined (Klienenberg 2004). Moreover, communities that have less access to and control of resources (e.g., financial, land, infrastructure, social) are more susceptible to extreme events than others urban dwellers, in part, due to historical environmental injustices that hamstring preventative actions.

One sobering interpretation of unabated increases in temperatures, which the UN estimates upwards of four degrees Celsius by the end of this century, will cause damage to urban infrastructure valued at over $600 trillion[2]—a value that is double the total global wealth today. In fact, as soon as 2050, people in places like Doha and Delhi will face a lethal risk of setting foot outside in the summer. These temperature conditions may create cascading effects in the form of climate refugees—those who are moving out of uninhabitability places. The UN's conservative estimate for the number of climate refugees that could be produced by 2050 is upwards of 100 million people. These are implications that we are beginning to see already in many parts of the world, though we will also encounter other cascading effects currently unknown.

Urban climate adaption may be a direct means for improving the livability of regions undergoing major climate stress. Yet to understand the what systems may be most at risk and to what climate stressor, we will first need to understand, empirically, the relationship between the current form of our cities and the extent to which we can modify and temper potential impacts. One way to advance an adaptation agenda is to provide evidence about the current distribution of climate-induced events, explore options for mitigating impacts, and project future scenarios for meeting livability goals.

To that end, and to illustrate a systematic approach to addressing climate-induced hazards, this book seeks to identify the distribution of one climate stressor—urban heat—and examine the opportunities for adapting the built environment for increasing temperatures. Urban heat emerges as a result of trapping solar radiation, and amplifying it through the built environment. While an ever-expanding literature points to the known and novel effects of the urban heat, including the acceleration of several natural processes (e.g., evaporation, net primary productivity, species migration, etc.), our intention is to assess the characteristics of the features we can directly control through land-use policy and programs. We posit that by assessing the capcity of the built environment to amiliorate high temperatures, we can reduce exposure to extreme urban heat, thereby reducing fatalities and improving livability.

We focus on urban heat because it is a "silent killer". Outdoor daytime air temperatures in many cities test the human body's ability to tolerate being outdoors throughout much of the year. The rapid rise in urban populations, combined with increasing frequency of extreme heat events, increases the likelihood of communities suffering from respiratory illnesses, heatstroke, and cardiac failure (Luber and McGeehin 2008; Reid *et al.* 2009). Heat stress is, in fact, one of the leading weather-related causes of death in many parts of the globe (Knowlton *et al.* 2007; Balbus and Malina 2009). Therefore, finding ways to reduce the intensity of urban heat stress poses an important challenge to public health, tourism, and the livability of cities in general.

Our focus is on using the land-use planning system to understand and ameliorate potential exposure to extreme heat. Characteristics of the built environment generate a phenomenon generally known as the urban heat island (UHI) (Oke 1995;

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[2] *United Nations, 2018. The Summary for Policymakers of the Special Report on Global Warming of 1.5 °C (SR15). Intergovernmental Panel on Climate Change, United Nations.*

Voogt and Oke 2003). The UHI occurs where measurable differences in both air and surface temperatures are found between an urban area and surrounding rural areas (Oke 1969; Landsberg 1981). A range of factors, including the city size, as measured by population, the increased density of human-made structures and surface materials that are drier than their surroundings and radiate sensible heat, and anthropogenic sources of heat, such as waste heat from vehicles and buildings, are known to contribute to the UHI (Oke 1982; Golden 2004; Levermore *et al.* 2015). The regional-scale description of urban heat complements an emerging body of evidence that describes differences in temperatures within metropolitan areas.

This regional-scale description of UHIs complements an emerging body of evidence that describes local thermal anomalies (LTAs)—those areas within a city that are relatively hotter than other areas. In fact, a growing body of literature emphasizes the role of the built environment as a mitigation strategy for UHI (Younger *et al.* 2008; Santamouris, Synnefa and Karlessi 2011; Aflaki *et al.* 2017; Gunawardena, Wells and Kershaw 2017; Santamouris *et al.* 2017). Commonly proposed interventions include tree planting, use of green roofs, and an overall increase in green spaces (Oliveira, Andrade and Vaz 2011; Santamouris 2014; Upreti, Wang and Yang 2017), as well as lightening roads, roofs, and buildings to increase albedo (Radhi *et al.* 2017; Kyriakodis and Santamouris 2018). Further evidence suggests that desert cities, unlike cities in temperate zones, often show a UHI effect, inverting the urban heat island phenomenon, with the result that specific urban areas appear colder than suburban areas during the daytime (Lazzarini, Marpu and Ghedira 2013; Rasul, Balzter and Smith 2015). As a result, urban development patterns have the potential to reduce temperatures and increase accessibility to the outdoor environment through modifications to the built environment. Previous research in the arid desert cities of Phoenix, Dubai, and others suggests that a combination of vegetation, the presence of water, and landscape design all affect the thermal comfort of human inhabitants (Brazel *et al.* 2007; Nassar, Alan Blackburn and Duncan Whyatt 2014).

Adapting urban environments to address LTAs requires an understanding of the role of land-use planning in ameliorating urban heat, though the differences across places can often hinder rapid deployment of relevant information. This book is admittedly an early contribution to understanding urban climate adaption efforts, though the empirical analysis contained herein offers glimpses into the possibilities for sustaining urban places, and improving the chances of making them livable during a rapid acceleration of global temperatures. We believe that anybody with a general interest in climate and cities will find in the following seven chapters, a promising set of practices that help to prepare regions for a warming planet. The ideal audience would consist of an individual or groups who, either through their own or external interests, recognize the severity and formidable challenge of transforming cities into climate-adaptive landscapes. This book is not a political statement, nor does it aim to engage only those who "believe" in climate change; rather, it offers a pragmatic and empirical assessment about the potential consequences of greater amounts of greenhouse gases in the atmosphere, and the approaches for enabling cities and their communities, infrastructure, and ecosystems to cope. Professionals—current and emerging—working in the fields of city and regional planning, public health, architecture, landscape architecture, natural resource management, and community development will find familiarity in these concepts.

We begin by describing the relationship between urban heat and livability, underscoring historical and contemporary interpretations. We then provide an analytical description of our case study city—Doha, Qatar—as it grew from a small pearling village on the Persian Gulf to a global city, whose infrastructure has grown at a blistering pace (Chap. 2). By examining the entire region, we are then able to examine specific areas of the city and how they vary in terms of exposure to urban heat (Chap. 3). These neighborhood-scale analyses are where we find the profound implications between the built environment and temperature differences (Chap. 4). By selecting specific neighborhoods of Doha, we are then able to examine how alternative urban designs can mediate temperatures and reduce exposure to extreme urban heat. We also examine how future projects of urban development might vary as a result of instituting an urban growth boundary (Chap. 6). We conclude by describing potential changes in the built environment, speculating on changes in exposure to urban heat, and identifying planning mechanisms that can improve the adaptability and livaiblity of increasingly uninhabitable cities (Chap. 7). We believe that this empirical assessment will be instrumental in showcasing and modeling approaches that other regions can employ for understanding the relationship between climate stressors and opportunities for urban adaptation.

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