THE IMPORTANCE OF DESIGNING CLIMATE-RESILIENT CITIES FOR FUTURE SCENARIOS: CASE OF ANTALYA

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THE IMPORTANCE OF DESIGNING CLIMATE-RESILIENT CITIES FOR FUTURE SCENARIOS: CASE OF ANTALYA

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ABSTRACT

THE IMPORTANCE OF DESIGNING CLIMATE-RESILIENT CITIES FOR FUTURE SCENARIOS: CASE OF ANTALYA

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It has been recognized that a climate crisis is on the horizon, and the underlying reason is not simply a natural shift, but global warming caused by human activities. With the emergence of technological advancements and industrialization, human-caused climate change brings even more "natural" disasters. To survive, cities of the future world must be designed to be climate resilient. Meantime, adapting to extreme conditions and mitigating their effects are crucial considerations.

This research focuses on not only climate change and the resulting disasters, but also global adaptation and mitigation strategies to fight them. These common strategies work as an observational tool to conduct a study of problematic cities in Turkey, where deaths and economic losses are not taken seriously enough. Among many, Antalya is chosen as a case study, since its gradually rising temperatures threaten the daily life of the citizens. The seemingly trivial problem continues to affect this well-known tourist attraction, which is also a trending retirement destination for the aging population. The unbearable temperatures started to change tourist preferences, causing Antalya to lose its economic dominance, and began to pose a serious death threat to the elderly people.

To better understand this phenomenon, known as the urban heat island effect, an ongoing urban transformation project in Antalya is analyzed. Through a series of future scenarios, and by exploring the estimated outcomes of the investigated strategies, this study is an attempt to raise awareness about what is inevitably waiting for the world. Reducing the urban heat island effect and adapting to the discussed potential scenarios are aimed on behalf of a more livable city.

Keywords: Climate Change, Urban Heat Island, Adaptation and Mitigation Strategies, Climate Resilience, Antalya

ÖZ

GELECEK SENARYOLARI İÇİN İKLİME DAYANIKLI ŞEHİRLER TASARLAMANIN ÖNEMİ: ANTALYA ÖRNEĞİ

Baygül, Şevval Simruy
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Ufukta bir iklim krizinin yaşandığı ve bunun altında yatan nedenin sadece doğal bir değişim değil, insan faaliyetlerinden kaynaklanan küresel ısınmanın olduğu netlik kazanmıştır. Teknolojik gelişmelerin ve sanayileşmenin ortaya çıkmasıyla birlikte insan kaynaklı iklim değişikliği daha da fazla "doğal" afeti beraberinde getirmektedir. Geleceğin dünyasının şehirleri hayatta kalabilmek için iklime dayanıklı olacak şekilde tasarlanmalıdır. Bunu yaparken ekstrem koşullara uyum sağlamak ve etkilerini azaltmak en önemli hususlardandır.

Bu araştırma, yalnızca iklim değişikliğine ve bunun sonucunda ortaya çıkan afetlere değil, aynı zamanda bunlarla mücadele için küresel çapta kabul gören adaptasyon ve mitigasyon stratejilerine de odaklanmaktadır. Söz konusu bilinen stratejiler, Türkiye'deki gibi ölümlerin ve ekonomik kayıpların yeterince ciddiye alınmadığı riskli şehirler için bir araştırma yapmak adına gözlemsel bir araç işlevi görmektedir.

Giderek artan sıcaklıkların vatandaşların günlük hayatını etkilemesi sonucu Antalya vaka çalışması olarak seçilmiştir. Görünüşte önemsiz olan sorun, yaşlanan nüfus için de popüler bir emeklilik destinasyonu haline gelen bu turizm merkezini etkilemeye devam etmektedir. Dayanılmaz sıcaklıklar turist tercihlerini değiştirerek Antalya'nın ekonomik hakimiyetini kaybetmesine neden olmakla birlikte, yaşlılar için de ciddi bir ölüm tehdidi oluşturmaya başlamaktadır.

Kentsel ısı adası etkisi olarak bilinen bu olguyu daha iyi anlamak için Antalya ilinde devam eden bir kentsel dönüşüm projesi incelenmiştir. Bir dizi gelecek senaryosu aracılığıyla araştırılan stratejilerin tahmini sonuçlarının keşfedildiği bu çalışma, dünyayı kaçınılmaz olarak bekleyenlere karşı bir farkındalık yaratma girişimidir. Daha yaşanabilir bir kent adına kentsel ısı adası etkisinin azaltılması ve tartışılan potansiyel senaryolara uyum sağlanması hedeflenmektedir.

Anahtar Kelimeler: İklim Değişikliği, Kentsel Isı Adası, Adaptasyon ve Mitigasyon Stratejileri, İklime Dayanıklılık, Antalya

To all my lodestars who left this world far too soon;

Ömer Okutucu, İ. Sıdkı Özdemir, Kerim Kuş, Nurcan Kocaçay,
Funda Şenova Tunalı, Nuri Metin and Ali Baygül

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TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

LIST OF ABBREVIATIONS

AFAD: Afet ve Acil Durum Yönetimi Başkanlığı (Disaster and Emergency Management Presidency)

AMIA: Adaptation and Mitigation Interaction Assessment

C40: C40 Cities Climate Leadership Group

CCOL: Coordinating Committee of the Ozone Layer

COP: Conference of the Parties

CRED: Centre for Research on the Epidemiology of Disasters

DGNB-UD: Deutsche Gesellschaft für Nachhaltiges Bauen (German Sustainable Building Council) for Urban Districts

EM-DAT: Emergency Events Database

EPW: EnergyPlus Weather

GNP: Gross National Product

IPCC: Intergovernmental Panel on Climate Change

MGM: Meteoroloji Genel Müdürlüğü (Turkish State Meteorological Service)

NBS: Nature-Based Solutions

OECD: Organization for Economic Co-operation and Development

RCP: Representative Concentration Pathways

SEAP: Sustainable Energy Action Plan

SECAP: Sustainable Energy and Climate Change Action Plan

SUDS: Sustainable Drainage Systems

UNEP: United Nations Environment Programme

UNFCCC: United Nations Framework Convention on Climate Change

UNISDR: United Nations Office for Disaster Risk Reduction

USARC: United States Arctic Research Commission

USD: United States Dollar

WHO: World Health Organization

WMO: World Meteorological Organization

WSUD: Water-Sensitive Urban Design

CHAPTER 1

INTRODUCTION

This study investigates natural disasters and extreme conditions due to the increasing effects of climate change, as well as an analysis of an ongoing urban transformation project in the selected Antalya city. This chapter briefly explains the main statement of this study, including background information about the topic.

1.1 Argument

Rapid urbanization is the most evident return of the increasing world population. From agricultural to touristic activities, industrialization keeps expanding the carbon footprint of the settlements, turning more and more rural into urban nodes. Correspondingly, climates are changing faster than ever and leading to unpredictability in the short term. However, what is crystal clear in the long term is that the earth is getting hotter. Now that the climate crisis is an established issue, the terms used so far are trendier than ever. In contrast, applications of these trends are not very embraced. What should be the essence of design, respect for its environment before the rest, is still neglected. Consequently, city blocks keep growing like viruses.

Research in the field points to future risk often through case studies. All the deaths and economical losses caused by disasters, which are no longer natural but man-made due to excessive interference, indicate that humankind cannot be saved if precautions are not taken against climate change. From floods to forest fires, disasters that are becoming more frequent day by day, and extreme conditions such as drought are key subjects of the future scenarios centered in current studies. There are adaptation and mitigation strategies to reduce the risk and minimize the losses when these scenarios inevitably turn into reality.

These strategies are widely discussed since each city around the world faces different dangers at different levels, in relation to their changing climate. Where responses need to be customized, they become stereotyped because of various limitations. Even worse, although developed countries have started to prioritize fighting climate change either by stereotypes or customizations, many developing countries continue to ignore it due to financial constraints. Considering that individual health is dependent on the health of the planet, preserving the natural balance is far more important than profit in the field.

At this point, especially for developing countries, every small step can lead to a big impact. As a starting phase, nature-based solutions should be proposed, and their implementation should be encouraged for precarious zones that suffer remarkably from climate change. Thus, a belated public consciousness that will set off a chain reaction towards leaving a still-habitable world to future generations can finally be achieved.

1.2 Aim and Objectives

The aim of this study is to examine the various adaptation and mitigation strategies for natural disasters and extreme conditions that cities face all around the world. Through the review of existing literature, this study acknowledges that disasters occur more frequently and extreme conditions are experienced on a wider scale, compared to the past. Caused by increasing human activity, climate change plays a major role in these incidents. Therefore, effects of climate change on particular disasters are also investigated at the outset.

With the analysis of main disaster types and their results, this study reveals that the climate crisis will catch more lives off guard if proper provisions are not made. In order to be prepared, every city should be aware of the risk they contain and integrate suitable strategies. For a successful plan, cooperation between the governments and public is necessary.

One objective of this paper is to shortlist appropriate strategies over a case study and to elaborate on their efficiency. Antalya has been identified as the relevant city because one of the most prominent features of the climate crisis, the urban heat island effect, is progressing as a result of rapid urbanization and the contribution of ongoing forest fires.

The other objective of this paper is to analyze a government action, which is a large urban transformation project promoting a healthy urban environment. The use of such a case study helps to compare the estimated outcomes of various strategies to the actual performance of the transformation project.

1.3 Procedure

The first stage of this study consists of a literature survey chapter. This chapter involves data obtained from numerous references in the field. The definition of climate change and its effects are presented to understand their relationship with the disasters and extreme conditions better. Reports comparing the past and current conditions of the worldwide cities and applied climatic solutions are examined to gather the most accurate information on the strategy selection criteria. After a downscaling on the problematic cases in Turkey, complete information on the selected Antalya city is given in the 'Material and Method' chapter. The data is acquired from firstly existing literature to discover past incidents, secondly from site analysis to point out the current condition, and thirdly creating tables to project future risk. Contact with the municipality and access to particular authentic documents also support the analysis.

The next stage of this study comprises results and discussion. Subjected future risk in the existing literature is matched with appropriate strategies using the projections. The urban transformation area is then focused on evaluating the efficiency and testing the estimated results of specific strategies. The final stage of this study includes a conclusion with further discussions.

1.4 Disposition

This study is composed of five chapters. Chapter 1 is the introduction chapter that presents the background information regarding climate change and its increasing effects on the urban environment. The mentioned adaptation and mitigation strategies highlight the future risk for cities. Thereafter, the aim and objectives of this study are given.

Chapter 2 continues with literature review on this research field. The definition of climate change and later the urban heat island effect are given. The impact of climate change on extreme events in global scale and in Turkey is detailed from floods and sea level change to wildfires. Following, city mitigation and adaptation strategies are explained with published international and national approaches. Additionally, the situation of Antalya is viewed as a reference to the case study.

In Chapter 3, the material and method of this study are explained. The materials of this study are the before and after aerial views of the urban transformation area, accordingly the three-dimensional models of these two cases. In addition, a part of the literature review is used as a material to evidence extreme events for Antalya. There are two methods which are the outcome estimations of a strategy set, and the comparative analysis over simulations with the introduced tools.

Chapter 4 is the results and discussion section of the whole study, where the site observations and graphs are analyzed and calculations are made to develop a future scenario. This chapter discusses the ongoing urban transformation project with the results of analysis, calculations and adaptation and mitigation strategies mentioned in the literature review.

In Chapter 5, there is a concluding summary of the entire study with further discussions that include feasibility and knowledge gaps on the examined topics.

1.5 Contribution

As an attempt for tactical urbanism, the key adaptation and mitigation strategies on an urban scale are provided, in view of the definition of climate change and its effects on each extreme event, predominantly on natural disasters. This detailed analysis works as a successful tool to carry out a study not only about the importance of acting against the climate crisis but also the future scenarios for risky cities.

The cause-and-effect relation throughout this study on the most common disasters helps to call attention to the topics of risk assessment and climate resilience. Using prior studies detecting risk and actualized solutions for specific zones, cumulative research has been introduced to analyze governmental action in a promising city. Due to lack of information on such cities, finding more relevant data can further develop this kind of studies for observing and taking actions on climate change. Therefore, first drawing attention to the losses from extreme events is important. By generating more future scenarios in more cities, it should be possible to expand the risk assessment, as aimed in this study. The more actions taken, the less climate change can be accomplished.

Considering only a limited amount of analysis can be reached for developing countries, this study also faces difficulties in finding relevant information on Turkish cities. Existing literature on Turkey focuses almost entirely on the city of Istanbul, which is the most crowded city holding nearly one-fifth population of the whole country, and partly on Ankara, which is the capital city. Therefore, what this study offers to the field is another city among many problematic ones that are also mentioned in the study, which require measures no less than already studied zones. As a Mediterranean city in a hot-humid climate region that is becoming warmer by the day due to increased tourist activity, Antalya is being studied in terms of the contribution of the urban heat island effect, and correspondingly, measures to reduce this effect are being discussed. Thereby, this study reframes all-natural disaster types by accounting for both the historical record and future risk in order to gain a better understanding of what awaits the world. At the end, it is expected that more studies would be conducted for more cities, to detect their risk as well and to make more specific provisions.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews and summarizes existing theory, research, and methodological contributions to this field to reinforce the purpose of this study. The first part of the literature review discusses the definition of climate change and the term urban resilience, for understanding their importance. Following, the relationship between climate change and extreme events is examined. Both in global and Turkey scale, main disaster types are evaluated. Thereafter, again both international and national approaches on city mitigation and adaptation strategies are outlined. Lastly, as a city having climatic problems, Antalya is taken as a case study through extreme events in its past. Accordingly, future risks that await the city and existing action plans are investigated.

2.1 The Definitions of Climate Change and Urban Resilience

The United Nations defines climate change as long-term shifts in temperatures and weather patterns. However, there is a reason why this term is being used more commonly over global warming in recent years. The United States Environmental Protection Agency (2008) distinguishes between the two terms by emphasizing the further transformations that occur with climate change besides increasing temperatures. There is various research about the connection between these transformations and natural disasters. Accordingly, the fact that natural disasters are no longer just natural but more man-made due to rising human activity is widely accepted. With the continuous urbanization, The World Bank (2009) had already predicted an escalation in the amount of individuals subjected to disasters in climate-critical regions (Czapiewska, Roeffen, and de Graaf 2012). Therefore, climate resilience becomes essential for survival. On the other hand, Frantzeskaki and McPhearson (2021) remind that climate-driven disasters have the potential to damage facilities, transportation networks, electric utilities, and other critical infrastructure. Hence, not only are human lives at stake, but also the investments.

Climate resilience on an urban scale is commonly referred to as urban climate resilience, or simply urban resilience. It is the capability of a city to react to inside and outside forces. When developed in accordance with social factors such as population age and a variety of social activities, urban resilience is more than just a defense mechanism with a bunch of trees; it also contributes to financial development and public welfare (Liu et al. 2022). Speaking of public welfare; there is a remarkable argument that the single difference between developed and developing countries is resilience and recovery rates, where urban resilience is determined in terms of infrastructure via financial growth, and recovery is based on proper management, strategic planning, and an effective policy (Oloke et al. 2021). Apostu et al. (2022) use the recent pandemic to support the relationship between development level and resilience; the response of cities following the Covid-19 outbreak provides guidance for future resilience. The crisis did not halt the development of resilient cities because, rather than waiting for old patterns to return, a new normal was introduced. As a result, the resilience of cities was tested under pressure.

Building-scale certification systems are already popular, but urban-scale certification systems are emerging as well. A suitable example of the general criteria is proposed by the German Sustainable Building Council for Urban Districts (DGNB-UD). The five qualitative categories of the council are “environmental, economic, sociocultural/functional, technical and process”; whereas the ten sub-strategies are summarized by Jensen, Bjerre, and Mansfeldt (2016) as:

- appropriate mix of functions and users,
- maximized daylight,

- ideal density,
- life cycle consideration for materials,
- water management and greenery,
- wind optimization,
- energy and resources management,
- good transportation system,
- efficient design process,
- aesthetics for unique identity

While efficient land use is an agreed-upon strategy, discussions about its implementation continue. Again, the climatic conditions of a city should be used to determine density levels, as they have a direct impact on solar radiation.

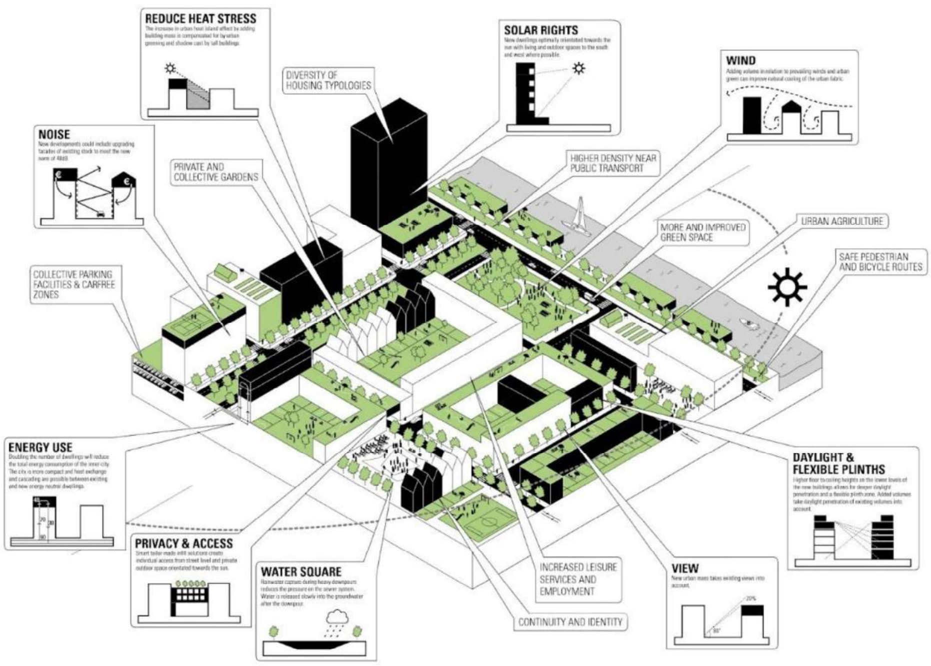

Figure 2.1. A scheme for ideal density (Tillie et al. 2012) [Doepel 2012]

In Figure 2.1, Tillie et al. (2012) present a scheme for smart and bioclimatic density design, emphasizing that urban resilience, in addition to successful management of extreme events, may boost the sociocultural and commercial quality of neighborhoods (Doepel 2012).

2.2 Impact of Climate Change on Extreme Events

One of the primary causes of extreme events is climate change. It has an impact on numerous issues such as temperature increases, basal sliding, change in sea levels, eutrophication, ecological disruption, and catastrophic weather conditions. As mentioned in the previous chapter, few of the existent research regarding the connection between climate change and these events will be shared through the collected work of Akay (2019):

The United States Arctic Research Commission (USARC) (2003) noted in its documents that continuous increases in temperatures caused by climate change bring risks in the Arctic and that glacial retreat due to weather leads to surface destabilization and biospheric shifts. Moreover, Brandes et al. (2018) and Masih (2018) agree that polar melt and rising seas may cause geological events like quakes on top of weather-related events like floods.

In return, several measuring associations exist to record the frequency of these events and thus provide a foundation for causal links and strategic plans.

2.2.1 Measuring Associations

The Centre for Research on the Epidemiology of Disasters (CRED), the Emergency Events Database (EM-DAT), and the United Nations Office for Disaster Risk Reduction (UNISDR) will be reviewed on behalf of global measuring associations, while the Disaster and Emergency Management Presidency (AFAD) as a governmental agency operating under the Turkish Ministry of Interior will be reviewed on behalf of national measuring associations.

CRED is the top global organization for monitoring human welfare under major catastrophes, covering disease statistics as well as the physical and societal consequences of natural and artificial emergencies and civil crises.

EM-DAT, a sub-branch of CRED with the contribution of the World Health Organization (WHO) and the Belgian state, includes the most complete record on the incidence and impact of over 21,000 natural and artificial emergencies from 1900 up to today. The primary goal of EM-DAT is to guide disaster relief at the global and local levels to optimize emergency policies, offer scientific evidence for measuring resilience against extreme events and assist decision makers in prioritizing. UNISDR, on the other hand, acts like a pivot for the United Nations to minimize catastrophic dangers.

CRED and UNISDR (2015) stated in the 21st Conference of the Parties (COP21) Weather Disasters Report that flood events, heatwaves, and many more climate anomalies have created the vast majority of crises during the previous two decades. EM-DAT issued an overall report of 6,457 weather-related disasters globally, causing 606,000 casualties with an extra 4.1 billion of people wounded, homeless, or seeking emergency supply. Figure 2.2 illustrates the occurrence rates and their consequences on individuals and the economy, on a smaller scale across Europe.

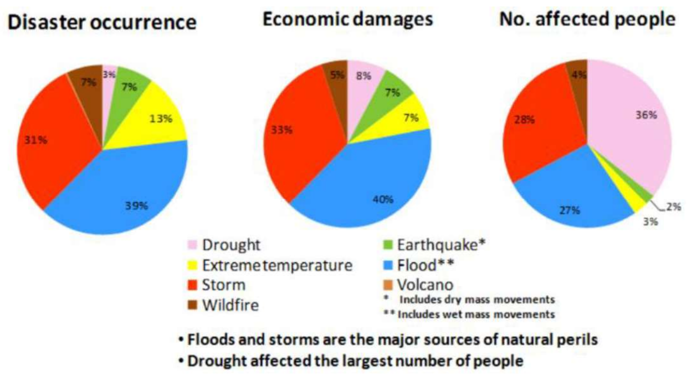

Figure 2.2. Natural disasters in Europe from 1998 to 2008, according to EM-DAT (Guha-Sapir and Below) [Escarameia et al. 2013]

Understanding how climate change affects extreme events is one of the foundations for designing more resilient cities. Developed countries have already realized this and are working to improve their resilience. It is critical to begin evaluating the case of unpredictability as soon as possible. Climate change scenarios and simulations must be integrated into the subsequent steps to calculate the danger potential and plan for precautions.

Natural disaster policies in Turkey as a developing country were first constructed following the 1939 Erzincan Earthquake. The governmental emergency aid statute, introduced in 1959, attempted to close the legal loophole on the issue. The disaster regulatory policies continued with the planning regulation, published in 1988, to guarantee that government facilities and emergency aid access the disaster location immediately.

The emergency preparedness of the country was tested by the 1999 Marmara Earthquake, which was a moment of truth. The tragic event resulted in massive mortality and financial loss, emphasizing the major role of disaster response.

Accordingly, the separate general directorates of Civil Defense, Disaster Affairs, and Emergency Management have been decommissioned. In 2009, all relevant authorities were merged, and the Disaster and Emergency Management Presidency (AFAD) associated with the Prime Ministry was established.

There are evaluations done over a long period of time, such as the one depicted in Figure 2.3 for the year 2017. The results reveal the most prevalent extreme events in Turkey include quakes, storms, floods, droughts, and wildfires. Apart from the death toll, these events cause social, ecological, and financial damage, with the latter amounting to 3% of Turkey's Gross National Product (GNP) annually (Akay 2019).

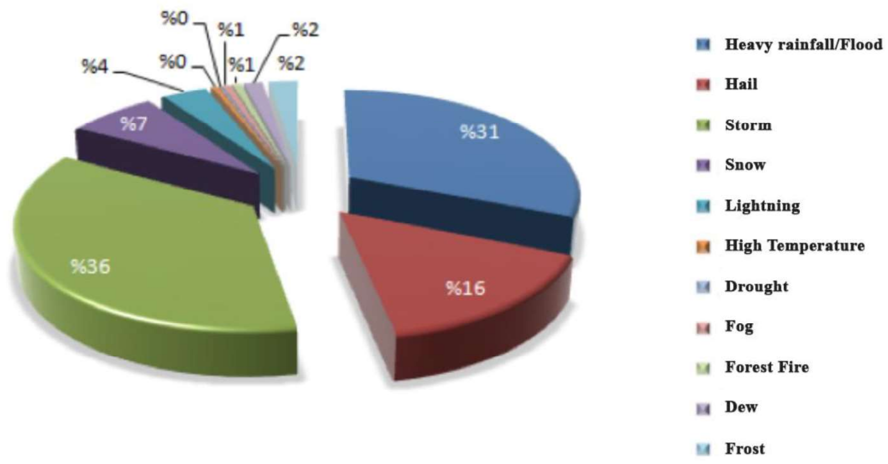

Figure 2.3. General Distribution of Meteorological Disasters in 2017 (Turkish State Meteorological Service 2018) [Akay 2019]

2.2.2 Classification of Extreme Events

Classifying extreme events serves a purpose in that it enables the understanding, identification, and assessment of disasters based on their causes. Understanding a disaster aids in dealing with its risk, thereby reducing damage. Table 2.1 shows the classification of natural disasters by type in the report of CRED and UNISDR (2015), whereas Table 2.2 focuses on the major climate change risks and their impacts according to AFAD reports (Akay 2019). The events shared by both tables expose how significant climate change is in the essence of disasters.

Table 2.1 EM-DAT classification of natural disasters (CRED and UNISDR 2015) [adapted by author]

Geophysical	Hydrological	Meteorological	Climatological	Biological	Extra-terrestrial
Earthquake	Flood	Storm	Drought	Epidemic	Impact
Mass movement	Landslide	Extreme temperature	Glacial lake outburst	Animal accident	Space weather
Volcanic activity	Wave action	Fog	Wildfire	Insect infestation	

Table 2.2 AFAD primary climatic indicators and climate change risks (Akay 2019) [adapted by author]

Atmospheric moisture	Temperature	Sea level	Wind	Desertification
Flash flood Heavy rain Water table level change Soil chemistry change Ground waters change Sea-salt chlorides	Heatwaves Cold waves Ice storm	Coastal flood Tidal flood	Wind-induced rain Windborne sand Windborne salt Wind direction change	Drought Depletion of water table

The same CRED and UNISDR (2015) report displays additional critical data between 1995 and 2015, including disaster occurrence rates (Figure 2.4), rates of people affected and killed by disaster types (Figures 2.5), and the reflection of disaster types in economic damage in United States dollars (Figure 2.6). As per Figure 2.4, floods have the highest occurrence rate (43%), followed by storms (28%), earthquakes (8%), extreme temperatures (6%), landslides and droughts (5%), wildfires (4%), and volcanic activity (2%). Figure 2.5 depicts the global population affected by climate-induced disasters between 1995 and 2015. Flood disasters were the most common, accounting for 56% of all disasters, followed by drought (26%), storm (16%), and extreme temperatures (2%). The majority of deaths, however, were caused by storms, followed by extreme temperatures and flooding. As indicated in Figure 2.6, the financial loss caused by these events is 1011 billion dollars for storms, 763 billion dollars for geophysical disasters, 662 billion dollars for flood disasters, 100 billion dollars for drought, and 119 billion dollars for weather-related other disasters.

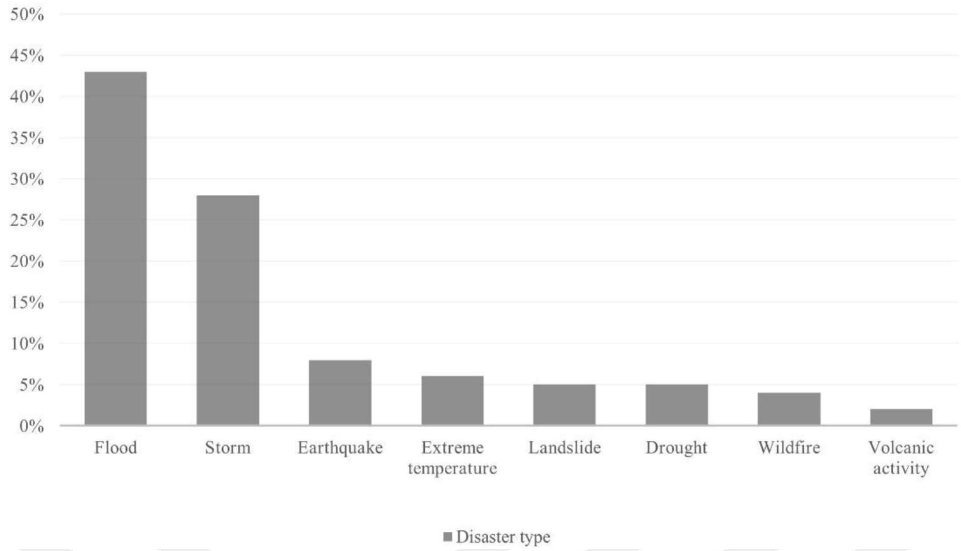

Figure 2.4. Rates of natural disaster occurrence by disaster category between 1995 and 2015 (CRED and UNISDR 2015) [adapted by author]

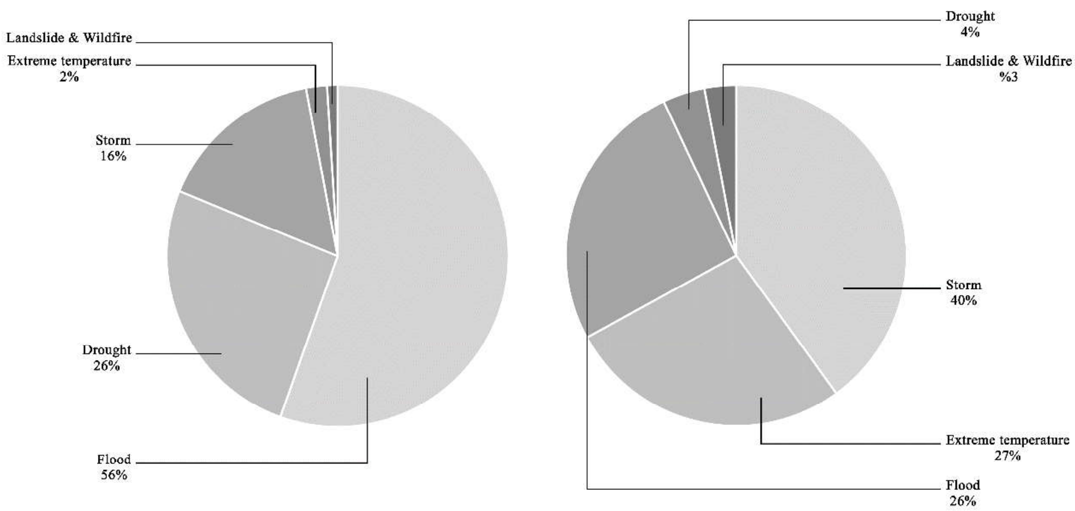

Figure 2.5. Percentages of individuals affected (left) and killed (right) by disaster category between 1995 and 2015 (CRED and UNISDR 2015) [adapted by author]

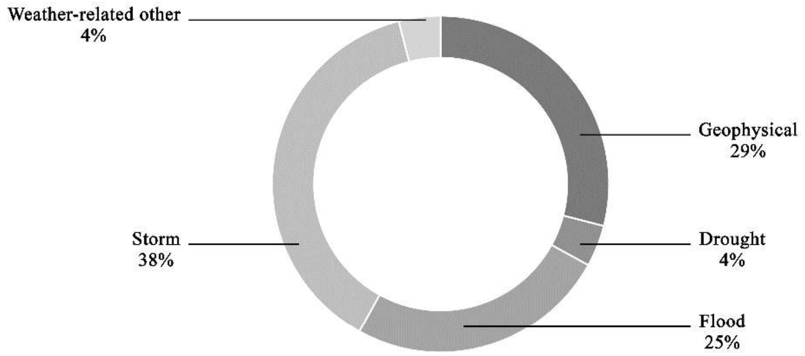

Figure 2.6. Economic loss documentation by disaster category between 1995 and 2015 (CRED and UNISDR 2015) [adapted by author]

2.2.2.1 Floods and Sea Level Change

Floods, which have the greatest effect on individuals and are the third leading cause of death among natural disasters, are becoming more common as the impact of climate change on weather conditions increases. Although southeast Asia dominated the general perception of flood concerns in previous years, there is currently no difference between the continents regarding flood risk. It is considered as the most serious disaster with respect to personal and property damage, even within the European Union. Climate change is predicted to result in more intense weather events and precipitation, along with rising streamflow and sea levels. This indicates that the risk is about to escalate dramatically. Figure 2.7 represents evidence with data on the total number of floods around the world.

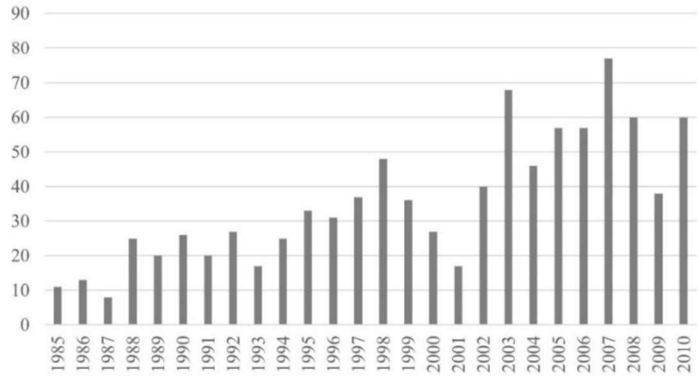

Figure 2.7. The total number of floods around the world (Graaf 2012) [adapted by author]

Aside from shifting weather patterns, changes in settlement patterns over time also have a significant impact on flood risk. Graaf (2012) states that a flood that would inflict massive destruction and claim lives now would have created far less harm a century ago. The primary factor for this is that the impacted area inhabitants and capital were substantially smaller at that period. The earliest settlements in delta zones were located on lifted parts of the coastal regions, but as they developed, they extended into wetlands and low elevations, resulting in the building of embankments. These embankments had a disadvantage in that they prevent silt formation and lead the soil to subside, making deeper level differences between the water and land. Consequently, most delta zones are partially submerged beneath the water level today, bringing major flood vulnerability. Delta zones associated with this issue include Jakarta, Bangkok, Shanghai, Venice, and among these places, unfortunately more than 10 cm of land sinking each year is common (Graaf 2012). In return, today as urban centers keep growing, a greater number of individuals are migrating to these risky zones. Graaf (2012) predicts that until 2100, 5.0 billion people will migrate to these centers and the majority of these urban inhabitants will reside in floodplains. It is also anticipated that by 2050, half of the worldwide population would live less than 100 kilometers from the shore.

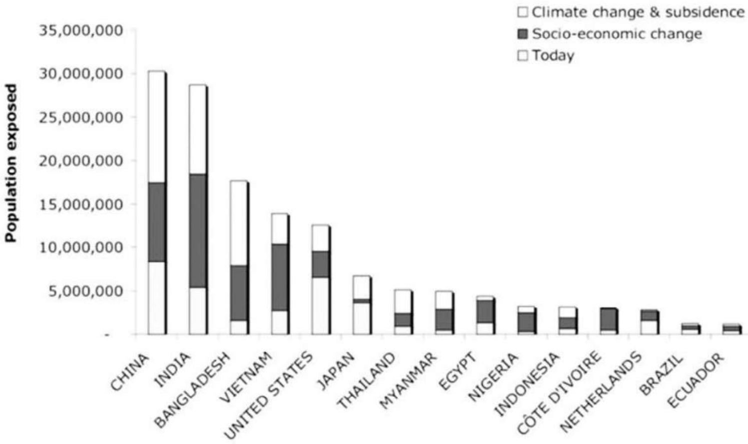

Figure 2.8. The top 15 nations by population are at risk of floods now and in 2070 (Nicholls et al. 2007) [Graaf 2012]

Figure 2.8 above demonstrates that the amount of individuals subjected to flood risk will rise, especially across China and India. The rise is due to the effects of climate change, while also economic growth including higher income levels and industrialization.

In addition to the previously mentioned locations, Cao (2021) adds to the risk component that is now widespread across the world by citing examples such as how flooding threatens one-third of the whole continental United States or the April 2009 floods that destroyed districts of Mozambique, Malawi, Zimbabwe, and Iran, causing an estimate of 1000 dead and thousands of others dislocated.

Under these circumstances, the importance of urban resilience must be emphasized once more. It is obvious that architecture cannot prevent floods on its own, but if no other land is available for expansion, it must be designed to be resilient. Various measures have been implemented in this direction over the last few decades. For instance, the European Union Floods Directive was issued in 2007 by the European

Parliament and Council in response to many flood disasters in Europe that resulted in deaths and big financial losses. Its objective is to mitigate flood risks on public health, the surroundings, culture, and the economy (Escarameia et al. 2013).

When it comes to the situation in Turkey, AFAD (2014) defines flood control as the construction of infrastructure including seawalls, channels, levees, and embankments to avoid or mitigate flood damage. Throughout history, floods resulted in severe lives and material loss in Turkey. Both the severity and occurrence have increased, particularly over the previous decade (Figure 2.9). The northern region of the Black Sea gets rainfall virtually all year. Moreover, floods appear throughout the warmer months of the year as a result of meltwater. 187 flood disasters were documented only in 2017 and since 2000, there have been 50 and more floods per year (Akay 2019).

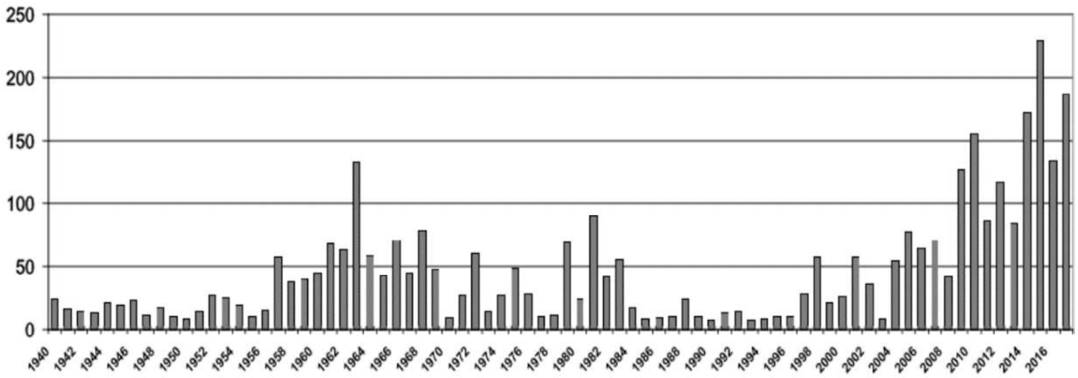

Figure 2.9. The number of floods that occur over a long period of time according to the Turkish State Meteorological Service (MGM) 2018 database (Akay 2019)

Given the same MGM 2018 database, as for the flood analysis of other regions than the Black Sea; the Marmara district had 49 documents, the Aegean district had 31, the Mediterranean district had 38, and the Central Anatolian district had 24. The Eastern Anatolian and Southeastern Anatolian districts are less dangerous, with documentation of 9 and 6, respectively.

2.2.2.2 Storms

While not as common and thus having less of an impact on people as floods (Figures 2.4 and 2.5), storms are the most fatal kind of disaster (Figure 2.5), causing over 242,000 casualties between 1995 and 2015. Despite facing only 26% of total storms, low-income nations had the highest casualty rate of 89% (CRED and UNISDR 2015). Developed countries, on the other hand, may not suffer as many deaths but must still deal with economic damage, highlighting the importance of urban resilience once more. Escarameia et al. (2013) recall the devastation caused by Hurricane Sandy on the eastern shore of North America and the Caribbean in 2012. Because of its devastation power and broad damage to infrastructure, it was ranked as one of the most costly storm disasters for companies. The massive power outage, which left thousands lacking electricity, resulted in higher economic damage than anticipated. Escarameia et al. (2013) also emphasize that most of the damage could be prevented if the major yet quite susceptible infrastructure of New York City had been secured in a timely manner.

Based on the occurrence data on Turkey, storms have various definitions and classifications. According to the Turkish State Meteorological Service (MGM), there are five major categories. Wind speeds of 39-61 km/h are classified as strong, 62-74 km/h as storm, 75-88 km/h as a strong storm, 89-102 km/h as full storm, and above 103 km/h as hurricane. Long-term statistics show that storm disasters in Turkey began to increase remarkably about 2000 (Figure 2.10). More than 200 storms have happened in the previous three years alone. With the impact of climate change, storms had a record-breaking year in 2016. The storm event has become prevalent in the Aegean and Mediterranean coasts of Turkey. However, as the severity level rises, so do the losses. Akay (2019) also recognizes that this disaster type has recently begun to cost more and more lives, besides inflicting far more financial, social, and environmental damages.

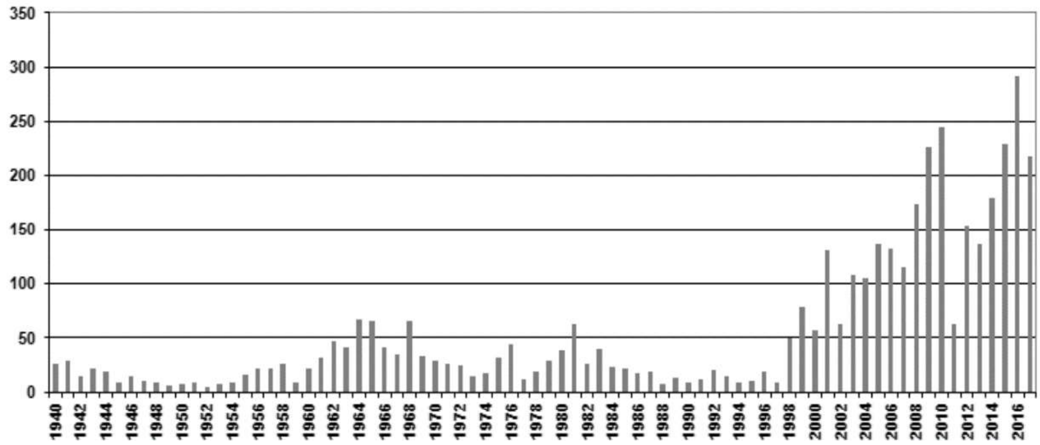

Figure 2.10. The number of storms that occur over a long period of time according to the Turkish State Meteorological Service (MGM) 2018 database (Akay 2019)

2.2.2.3 Mass Movements

Mass movements fall into the same geophysical disaster category as earthquakes but differ in the subtype. While earthquakes are primarily thought of as ground motion, mass movements like rockfalls and landslides are more directly affected by a larger problem called soil erosion, which is a serious outcome of climatic conditions such as changes in precipitation rate. Like many other disasters, mass movements have little impact on developed nations. Conversely, these sorts of events have a serious effect on developing nations by creating a remarkable economic decline in these areas. Furthermore, another important concern it brings is related to the aforementioned disasters. Soil erosion causes most flood management systems to fail (Figure 2.11). Erosion steps are among the most common failure patterns in urban risk assessments, thus, Escarameia et al. (2013) suggest that mass movements in general need more understanding to not only minimize life and economic losses but also to complete a good performance evaluation of urban flood barriers.

Figure 2.11. Collapse due to backward erosion during Deltares pipe test in the Netherlands (Escarameia et al. 2013)

2.2.2.4 Heatwaves and Drought

According to CRED and UNISDR (2015), despite drought contributing below 5% among all-natural disasters, EM-DAT reported over thousands of millions impacted by droughts between 1995 and 2015, accounting for above 25% of all individuals impacted by all kinds of catastrophes globally. Furthermore, from 1995 to 2015, severe temperatures were responsible for 27% of casualties linked to weather-related events, particularly heatwaves accounting for the dominant part with 148,000 casualties out of 164,000.

Examples from around the world demonstrate that the contrast between the occurrence rate of these extreme events and their fatality should be taken seriously because the consequences are irreversible. Altogether, 92% of heatwave fatalities were documented in high-income nations, with Europe accounting for the majority with a 90% rate. Over 55,000 individuals died throughout a heatwave in Russia in the summer of 2010, whereas massive heatwaves in Western and Southern Europe killed more than 72,000 and 3,400 individuals, in 2003 and 2006. India lost 2,500 individuals in only a single month between May and June of 2015, and Pakistan lost 1,230 due to the same heatwave (CRED and UNISDR 2015).

Doepel (2012) emphasizes the criticality of this extreme event type by linking the term "heat island effect," which is an excess heat generated by vehicles, the built environment, and a lack of greenery within the urban zones. He uses the summer of 2011 in Rotterdam as an example, when a record-breaking temperature differential of +7ºC was observed, thus affecting the daily lives of many citizens. There are various factors that influence this phenomenon such as the heat absorption by hard surfaces, street configurations for wind flow, and passive cooling from urban pools and parks. Table 2.3 shows that Turkey is also one of the risky countries in terms of extreme temperatures and drought.

Table 2.3 Countries in the top 1% and top 10% in terms of disaster risk (Akay 2019) [adapted by author]

Extreme event	Risk	Countries in the first 1%	Countries in the first 10%	Evaluated countries
Heatwaves	Death rate	India	India, Pakistan, USA, Iraq, Russia, Ukraine, Spain, China, Germany, **Turkey**, France, Iran, Poland	129
Cold waves	Affected population	China, India	China, India, USA, Russia, Pakistan, Bangladesh, Brazil, Mexico, Germany, Egypt, Japan, South Korea, Iran, United Kingdom, **Turkey**, Ukraine	161
Drought	Yield loss (corn)	USA	USA, China, Russia, Brazil, Spain, Afghanistan, Kenya, Argentina, Mexico, **Turkey**, Ukraine, Kazakhstan, South Africa, Tanzania, Iraq, Australia	146

When the solutions to avoid such undesirable events are considered, heat waves have a greater negative impact. Air conditioners are unavoidable, especially during the summer months when heat waves become even more unbearable. This pattern increases energy demand and has a direct impact on the economy, as well as several inconveniences such as energy disruptions due to excess demand.

Drought is defined by AFAD (2014) as a meteorological period in which precipitation falls less than 80% of the seasonal average, a hydrological period in which dams, ponds, and groundwater levels fall below long-term annual averages, and a lack of water needed by humans and other living beings in terms of agricultural purposes (Akay 2019). According to the same AFAD report, semi-arid, arid, and semi-humid areas account for 60% of Turkey's surface area, but this data is now eight years old. Meanwhile, the rates rose rapidly. Figures 2.12 and 2.13 depict the country's drought maps in 2017 and 2022, respectively. The rate of change is alarming.

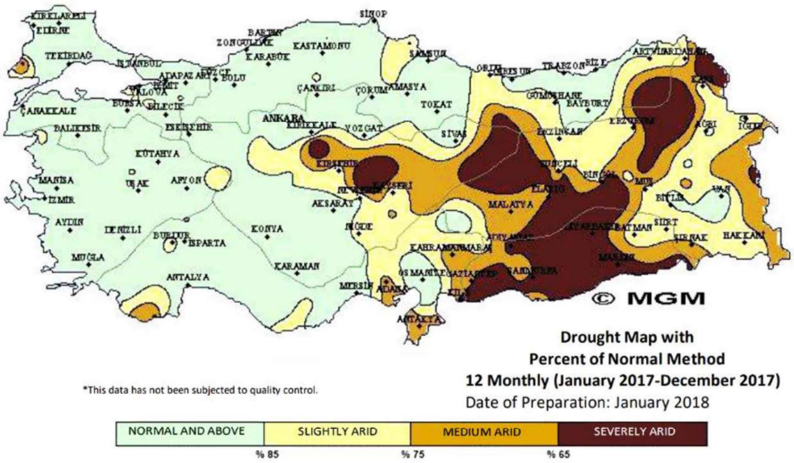

Figure 2.12. 2017 drought map of Turkey according to index of normal (MGM 2018) [adapted by author]

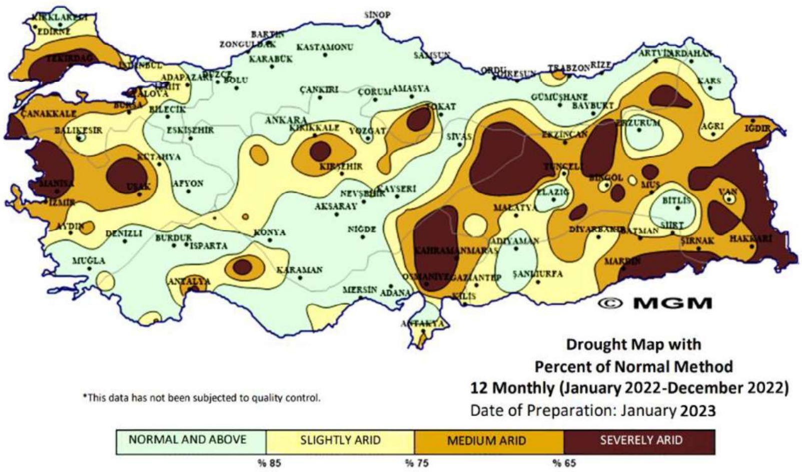

Figure 2.13. 2022 drought map of Turkey according to index of normal (MGM 2022) [adapted by author]

2.2.2.5 Wildfires

Each year, wildfires impact billions of acres of forested zones throughout the world, resulting in fatalities and material damages as well as management expenses. Deforestation leads to desertification. As a result, it triggers climate change by causing soil erosion, increasing air pollution (especially contributing to CO_2 emissions), and welcoming many other disasters such as floods and landslides. Vice versa, due to the increasing effects of climate change such as heatwaves and droughts, wildfire occurrences are expected to spread even further. There have been numerous instances of this vicious cycle in the past. 111592 hectares of forest were destroyed following the 30417 wildfires which took place from 2005 to 2017 and during this time span, 27% of the burnt land fell in 2008. In 2008, 29749 hectares of forests were burnt as a consequence of 2135 forest fires, 19 of which were drastic in scale. The fact that 2008 was a dry year, unfortunately, had a huge impact on this (Akay 2019). The reverse situation is stated too, by the Ministry of Environment and Urbanization of the Republic of Turkey (2012); the consequences of climate change in Turkey are connected to the extent and length of wildfires as the severity of hot and arid seasons rise. This is considered to be a year-round threat in the Mediterranean region, particularly in southern parts, and it is anticipated that the surge in wildfires would result in the expansion of invasive species, and hence spread it to even larger regions.

Kucukosmanoglu and Uzmez (2019) agree on the specified threat predictions according to the provincial forest directorates and allocation of wildfires from 2006 to 2015. They share that Izmir, Antalya, and Mugla provinces have the maximum statistics. As a result, as shown in Figure 2.14, it is reasonable to assume that wildfires in Turkey are primarily centered along the coastline, including these three regions.

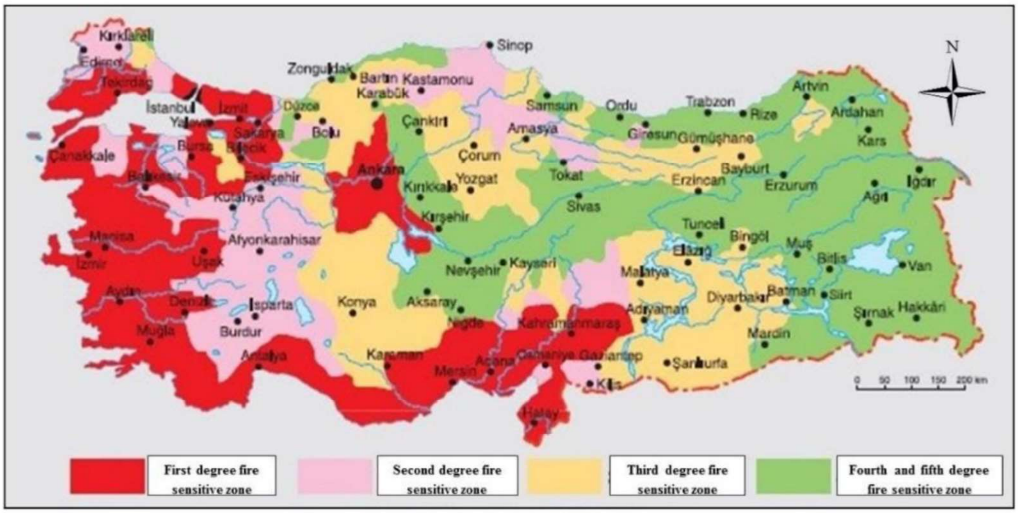

Figure 2.14. Vulnerability to wildfires in Turkey (Kucukosmanoglu and Uzmez 2019)

2.3 Steps towards Climate Resilience

There is no industry left that has not been dominated by greenwashing. As the term "sustainability" became popular, rating systems to assess reliability were developed. According to Doepel (2012), while such rating systems are useful for putting constraints on the design and guiding it properly, they have two major shortcomings. A rate-based system, by definition, does not provide an alternative. More importantly, at large scales, these rating systems become ineffective. Passive solutions have begun to be used at the building scale, and climate-adaptive building shells with parametric design are already being proposed. However, solutions on an urban scale remain a secondary concern.

2.3.1 Approaches

Before exploring urban resilience strategies, some of the most significant measures implemented globally to date will be addressed in chronological order. Following a brief explanation of international measures, national measures on Turkey and the extent to which international approaches are being applied will be discussed.

2.3.1.1 International Approaches

With the establishment of the Coordinating Committee of the Ozone Layer (CCOL) by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to study ozone depletion on a regular basis, experts on the ozone layer gathered in 1977. The first international contacts on reducing ozone-depleting chemicals began in 1981, and this endeavor led to the March 1985 approval of the Vienna Convention for the Protection of the Ozone Layer (AFAD 2014).

The United Nations Framework Convention on Climate Change (UNFCCC) was established seven years later, in 1992, at the United Nations Conference on Environment and Development. The ultimate goal of the convention is to halt the accumulation of greenhouse gasses in the atmosphere at a level that minimizes the hazardous effect caused by human activity on the climate. Parties agree to take steps to avert climate change and achieve effective adaptation to its impacts (Moosmann et al. 2021).

The Kyoto Protocol was approved in 1997 at the third UNFCCC Conference of the Parties in Kyoto. The protocol reflects the goals and establishment of the convention, however, the most significant contrast between the two agreements is the legal character of the duties they govern. While the convention outlined a non-binding requirement for developed nations to maintain their greenhouse gas emissions, the protocol added strict greenhouse gas emission restrictions and reduction duties to developed nation members (AFAD 2014). According to Moosmann et al. (2021), the declines or restrictions accepted about the first phase of the program were somewhat lower than the emissions levels of 1990, but in particular nations, they represented a rise over that year.

Akay (2019) mentions two more actions as the most recent initiatives prior to the Paris Agreement. First is the Hyogo Disaster Risk Reduction Framework Action Plan. The United Nations acted to minimize catastrophic threats and accepted them in 2005 to promote resilience against extreme events till the target of 2015. It consists of five core objectives, three strategic milestones, and various performance measures for achieving the shared goal of disaster risk reduction. Second is the Sendai Framework for Disaster Risk Reduction. It was framed by the United Nations and signed by party countries in March 2015, in Sendai, Miyagi Province of Japan. Likewise, this program statement includes activities, goals, and guidelines for minimizing crisis vulnerabilities after 2015 and through 2030.

Until 2015, the agreements mentioned so far had a fixed number of members, but the fight against climate change required a larger-scale partnership, namely a global movement. Since the 1997 Kyoto Protocol, the world has been attempting to achieve this new global accord, however, a deal where all nations would agree at a consensus could not be obtained. On decreasing emissions of greenhouse gasses there was a significant disagreement, particularly among developed and developing countries. Shortly after the Sendai Framework for Disaster Risk Reduction was established, as Moosmann et al. (2021) explain, negotiations on such a consensus concluded in 2015 led by the French COP chair. Parties achieved an accord on 12 December 2015 and signed the Paris Agreement. It marks the first global agreement mandating all parties to take efforts to mitigate and adapt to climate change measures. Though each party decides the scope of its activity, the Paris Agreement includes global standards that are binding to all parties, creating a common procedures framework. According to Article 14, the Conference of the parties to this agreement will conduct its first worldwide assessment in 2023 and each five years afterward (UNFCCC 2015). The Paris Agreement, which emphasizes adaptation to the adverse consequences of climate change, also makes commitments to endorse susceptible undeveloped countries that will be severely affected by extreme events.

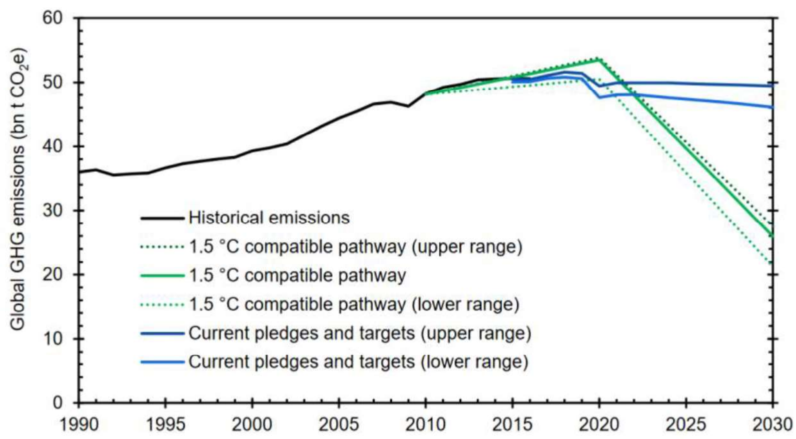

Figure 2.15. Emission paths to minimize global temperature rise and predicted pathways based on existing commitments and objectives according to Climate Action Tracker (Moosmann et al. 2021)

In relation to Figure 2.15, the objective is to keep the worldwide mean temperature rise far below 2°C over agrarian rates and to pursue measures to keep the temperature rise to 1.5°C over agrarian rates, understanding that doing so would greatly minimize the threats and consequences of climate change. However, Karakaya (2016) claims that the essence of such an assertive and ambitious goal is that a planet whose countries now use well over 80% fossil fuels should simply begin abandoning oil and natural gas, particularly coal, in favor of renewable energy. Currently, it is expected that the intended regulations of 187 countries aiming to reduce emissions with their National Contribution Statements submitted to the UNFCCC will exceed 2.7°C, which is well above the limit stipulated in the agreement.

2.3.1.2 National Approaches

The increasing frequency of natural disasters not only around the world but also in Turkey, has raised the question of how far the human role in these disasters should be tolerated in an industry that evolves with technology. Cities are the core of the climate change that is taking place because they create the majority of greenhouse gases. Per the estimations, urban settlements account for 70% of greenhouse gas emissions in Turkey compared to 80% in Europe. Thus, it is critical to identify potential threats in order to handle crises caused by climate change. Coordination between relevant parties and enhanced collaboration across institutions are essential for this activity to be executed in order to carry out new projects in a more efficient and well-organized manner. In this context, disaster management, drill incentives, and training activities are being implemented.

Turkey has made promises on disasters induced by climate change in a number of international policy instruments, including the United Nations Framework Convention on Climate Change, which it joined in 2004, and the Kyoto Protocol, to which it became a party in 2009. Turkey is also committed to implementing the Sendai Framework for Disaster Risk Reduction 2015-2030, the 2030 Agenda for Sustainable Development, the Paris Agreement on Climate Change, and the United Nations Convention to Fight Desertification (Akay 2019). Nevertheless, physical progress is arguable. Figure 2.16 compares Sendai Framework reporting from 2005 to 2021, and while neighboring countries routinely meet targets or somehow improve, Turkey appears to have gone in circles. Worse, no data sharing has occurred on behalf of Turkey since 2022.

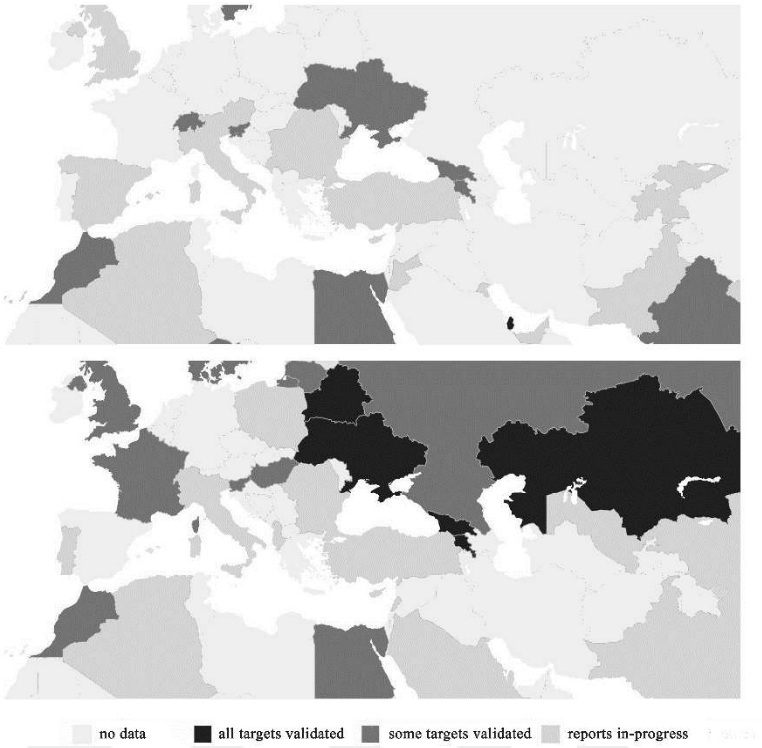

Figure 2.16. Sendai Framework for Disaster Risk Reduction global target reporting maps of 2005 and 2021 (https://sendaimonitor.undrr.org/) [adapted by author]

In the overall picture, however, there is a situation of compensating efforts. In retrospect, at the Rio Conference of the United Nations General Assembly in 1992, three fundamental environmental treaties were adopted: Climate Change, Biodiversity, and Combating Desertification. In 1994, the Convention to Fight Desertification was signed in Paris. Turkey is a signatory to the treaty, as are other Mediterranean nations suffering from drought. The Ministry of Forestry and Water Affairs, General Directorate of Combating Desertification and Erosion, is in charge of national contract coordination on Turkey's behalf. From 2013 to 2017, numerous action plans for fighting erosion were established and rebuilt based on this work (AFAD 2014). Besides, the Environment and Urbanization General Directorate of Environment Management Department of Climate Change of the Republic of Turkey

Ministry initiated a climate change action plan in 2012. A series of objectives and targets are listed under the principles of building, industry, agriculture and food security, land use and forestry, water resource management, and human health in this plan, which spans the years 2011 to 2023. With a strategy of balancing modes of transport in the transport sector, increasing rail transport, and decreasing road transport, thus limiting emissions from individual vehicles; alternative fuel and clean vehicle promotion are among the important targets. Despite this, it is still open to question how much of these were carried out until the target date, which is today.

The Sustainable Energy and Climate Change Action Plan (SECAP) Report of Antalya Metropolitan Municipality (2020) can be used to demonstrate why these actions should be taken more seriously in Turkey. The report states that just 14 of 30 metropolitan municipalities of the country own greenhouse gas inventories, as illustrated in Figure 2.17. In particular, nine of those municipalities have established a reduction, and five have developed an adaptation plan.

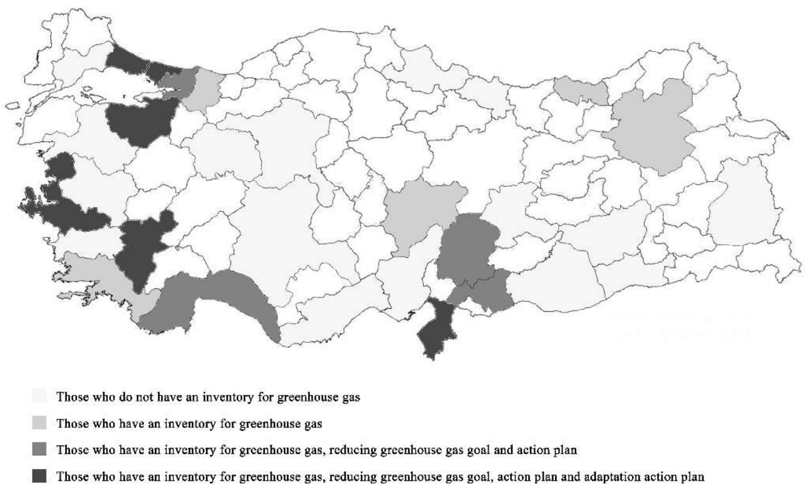

Figure 2.17. Local climate change action plans and municipal status as of December 2019 (Antalya Metropolitan Municipality 2020) [adapted by author]

On the other hand, the Eleventh Development Plan of Turkey for the next five years was announced in the Official Gazette of 2019. Climate change was addressed in a variety of ways in the strategy. The attention was centered around the worldwide expansion of climate change, but it was argued that the promises of developing economies in the framework of the Paris Agreement were insufficient to accomplish the defined mission and objectives (Akay 2019). To clarify this argument, it is necessary to examine the classification of Turkey in the agreement. Turkey has been placed on the Annex-I category of nations that will follow the reduced emissions expectation under the United Nations Framework Convention on Climate Change. Yet, solely for being an Organization for Economic Co-operation and Development (OECD) member, it was also added to the Annex-II category which financially supports underdeveloped nations. Correspondingly, Turkey opposed this placement and was removed from the second category in 2001 but kept on the Annex-I category. According to Karakaya (2016), Turkey benefited from the flexibility factor in the process and failed to generate climate awareness within the nation, thus falling behind in climate change actions. Considering that Turkey is a developing country, and the development of the economy is directly proportional to its energy demand, the negligent attitude in question is concerning. Moosmann et al. (2021) highlight this negligence by noting that Turkey continues to depend on fossil fuels and even aims to grow its coal capacity while being one of the nations in Europe with the greatest potential for the spread of clean energy. They estimate that, excluding hydropower, clean sources provided approximately 6% of electricity in 2015 and currently contribute 52% of built capacity. In this case, it is pivotal to correctly assess such a potential for the future of not only the country but the rest of the planet. Integrated with renewable resources, the application of adaptation and mitigation strategies should also be expanded by analyzing patterns from around the world.

2.3.2 Adaptation and Mitigation Strategies

It is acknowledged that human activity keeps heating the atmosphere and causes disruptions in the climate. Nonetheless, the distinguishing quality of weather-related disasters is that their risk can still be decreased and even avoided by tracking early warnings. Mitigation is a critical component of the fight against these threats of climate change, but adaptation is also required as a supplementary strategy. A commonly used hypernym that covers a wide range of both strategies is called nature-based solutions (NBS). The European Commission (2021) defines this term as nature-inspired schemes contributing to the development of environmental resilience, as well as having economic and social advantages. As shown in Table 2.4, these customizable and eco-friendly practices introduce more diversified surroundings into cities.

Table 2.4 Nature-based solutions (NBS) as an umbrella term (European Commission 2021) [adapted by author]

NATURE-BASED SOLUTIONS

Strategic Dimension	Spatial Planning Dimension	Soft Engineering Dimension	Performance Dimension
EbA: ecosystem-based adaptation	**GI**: green infrastructure	**SuDS**: sustainable urban drainage systems	**ESS**: ecosystem services
Eco-DRR: ecosystem-based disaster risk reduction	**BI**: blue infrastructure	**EE**: ecological engineering	
	GBI: green-blue infrastructure	**BMPs**: best management practices	
	UF: urban forestry	**LID**: low-impact design	
		WSUD: water-sensitive urban design	

The advantages of NBS rapidly drive cities to prioritize it against environmental problems and integrate these solutions within their bases. Frantzeskaki and McPhearson (2021) exemplify multiple applications across the world with the rain gardens of Malmo, Sweden which are expanded to serve as the main urban sewerage system, the living facades of Mexico City, Mexico to filtrate pollutants, and the Sponge Cities project of China as a classic prototype of NBS for flood control. Considering the rapacious attitude of present-day settlements, which generate waste and get their supplies from rural regions or already endangered ecosystems, NBS must be more widespread to protect populations from the increasing risks with each passing day. Figure 2.18 depicts the problem in modern cities and offers a new viewpoint on the ideal metabolism, in which every product becomes a reactant for another, resulting in a closed cycle.

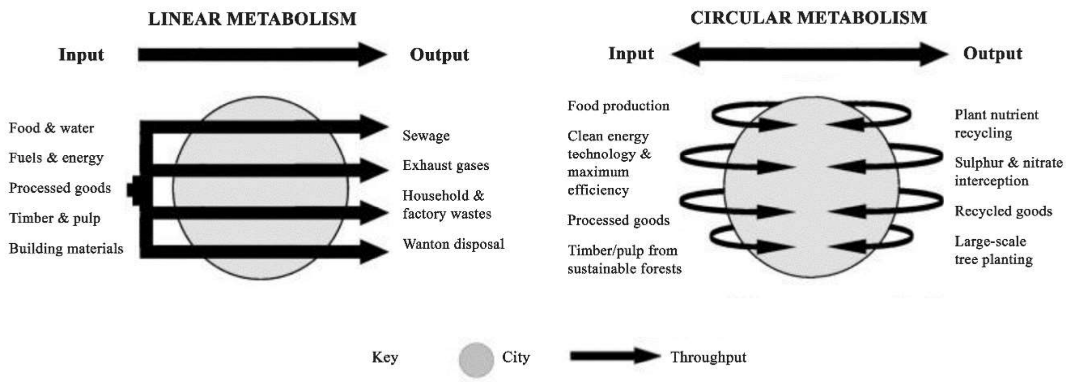

Figure 2.18. Linear and circular metabolism (Blogspot 2007) [Czapiewska, Roeffen, and de Graaf 2012]

The circular metabolism is expected to provide cities with not only increased efficiency but also increased resilience to future risk. The strategies that will be discussed in this section are based on the circular metabolism concept, with the goals of reducing future risks, expanding usable lands rather than rapidly erecting buildings, and thus supporting natural habitats and creating a better effect on the environment. As a scheme, conventional strategies will be introduced first, followed by more innovative approaches.

Recalling Figure 2.4, where floods are shown to have the highest occurrence rate, floodproofing is one of the most common ways of preparing for this type of disaster. Cao (2021) summarizes floodproofing fundamentals as lifting the structure above the water levels, waterproof construction, and installing barriers such as floodwalls or levees. Sensitive units such as heating, ventilation, and air conditioning equipment, as well as other technical systems should be addressed when lifting the structure. Waterproof construction, on the other hand, includes coating, sealant, and waterproof varnish. These are dry floodproofing components, but wet floodproofing with foundational valves or dewatering pumps is also an option. Because wet floodproofing allows water to enter the building, flotation must be considered, so reservoirs and other crucial devices must be fixed. Extra attention should be paid to protect the key infrastructures and emergency facilities on an urban scale.

Another conventional practice is to take advantage of heavy rains that cause flooding. The cities who are aware enough to properly make use of rainwater, implement it from flushes to nourish greeneries, rather than sending it to drainage. With a simple solution like buried tanks, even the most concrete and asphalt jungle cities can store rainwater. Hence, this strategy can decrease the demand for additional water supply. Australia advanced this concept by pioneering water-sensitive urban design (WSUD) around the world, as referred to in Table 2.4. It is a still developing field that incorporates surface waters and substructures in the preliminary phases of urban plan regulations. Not only can urban water planning help with distribution management, but it can be used to generate power as well. The Dutch city of Hertogenbosch is a good example of this principle in action. The pool in Figure 2.19

is placed to capture the most sunlight during the summer. The heat of the pool is kept in thermal storage and throughout the winter, it is deployed to warm up the residences and workplaces around the neighborhood.

Figure 2.19. A depthless pool in Hertogenbosch acts like a solar panel for the surrounding buildings (Aparicio 2008) [Graaf 2012]

On the other hand, more holistic approaches are required now that the world has reached a point of no return due to global warming, making partial solutions obsolete. On his way to the overall picture of an ideal settlement, the cities of the future, Graaf (2012) draws attention to the benefits that urban densification can provide. First, empty grounds will enlarge, bringing a second chance with an effective approach to natural assets. Accordingly, when the urban boundaries shrink, energy demand for mobility will decrease. The accessibility of cities will improve, mass transit and even bicycles will become the preferred mode. However, to make this strategy work, the designed plots must include multi-purpose programs when the population is pushed to fit into them, as opposed to the separated fixed functions of modern-day cities.

The entire point of the densification argument is to gain as much space from the land surface as possible, which leads to a larger move in the form of expanding multifunctionality into water surfaces. In particular, floating settlements allow for more flexible utilization of space in highly inhabited zones and cause no structural harm due to flooding since they adjust to changing sea levels. Furthermore, reefs can be imitated to guard the water surface from tides while providing excellent homes for a variety of wildlife. Czapiewska, Roeffen, and de Graaf (2012) agree on the benefits of floating settlement, and a future vision is depicted in Figure 2.20. They focus on delta cities as a pilot study for this major step because these areas already have limited room for either urban or agricultural growth, in addition to being the most prone to flooding.

Recalling the principles of circular metabolisms, production is essential to balance out the waste of urban machines. Reef implementations realize this up to a certain point, but the idea can be improved. Using innovative solutions for water-based agriculture, such as the aquaponic system, can result in a win-win situation when combined with floating settlements. Aquaponics mimics a self-sufficient environment that involves both plant and fish breeding since plants and microorganisms clean the water by consuming fish waste (Figure 2.21). While meeting the increasing protein needs of the world, this strategy also secures the land gains discussed above by reducing livestock raising on plains. In short, it all comes down to shifting every possible function on the water so that nature can be restored with farmlands on the ground (Graaf 2012).

Figure 2.20. Future vision for floating settlements, titled “Cyclicity” (Czapiewska, Roeffen, and de Graaf 2012)

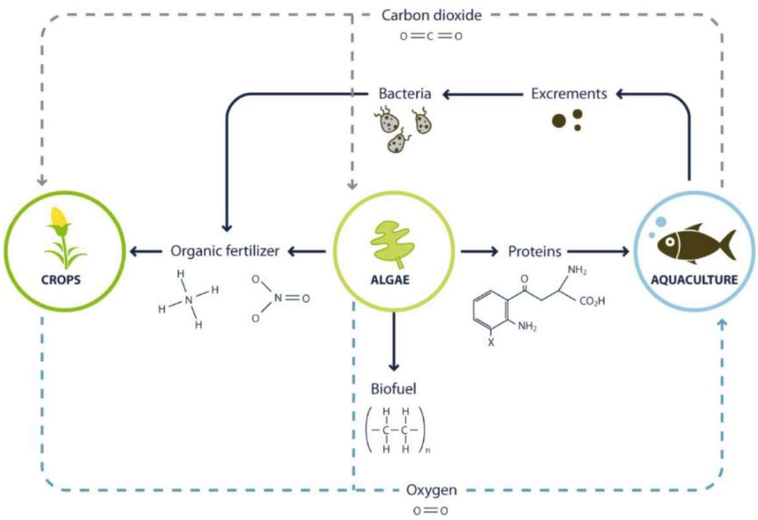

Figure 2.21. Potential pollutant conversion to essential nutrients (Czapiewska, Roeffen, and de Graaf 2012)

It has been priorly mentioned that adaptation is required as a supplementary strategy to mitigation. Now that these supplementary strategies have been introduced, the mitigation strategies will be covered as a more critical component in the fight against climate change. Aside from the fact that climate change poses an indirect threat to the future, there are current reflections that directly endanger the health of all living beings. One of the reflections appears to be air pollution. Its effects are most noticeable during warmer seasons when human activity rises and still air prevents circulation. Yet, the percentage of particles is expected to climb as cities expand and exhaust emissions increase regardless of the season.

To begin with the conventional solutions, it is widely acknowledged that more greenery is required because there is not as much of it left on streets for residents with skyrocketing city populations. Before discussing the climatic benefits of greenery, it is worth noting that anything related to nature is extremely helpful to both physical and mental health. Even the most basic park can alleviate the pressure of city life, foster community, and enrich the city silhouette. On the other hand, greenery when integrated with buildings, may be the most rewarding yet effortless way to achieve desired climatic effects. They significantly decrease summer sun exposure by creating shade, and their insulation properties limit both sound and heat transmission from the building envelope in the winter. Thus, properly applied green surfaces maximize the efficiency of heating, ventilation, and air conditioning systems, which leads to lower utility bills. To encourage and disseminate their use, the Victorian Government (2014) describes the primary green surface options:

Green roofs are commonly classified as either extensive or intensive. The former is lighter and has lower maintenance because it is not open to the public, whereas the latter is heavier and intended as recreational areas that the community can use. Therefore, green roofs have several purposes including design expressions, public venues, increased worth of estates, and specific environmental gains such as rainwater management, heat insulation, or ecological variation. With a combination of natural and synthetic materials as shown in Figure 2.22, they can improve the longevity of a typical roof by securing the waterproof sheets as well as balancing out extreme weather changes. Moreover, green roofs which soak and hold water, can even contribute to urban flood control if widely used.

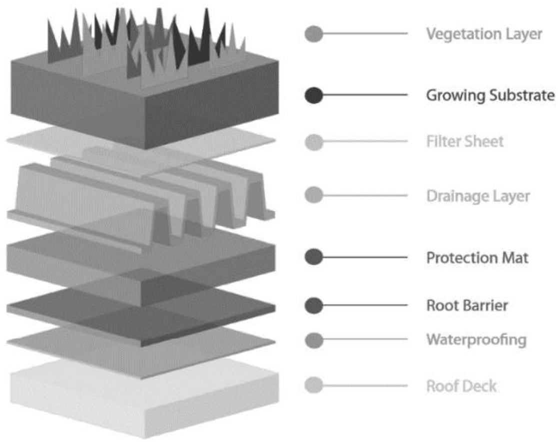

Figure 2.22. Green roof layers (Victorian Government 2014)

Victorian Government (2014) states that another green surface application is on walls, which is suitable for both the interior and exterior of a building. This vertical plantation method is typically built to make an eye-catching architectural statement while serving a greater purpose. Green walls cool and filter the air around them and are also adopted to preserve flora in strategic places where no other plantation can be applied. A green wall can be installed in multiple ways, some of which rely heavily on hydroponics, and the rest on potting. Nonetheless, they require a substantial amount of watering in both cases. Living facades, as an alternative, are applied with creepers, which cover the facade over time, and plants are usually rooted at ground level, hence it can be argued that they require slightly less labor to implement. After all, it is worth adding that in cases where a green roof or a green wall is not feasible, the use of high albedo surfaces may still be an advantageous option. Reflective tints on these surfaces function similarly to green surfaces in that they limit heat release, minimize the urban heat island effect and lower cooling bills.

As discussed in the adaptation strategies, more comprehensive mitigation approaches also provide more benefits at the urban scale. Similarly, to the floating city example (Figure 2.20), the Chicago Department of Transportation (2007) reimagines traditional neighborhood alleys and publishes a series of complementary urban-scale techniques. The starting point is that alleys serve a city enormously, yet as with any infrastructure, they demand regular upkeep and renovation. It is common in Turkey to cut and fill not only alleys but even busy streets in response to minor to major problems, which not only disturbs residents on a continuous loop but also costs a lot of money due to the repetition. Consequently, in light of pioneer examples, more sustainable and holistic measures must be executed as soon as possible. One of the most practical measures to transform cities is to convert impervious chunks of manmade grounds to permeable pavements. This seemingly trivial example of tactical urbanism, also known as "depaving", is incredibly profitable. According to the Chicago Department of Transportation (2007), if all alleys are built with permeable pavements, 80% of the annual rainfall can flow directly to the soil, so that flood risks can be minimized, underground water can be replenished, and budgets used for stormwater management can be saved. In an optimistic scenario where climate change does not bring recurring or heavier rainfall, the rapid urbanization which covers every green meter square with asphalt or concrete, will still pose a significant problem whenever it rains. That is why it is critical to reduce rainfall runoff and discover ways to appropriately integrate it with sewage systems. Even a few minor adjustments can result in a major effect.

Depending on the size of the depaving projects, expert support might not be required throughout the implementation process. On an urban scale, however, the financial estimates might appear expensive. Fortunately, in such cases, numerous financial options are available such as grant requests or fundraising through local charities.

Meanwhile, there is another option. The London City Hall Grey to Green Guide (n.d.) mentions the power of social media and suggests announcing depaving via different platforms so that local community activities can be organized. This way, an experience of unity can be gained through civic engagement. Nevertheless, there are certain issues to consider before depaving. As listed by Iserhott et al. (2015), some of these include soil analysis, infiltration assessments, drainage connections, and existing subsurface utilities. That being said, when depaving is combined with further plantation tasks, an aesthetically appealing spot can be achieved with comparatively less manpower, resulting in a peaceful place where neighbors can wander and connect with the outside. Given the recent Coronavirus quarantine, which has fueled the desire for nature and do-it-yourself project trends, raising awareness in different age groups may also be an important outcome by initiating events for teenagers too and disheartening them from dumping trash in their neighborhoods. Besides, real progress begins with the youth, and schools should be responsible to provide the ideal setting for environmental awareness through outdoor activities.

The Chicago Department of Transportation (2007) introduces more strategies for a sustainable neighborhood, ultimately leading to sustainable cities. One of them, as illustrated in Figure 2.23, is drainage optimization by slopes which forces water to pass through the middle of alleyways before reaching the main streets, removing the necessity for extra sewer pipes while protecting nearby houses against flood risks.

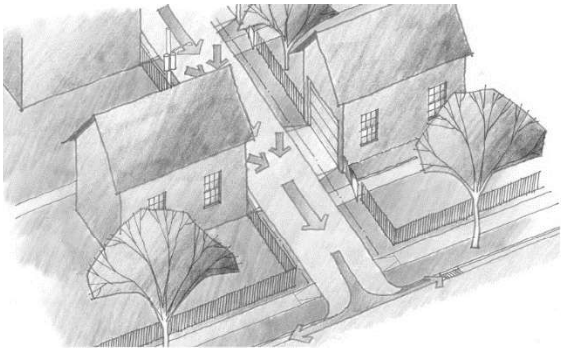

Figure 2.23. Sloped alley with walkway ramps and driveway aprons channeling water to the existing sewage system (Chicago Department of Transportation 2007)

Another strategy on the path to sustainable neighborhoods is the use of night sky sensitive streetlamps as shown in Figure 2.24. Such a small modification helps to eliminate glare and light pollution, but most importantly it saves energy. Kardel (2012) estimates that 30% of streetlights are wasted because they shine upward at night instead of lighting the streets. According to this estimate, approximately 22,000 gigawatt-hours are wasted annually, and it converts to $2.2 billion and 3.6 tons of coal each year, which unfortunately contributes to greenhouse gas emissions.

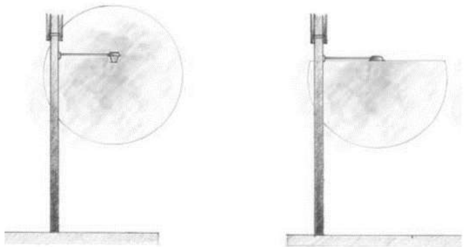

Figure 2.24. Common streetlamp and night sky sensitive streetlamp comparison (Chicago Department of Transportation 2007)

There are particular mitigation strategies for stormwater management as well, and those that are most prevalent, such as rain gardens and bioswales, demand little basis. The primary distinction between the two is that bioswales are intended to slow the flow of rainwater along a predetermined path, whereas rain gardens capture and infiltrate rainwater as it flows to buried pipelines. Bray et al. (2012) explain that rain gardens initially appeared in the United States in the 1990s, and imitation of this natural drainage was later promoted in the urban locations of the United Kingdom. This method eventually became known as Sustainable Drainage Systems (SUDS), which is directly connected to the previously described Water Sensitive Urban Design (WSUD). A rain garden is an excellent choice for mitigating the effects of impermeable surfaces because, as shown in Figure 2.25, it is simple, cheap, environmentally friendly, and visually appealing. According to the United States Department of Agriculture (2014), additional benefits of this application include clearing out puddles, less mosquito breeding, and more beneficial insects, resulting in a higher real estate worth with less garden maintenance. A bioswale, on the other hand, is a shallow, longitudinally sloped pit filled with native vegetation that manages stormwater overflows from roofs and roads (Figure 2.26). Iserhott et al. (2015) affirm that bioswales, like rain gardens, are cheaper than a typical sewage system, more appealing, and can improve wildlife habitat.

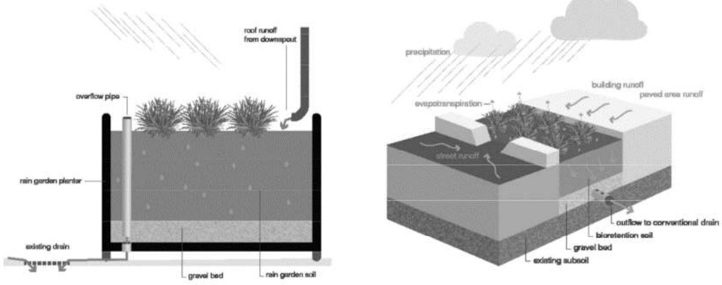

Figure 2.25. Rain garden on a residential and street scale (Bray et al. 2012)

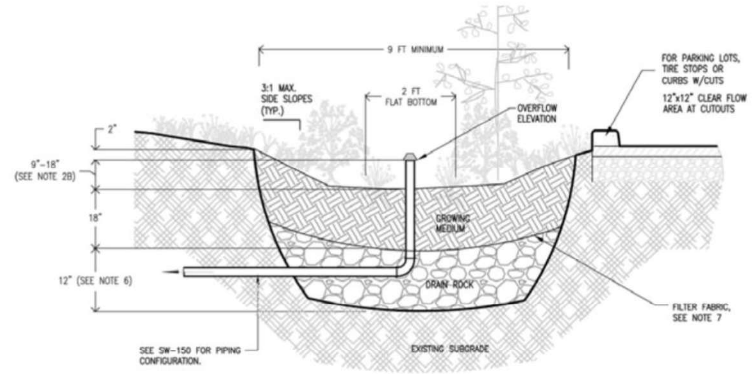

Figure 2.26. A vegetated bioswale (Iserhott et al. 2015)

However, these solutions can and should be supplemented with a couple of additional strategies for better results. For example, a rain barrel can capture and save rain from the top of a structure for a variety of purposes, such as watering gardens. This way rainwater would be recovered, and the amount of overflow would be controlled once more. For bigger scales, naturalized detention basins can be used to hold rainwater on ground level for a longer period before gradually discharging it in a systematic manner. The Chicago Department of Transportation (2007) explains that such basins are designed to appear and work like wetlands with indigenous vegetation sprouting on both sides of the water surface. They lower the amount and flow of rainwater, filter particles, and offer an inviting shelter for animals.

In summary, Table 2.5 categorizes the aforementioned strategies, as well as a few more fundamental solutions such as recycling, composting, planting, and native landscaping, into appropriate typologies. Once again, it should always be remembered that holistic thinking is the key to successful outcomes.

Table 2.5 Summarize of the solutions on residential, commercial, and industrial typologies (Chicago Department of Transportation 2007) [adapted by author]

Residential	Commercial	Industrial
✓ permeable pavement ✓ green roof ✓ energy efficient lighting ✓ recycling ✓ planting a tree ✓ native landscaping ✓ rain garden ✓ rain barrel / cistern ✓ **composting**	✓ permeable pavement ✓ green roof ✓ energy efficient lighting ✓ recycling ✓ planting a tree ✓ native landscaping ✓ rain garden ✓ rain barrel / cistern ✓ **naturalized detention** ✓ **bioswales**	✓ permeable pavement ✓ green roof ✓ energy efficient lighting ✓ recycling ✓ planting a tree ✓ native landscaping ✓ rain garden ✓ rain barrel / cistern ✓ **naturalized detention** ✓ **bioswales**

2.4 Antalya Case

The connection between rapid urbanization and climate change has already been discussed in previous sections. Turkey, like many other countries, especially developing ones, is severely affected by this issue. Being a country surrounded on three sides by the sea raises concerns not only in metropolitan cities but also along the coast. Indeed, Yiğit, Kaya and Şenol (2022) state that with the appearance of humankind, a huge portion of the global coastlines has come under attack, bringing significant shifts in a short period, including unregulated touristic activity, interruption of ecosystems on the shores, and certainly, climate change. The Mediterranean coast, in particular, is argued to be among the top areas prone to climate change, both in terms of global warming and additional risks associated with weather events; as recognized by the Intergovernmental Panel on Climate Change (IPCC) as well. In terms of discussed human activity, Antalya, a Mediterranean coastal city, is a well-known vacation spot both in the region and around the world. Masses of tourists from overseas and other localities visit the city, boosting the national economy immensely. The distinctive promotion policy of Antalya is the popular sun-sea-sand concept, which has been upgraded by more attractions, namely cultural and sporting events along its approximately 650 kilometers of coastline. Sports made an appearance in the national economy due to the convenient mild climate all year round, causing increased activity in off-seasons as well, with new facilities opening every year. Unfortunately, this investment resulted in even more forestry devastation. Figures 2.27 and 2.28 show the overall effects of such activities, which result in increased greenhouse gas emissions and weather-related disasters.

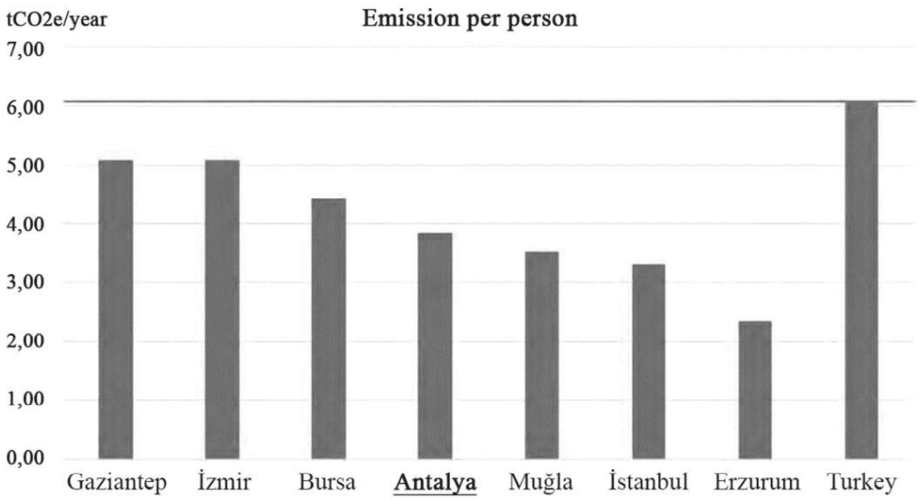

Figure 2.27. Emissions per capita for municipalities with a greenhouse gas inventory (Antalya Metropolitan Municipality 2020) [adapted by author]

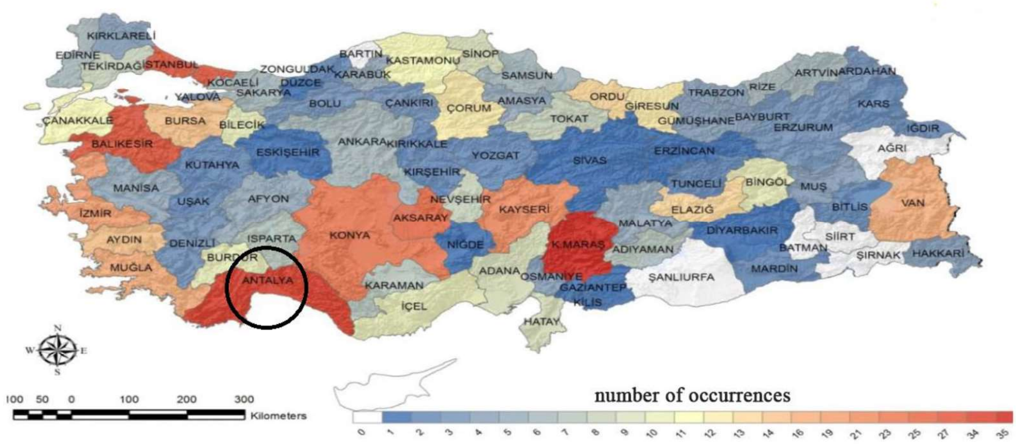

Figure 2.28. Weather-related disasters by the city in 2017 according to the Turkish State Meteorological Service (MGM) 2018 database (Akay 2019)

As shown in Figure 2.27, Antalya has surpassed the metropolitan city of Istanbul in terms of greenhouse gas emissions. The cause-and-effect relationship of the situation, on the other hand, is visible in Figure 2.28, ranking Antalya second after Kahramanmaraş city in terms of weather-related disaster occurrence rate. Furthermore, the fact that the latter analysis is three years behind the first highlights the critical state of Antalya in the coming years. In response, the city has begun to prioritize resilience strategies and has accelerated the development of action plans, particularly in the last five years. However, not many risky cities in the country are that aware of the common problem, nor do they have hands-on solutions. There are studies on major cities such as Istanbul, Ankara, and Izmir, and the severity of the situation is understood in these locations, but most of the remaining cities have insufficient data because they still do not prioritize fighting climate change. Antalya clearly falls between the two treatments by being more productive and willing to take an active role in combating climate change than the other neglectful cities, but studies in literature still lag behind the mentioned major cities. This position makes Antalya a convenient research subject. Therefore, the impact of the previously discussed extreme events on Antalya, potential risks that are expected to shape the future of the city, and existing responsive action plans will be covered in this section. Such a concentrated review will aid in determining strategies to contribute to and improve the resilience of Antalya in the following chapters.

2.4.1 Impact of Extreme Events

Given that the area surrounding the Mediterranean Sea ranks among the most vulnerable to global warming, sea level changes will inevitably hit Turkish Mediterranean cities too. AFAD (2014) reveals that sea level continues to rise by 4 to 8 millimeters every year, according to the Turkish National Sea Level Monitoring System reports. Unfortunately, the shift in water levels endangers millions of individuals who reside along these coasts, as well as utilities and farming fields. As the capital of the Mediterranean region in Turkey, Antalya is under severe threat in the long run when compared to other cities in the basin. Figure 2.29 depicts the tide records for six Mediterranean cities, and it is clear that the projected trends for Thessaloniki and Antalya shift faster in comparably less time. Global warming also causes more irregular and prolonged precipitation than ever before, leading to overflows in Antalya. Yilmaz (2015) reports that precipitation rates in Antalya have been shown to rise by 23% in the following years. In return, Figure 2.30 from Climate Central depicts the potential risk in Antalya, showing that areas marked in red are expected to sink at least one meter by 2070.

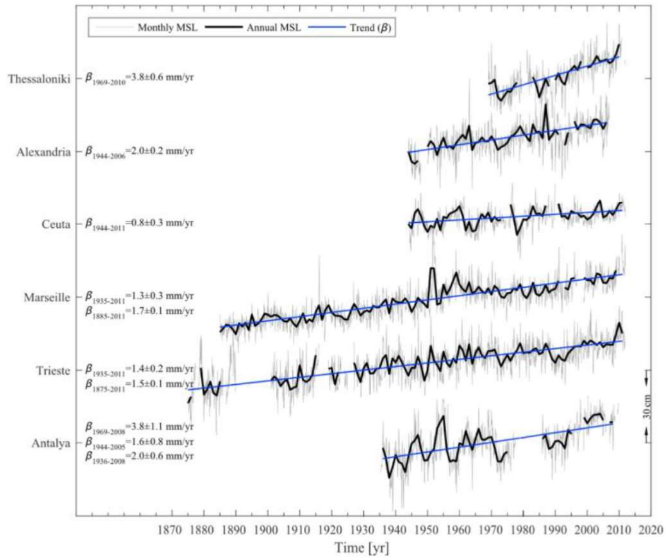

Figure 2.29. Monthly and yearly mean sea level of tide gauge data, as well as their projected trends (Ozturk et al. 2018)

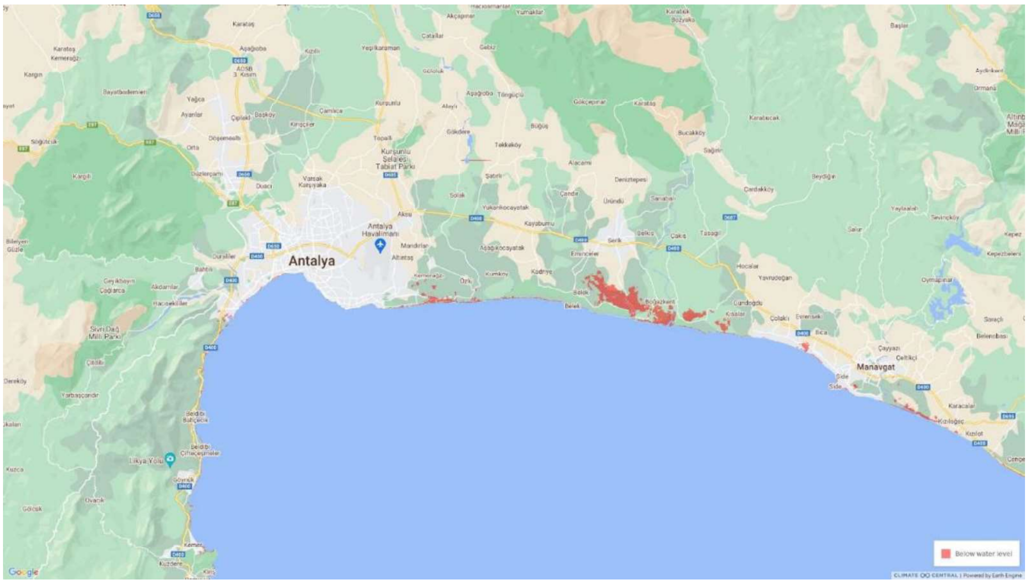

Figure 2.30. Coastal risk screening tool displaying ground below 1.0 meters of the sea by 2070 (Global Screening Tool 2023) [generated by author]

Aside from the heavy rainfall that affects flood occurrence rates, storms have also started to bring strong winds in recent years, which is not a common weather event in Antalya. According to Figure 2.31, Antalya was one of the top three cities in the country where storms and strong winds struck in 2017. A storm that took place in 2019 as shown in Figure 2.32, on the other hand, can be used to exemplify the benefits of making a timely announcement. Akay (2019) recalls that the Meteorology 4th Regional Directorate issued an announcement of severe rainfall and whirlwinds in the urban center at the time, and indeed, the expected incident happened following this announcement. It swept off roofs and flipped a bus, but fortunately, no one was killed.

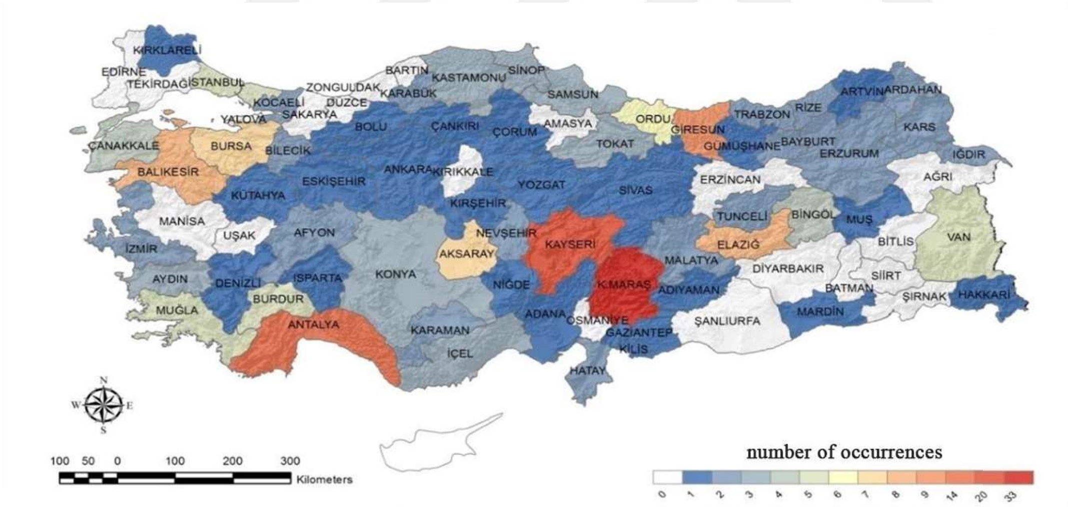

Figure 2.31. Cities affected by storms and winds according to the Turkish State Meteorological Service (MGM) 2018 database (Akay 2019)

Figure 2.32. The whirlwind that hit Antalya (Sabah 2019) [Akay 2019]

As mentioned in previous sections, changes in precipitation rates affect even mass movements, such as soil erosion. While earthquakes are the main cause of mass movements, they are not a priority problem in Antalya compared to other cities because it is free of active fault lines, as shown in Figure 2.33, but soil erosion is still a concern. Yiğit, Kaya and Şenol (2022) reported remarkable erosion over 5 and 35-year time periods, measuring nearly 20 meters of erosion and 10 meters of accretion. The levels of erosion along the Konyaalti coast are represented in Figure 2.34.

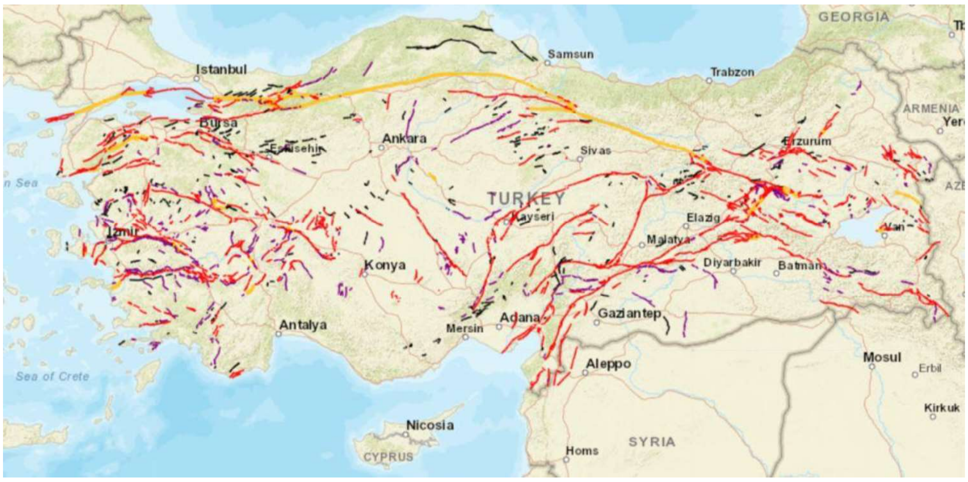

Figure 2.33. Active fault map of Turkey (General Directorate of Mineral Research and Exploration 2023)

Figure 2.34. The Digital Shoreline Analysis System outcome for Konyaalti, Antalya (Yiğit, Kaya and Şenol 2022)

On the other hand, the most noticeable long-term change for Antalya is the worsening effects of global warming. The dry and hot weather of the Mediterranean climate becomes unbearable, and the summer season extends into the fall season, causing agricultural processes to shift. Another impact of this change applies to tourist activities of the city, resulting in high density for longer periods, and contributing to the urban heat. The interrelationship between global warming and human activity has led to drought in Antalya over the last decade, which is one of the most critical extreme events that millions of people worldwide are already suffering from. The Antalya city center is framed within the D3 category by the National Integrated Drought Information System (2023), as displayed in Figure 2.35.

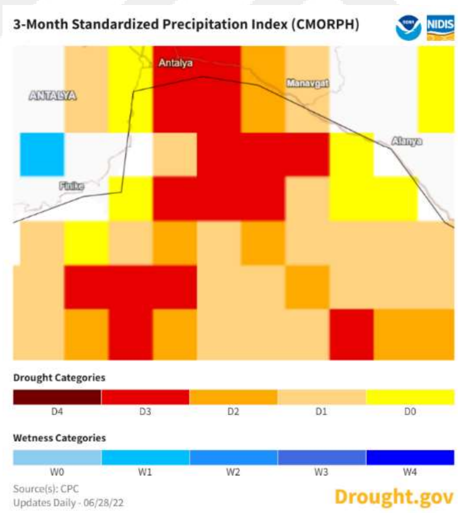

Figure 2.35. International drought data for Antalya (National Integrated Drought Information System 2023) [generated by author]

Unfortunately, extreme events work as chain reactions, and in this regard, drought is a catalyst for wildfires since greenery dries and gets combustible. Furthermore, when wildfires erupt, massive amounts of CO_2 emissions, as well as other released pollutants, degrade air quality and add to global warming in the chain reaction. The 2008 Antalya wildfire, which was announced by mass media as the largest forest fire in national fire statistics up to that point, is subjected to a radiometer efficiency study by Baldassarre et al. (2015). The fire was so severe that it destroyed approximately fifteen thousand hectares of forest in just a few days, dramatically increasing CO and NH_3 concentrations. Following the 2008 disaster, many smaller-scale wildfires occurred during the summer seasons. However, in 2021, another critical wildfire broke out and lasted nearly two weeks (Figure 2.36). According to the Turkish State Meteorological Service (MGM) climate assessment report for 2021, the fire began in Antalya and spread to 44 towns across Turkey, killing three people and injuring hundreds of others while burning hundreds of thousands of hectares of forest and residential areas, killing thousands of animals, and evacuating thousands of people. Figure 2.37 depicts wildfires in 2021, with hundreds of fire alerts captured within the borders of Antalya, and they are classified as high level in relation to the past until 2012.

Figure 2.36. 2021 Antalya wildfire (MGM 2022)

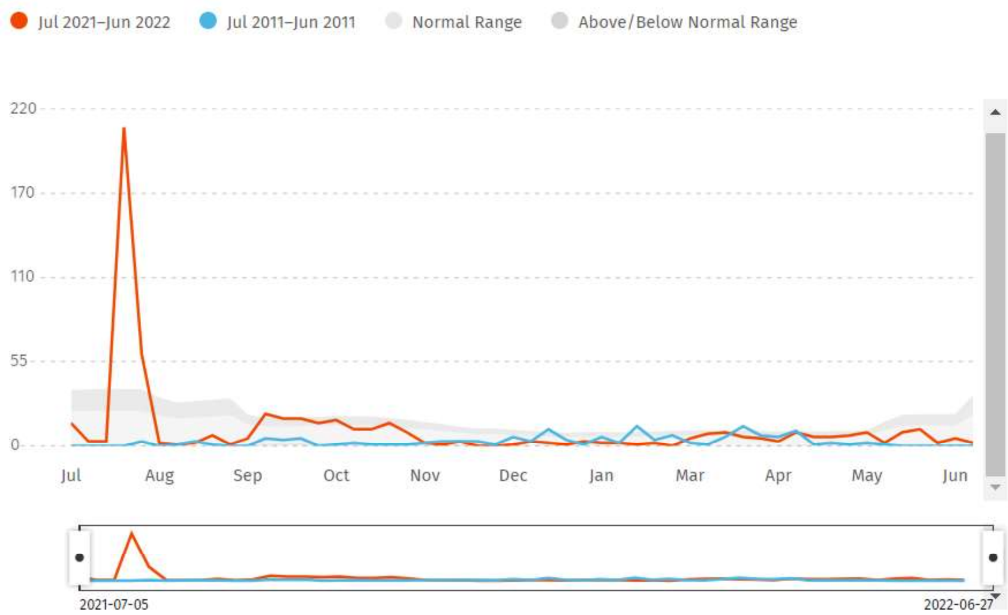

Figure 2.37. 2021 Antalya wildfire compared to the years dating back to 2012 (Global Forest Watch 2023) [generated by author]

2.4.2 Potential Risks

To build climate-resilient cities, it is critical to archive past extreme events in the history of a city and assess the cause-and-effect relationship of these recorded disasters. However, a worthier approach for more effective response actions is to thoroughly investigate the source of the problem. The previous section revealed that the major issue in the Antalya case was the consequences of global warming, such as increased drought and wildfires, which extended the intolerable hot seasons over almost a whole year. Therefore, the sources of excessive heat in Antalya and the potential risks they pose will be reviewed in greater depth.

2.4.2.1 Rapid Urbanization and Carbon Footprint

It is widely acknowledged that rapid urbanization implies increased human activities and a corresponding rise in greenhouse gas emissions directly contributes to global warming. Yet, aside from urban heat, another long-term issue caused by rapid urbanization is resource scarcity. Figure 2.38 reveals that the human race currently consumes an additional 50% of the resources that the earth is able to supply. In other words, natural wealth is running out quicker than it is renewed. Graaf (2012) predicts that a total of three earths will be required to meet the demands of the global population in 2050, which indicates that the increasing population and the expansion of urban areas result in a severe scarcity of land. Furthermore, global warming will exacerbate the scarcity problem due to carbon emissions from nonrenewable resources that are heavily relied on around the world.

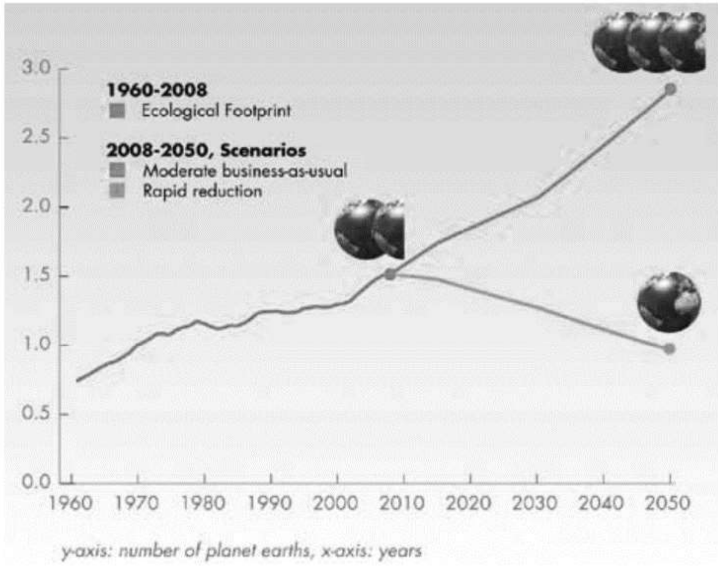

Figure 2.38. Global footprint estimation (Graaf 2012)

The situation in Antalya is not much different. Despite an irregularity in the annual population growth rates of Turkey, Table 2.6 highlights the share of Antalya on the national scene. The population ratio of the city to the country, in particular, appears to be steadily increasing. Also, Figure 2.39 illustrates the population density of the city in 2015 and the expanding urban area around the city center draws attention. For a clearer understanding, Figure 2.40 depicts a comparison from 1975 to 2015 and it appears that from 1990, the rural areas of the city face a decline in population, only to be concentrated in the city center. A closer look at the city center, as shown by satellite images in Figure 2.41, reveals the increasing density caused by rapid urbanization.

Table 2.6 Average annual rate of population change (TUIK 2018)

Year	Antalya	Turkey	Antalya/TR Ratio (%)	Years	Annual Average Population Growth
1990	1.132.211	56.473.035	2,00	1990-2000	4,26 %
2000	1.719.751	67.804.927	2,54	2000-2008	0.98 %
2008	1.859.275	71.517.100	2,60	2000-2008	1,23 %
2009	1.919.729	72.561.312	2,65	2008-2009	3,25 %
2010	1.978.333	73.722.988	2,68	2009-2010	3,05 %
2011	2.043.482	74.724.269	2,73	2010-2011	3,29 %
2012	2.092.537	75.627.384	2,77	2011-2012	2,40 %
2013	2.158.265	76.667.864	2,82	2012-2013	3,14 %
2014	2.222.562	77.695.904	2,86	2013-2014	2,98 %
2015	2.288.456	78.741.053	2,90	2014-2015	2.96 %
2016	2.328.555	79.814.871	2,91	2015-2016	1,75 %
2017	2.364.396	80.810.525	2,92	2016-2017	1,53 %

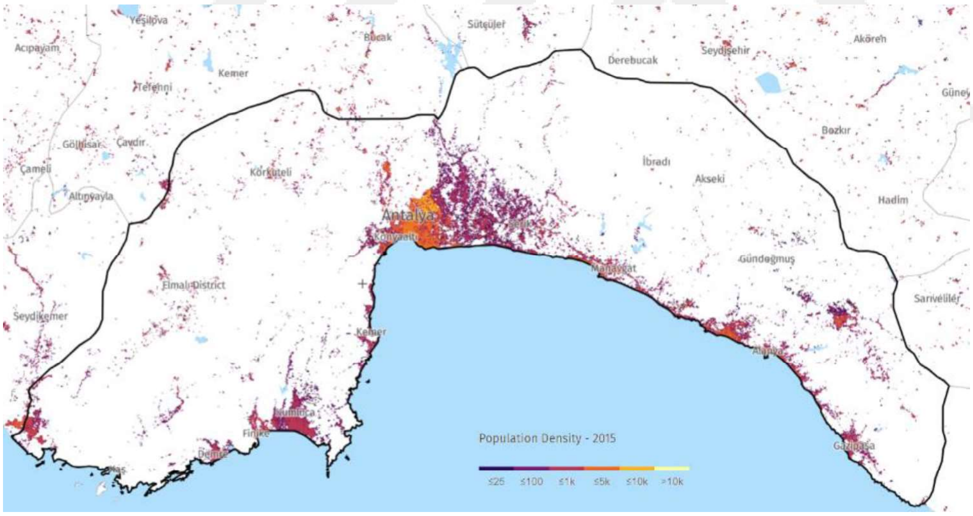

Figure 2.39. Antalya population density in 2015 (Global Forest Watch 2023) [generated by author]

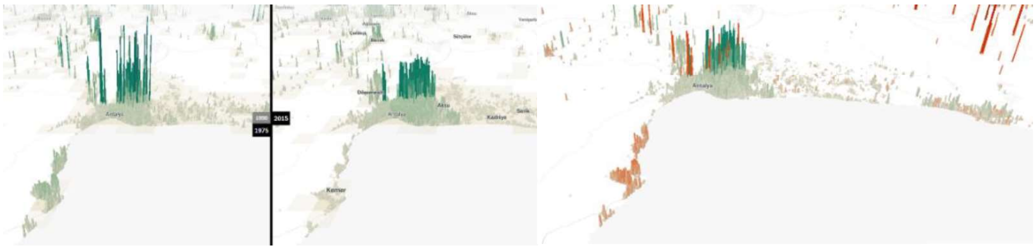

Figure 2.40. Population of Antalya in 1975 and 2015, and the decline is shown in red while growth in green from 1990 to 2015 (Human Terrain 2023) [generated by author]

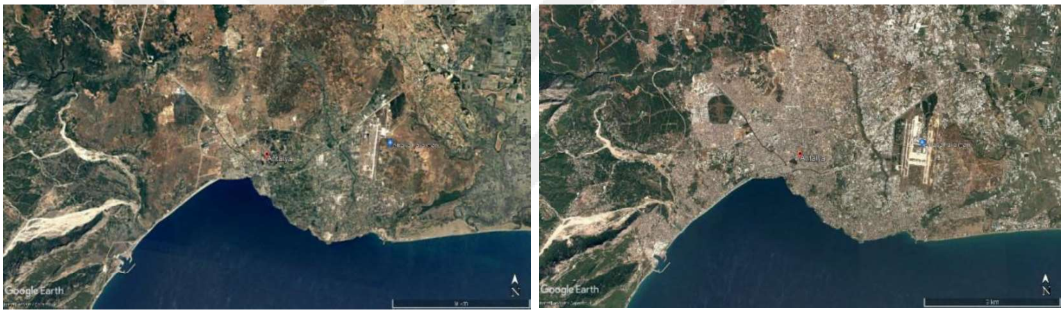

Figure 2.41. Satellite images of Antalya city center from 1984 and 2022 respectively (Google Earth Pro 2023)

Another great way to analyze urbanization rates is to check the figures of gross domestic product per capita. The logic behind such a relationship is that population growth and mass migration to urban centers from rural areas help to increase labor and goods which in turn expands the economy. Correspondingly, higher gross domestic product per capita indicates more urbanized areas. Given that Antalya is the established tourism center of Turkey, accounting for one-third of total tourist arrivals, this feature places it third among the top 15 cities that add to the gross domestic product percentage rate of the country as of 2019 (Figure 2.42). However, there is an important problem that has been overshadowed by economic gains. Rapid urbanization continues to deplete natural resources. Forestlands are critical for compensating for CO_2 emissions, and since tree cover loss has reached a significant level, CO_2 absorption has also decreased significantly. Although the Antalya wildfires of 2008 and 2021 make a notable appearance in the databases, the joining of rural areas into urban nodes has an impact on tree cover loss as well. One of the primary causes of urban heat is a lack of trees, which are possibly the most efficient shading devices in urban areas. In addition, it should be remembered that many recent forest fires were started due to human mistakes, or worse, on purpose. According to the Global Forest Watch data analysis displayed in Figure 2.43, Antalya lost 47.9 thousand hectares of tree cover from 2001 to 2021, a 15% decline from 2000, and it lost 76.2 thousand hectares more in 2021. Zooming in from 2013 to 2021, the overall loss in the natural forest was equivalent to 5.18 metric tons of CO_2 emissions.

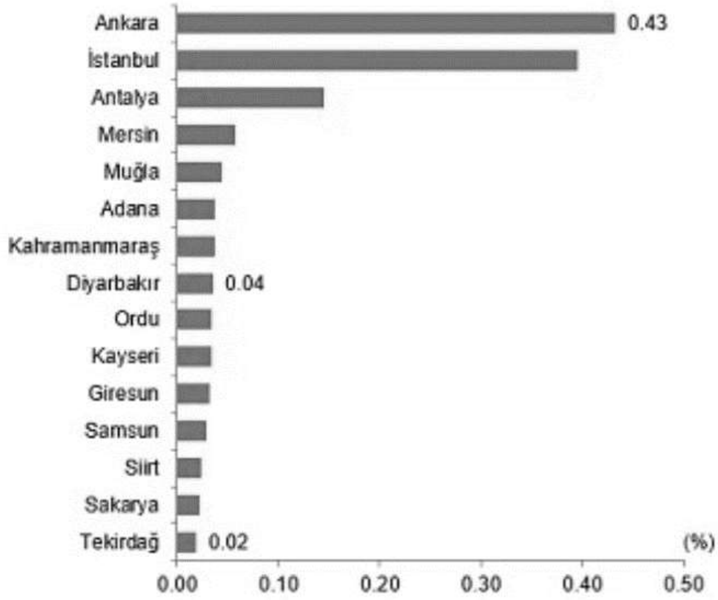

Figure 2.42. Top 15 cities adding to the gross domestic product percentage rate of Turkey (TUIK 2021)

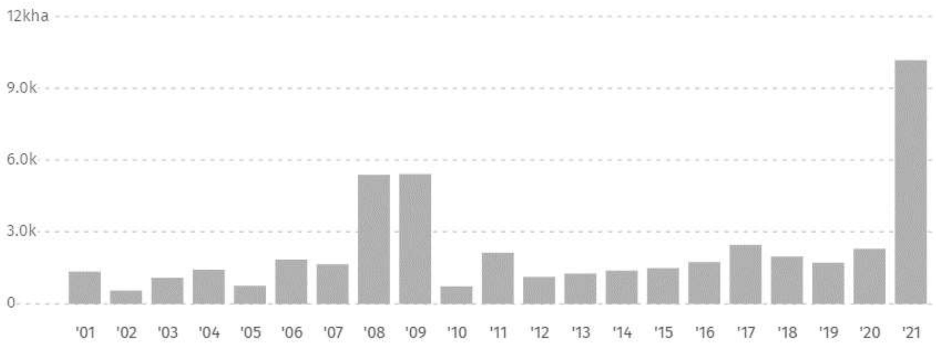

Figure 2.43. Antalya tree cover loss (Global Forest Watch 2023) [generated by author]

2.4.2.2 Urban Heat Island Effect

The Environmental Protection Agency of the United States (2008) describes urban heat islands as increased temperatures in urban centers relative to more rural towns, where it is basically classified as surface urban heat islands and atmospheric urban heat islands. Surface urban heat island exists at all hours of the day but is strongest in daylight and in the summertime. It is assessed in an indirect manner using remote sensing and the outcome is thermal images. Atmospheric urban heat islands, on the other hand, can be minimal or even absent in daylight yet peak at night and in the wintertime. It is monitored using fixed observatories and the outcome is maps and graphs. Although heat islands are driven by the geographical position and meteorological conditions of an area, key variables include urban growth and variations in the surface attributes of urban facilities, as well as urban planning, which affects local micro-climates by regulating air circulation. Victorian Government (2014) adds that rapid urbanization has shifted ecosystems into the built environment. Consequently, increased heat emissions from industrial equipment and heat accumulation on structures and roadways, has led to excessively hot weather in urban areas. Fortunately, there are several adaptation and mitigation strategies for urban heat islands, some of which were discussed in previous sections. Aside from dealing with this unwanted effect, such strategies provide energy efficiency, air purification, and carbon release reduction, ultimately contributing to the fight against climate change. In Figure 2.44, Voogt (2014) summarizes the influencing factors of urban heat islands, and widely accepted mitigation measures include natural or artificial shading elements, high reflective surface materials determined by their albedo value as a radiative property, surface moisture, and appropriate heat storage in construction materials. The United States Environmental Protection Agency (2008) makes an important point that the urban heat island effect might even be advantageous in the winter. The impact of heat can assist lower heating costs and melt snow and ice on roadways. In this regard, urban heat island mitigation measures often give all-year advantages, or their winter disadvantages are considerably less than their summer advantages.

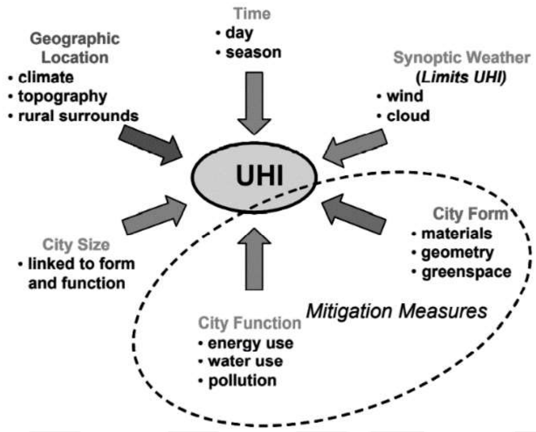

Figure 2.44. Influencing factors of urban heat islands (Voogt 2014)

There are numerous case studies on mitigating the effects of urban heat islands, and the common goal is to maximize the overall coverage per capita of public greenery in urban areas and their reachability to residents as well as to enhance air quality, thereby improving the quality of daily lives. This way, the number of walkers and bicycles can be increased, resulting in a decrease in the use of private vehicles which contribute significantly to carbon emissions. The Valladolid, Spain climate resilience challenge was introduced by the European Commission (2021), where a set of nature-based solutions was applied to supply essential ecological resources for healthy habitats, and an urban green corridor was implemented to encourage sustainable transportation. The urban core has several forms of green systems designed for highly dense regions, such as vegetated walls and roofs, and green shading elements, all of which address the heat island effect and air quality issues. The Victorian Government (2014) too, realizes that the relative absence of cooling by greenery in urban areas in contrast to rural parts is one of the main causes of the urban heat island effect, and green surfaces can minimize this effect if adopted as a city-scale policy. They exemplify a 2005 research in Toronto, Canada, which analyzed the impact of vegetated roofs on the urban heat island and determined that they would lower the local temperatures by 0.5 to 2°C. It was also projected that the lower energy consumption for cooling would save 21 million dollars per year. Finally, as shown in Figure 2.45, Ide and Rose (2018) present an application of the Georgia Tech Urban Climate Lab where 29 temperature monitoring devices were installed across campus, proving the cooling benefit of greenery in the urban context. Furthermore, the Landscape Department recovers all of grass trimmings and almost all scrap woods from pruning to be utilized in the campus landscape on a yearly basis, and preferred logs are kept and treated for construction components.

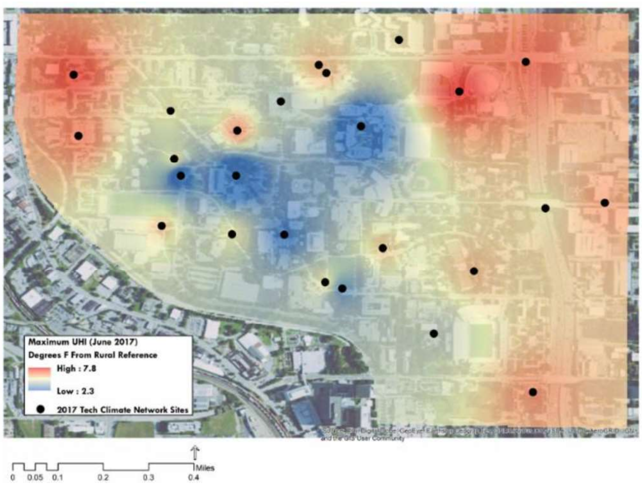

Figure 2.45. The Georgia Tech Urban Climate Lab implementation of temperature monitoring devices (Ide and Rose 2018)

Turkey is also affected by urban heat islands, which have become more prevalent in recent years as a result of global warming and an increasing population, which includes immigrants. AFAD (2014) reports that summer temperatures have reached record levels in the last half-century because of the urban heat island appearances, and the computations predict that the mean yearly temperature in Turkey will increase by 2-3°C until 2100. Moreover, summer temperatures might even reach +6°C. Figure 2.46 depicts the areas most affected by this change with the average temperature anomalies map for May 2023, and Antalya, like the dominant eastern region, appears to be in trouble. When the monthly data for Antalya is examined in greater detail (Table 2.7), the difference between 1982-83 and 2021-22 validates the future risk. According to an analysis performed with Solargis (2023), the annual averages of direct normal irradiation for Antalya are determined to be 1909.7 kWh/m^2 per year, while the monthly averages of direct normal irradiation are shown in Figure 2.47. Before discussing the contribution of these values to the formation of urban heat islands, it is worth noting that some benefits can be derived from certain drawbacks. Many publications in the literature examine convenient conditions for solar energy production toward cleaner and renewable energy sources, and Antalya is among the popular case study locations. Kırcalı and Selim (2021) state that Antalya has higher values in 8 months of the year than an average daily solar radiation value of 5 kWh/m^2, resulting in a more stable range of months with sufficient solar radiation. This situation provides Antalya with a high solar potential for solar farms, contributing to the production of clean energy.

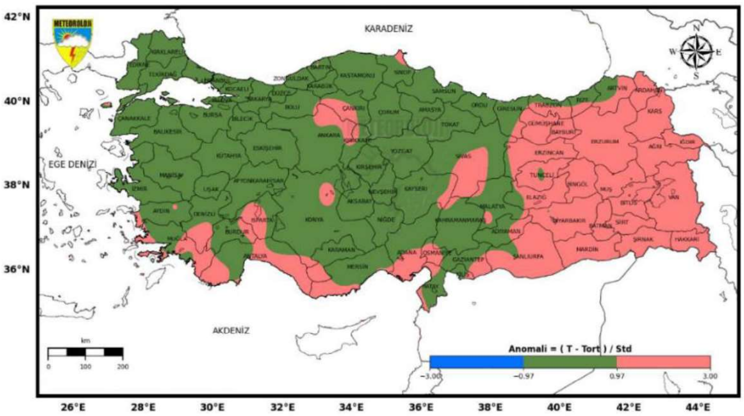

Figure 2.46. May 2023 average temperature anomalies map (Turkish State Meteorological Service 2023)

Table 2.7 Monthly Data for Antalya (Tokyo Climate Center 2023) [generated by author]

Months	06	07	08	09	10	11	12	01	02	03	04	05
Normal Mean Temperature (°C)	25.9	28.9	29.2	25.7	21.1	15.7	11.8	10.2	11.3	13.7	16.7	20.9
Observed Mean Temperature (°C) for 1982-83		27.0	27.3	25.1	19.2		9.8	6.9	7.8	10.9	15.7	20.6
Observed Mean Temperature (°C) for 2021-22	25.3	30.8	30.8	26.3	22..4	18.9	13.1	9.9	12.6	11.1	18.1	22.1

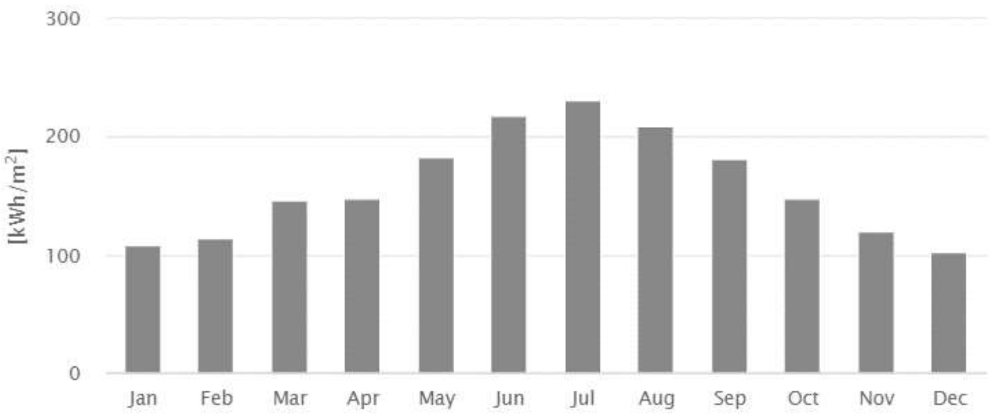

Figure 2.47. Monthly averages of direct normal irradiation for Antalya (Solargis 2023)

On the other hand, such a steady rise in temperatures in Antalya inevitably caused discomfort over time. The study of Aslan and Koc-San (2016) discusses that rapid urbanization plays a major role among different factors on the elevated temperatures in Antalya. Although the land surface temperature is estimated to have risen by 2.5°C between 2001 and 2014, urban zones have reached as much as 3.62°C. They concluded that the findings depend on the surface attributes, with urban zones being warmer than industrial zones and greenery zones being cooler than irrigated agriculture zones. As shown in Figure 2.48, urban and industrial zones expanded and bare land and rock zones decreased greatly from 2001 to 2014, causing the urban heat island effect to rise by 1.2°C from 5.6 °C to 6.8 °C. Therefore, the direct relationship between human activity and the urban heat island effect has been established.

Another study from Demiroglu et al. (2020) analyzes RCP (Representative Concentration Pathways) 8.5 scenarios to understand the level of discomfort in Antalya for the tourism sector. RCPs are projections for potential greenhouse gas concentrations where RCP 8.5 is the highest reference scenario among the four existing RCPs. As a result, estimations based on RCP 8.5 are usually more critical. Figure 2.49 exposes two future scenarios for Antalya, one between 2021 and 2050 and the other between 2070 and 2099, and it is clear that the city gradually progresses from ideal-acceptable range of conditions to great discomfort and even danger by 2099. This study provides an excellent overview of the economic challenges posed by climate change, as if cities become unbearably hot, tourist arrivals will decline. Given that economic gains are prioritized over the sake of the planet in the modern era, taking immediate action benefits more than just climate.

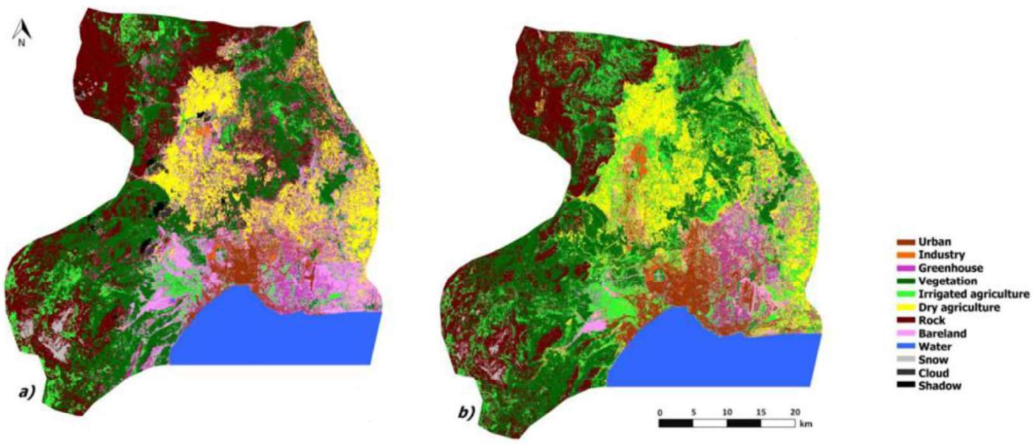

Figure 2.48. Antalya city center land use/land cover maps of 2001 and 2014 (Aslan and Koc-San 2016)

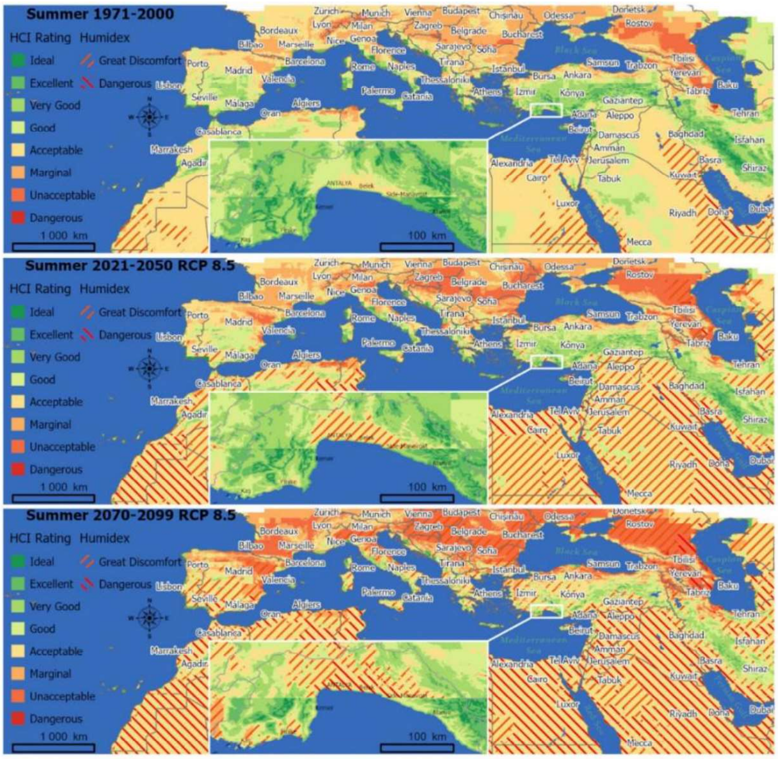

Figure 2.49. Antalya discomfort rating map (Demiroglu et al. 2020)

2.4.3 Action Plans

In the last decade, Antalya Metropolitan Municipality conducted several vulnerability assessments on both local and industrial scales to promote proper climate change action plans. In particular, 2013 was a turning point because Antalya signed the European Covenant of Mayors for Climate and Energy, making it the first Turkish city to commit to lowering the urban release of greenhouse gasses. As a framework of the Covenant of Mayors, Sustainable Energy Action Plan (SEAP) was developed, which accelerated climate actions as an intermediary step. Greenhouse gas emissions of Antalya were calculated in this regard and placed among the cities with a greenhouse gas inventory, reduction goals, and action plan in the coming years, recalling Figure 2.17. Antalya Metropolitan Municipality (2020) reports that total emissions for the reference year 2012 were found to be 8.966.179 tons of CO2e, and the major factors were determined as residential and industrial activities, as well as electricity consumption, accounting for 75% of total emissions. This action was followed by one of the most recent initiatives, the MatchUP Smart Cities workshop, in which Antalya was one of three implementing cities, along with Valencia, Spain, and Dresden, Germany, as of 2020. The workshop was successful in putting some smart city strategies into action, such as the bike path along the coast shown in Figure 2.50. More importantly, it served as a foundation for a larger action known as the Antalya Sustainable Energy and Climate Change Action Plan (SECAP), which was previously mentioned under the national approaches section. As summarized in Figure 2.51, what distinguishes SECAP from its predecessors is a more immediate approach by implementing short and middle-term actions with cooperation between inter-enterprises and related units, whereas MatchUP aimed to integrate sustainable components into long-term actions.

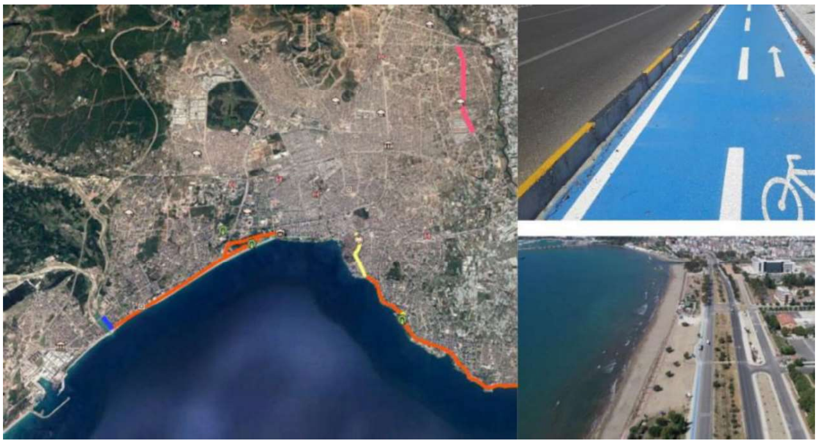

Figure 2.50. Application of the bike path that passes through the popular tourist zones (Oguz et al. 2020)

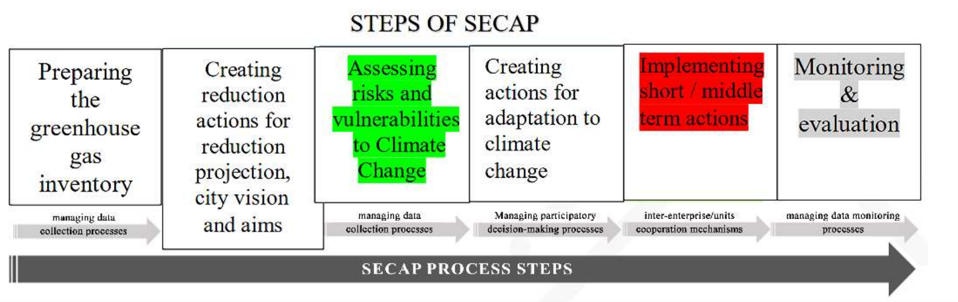

Figure 2.51. Revised SECAP process steps in light of the Covenant of Mayors for Climate and Energy (Antalya Metropolitan Municipality 2020)

On the other hand, the most recent and critical action of the Antalya municipality is the membership phase in the C40 Cities Climate Leadership Group. C40 is currently the largest global organization on climate change, connecting mayors and specialists from troubled cities around the world. It uses the Paris Agreement as a foundation to achieve the designated global warming objectives, and almost all subsequent local climate action plans are derived from the C40 risk assessment scheme, including the Covenant of Mayors, SEAP, MatchUP, and SECAP. This scheme first addresses the disaster features, such as their extent and incidence rate, and then classifies the potential risks as acceptable, tolerable, and intolerable while taking into account all vulnerable population groups and economic damage. It also provides projections up to the year 2050. The member cities are responsible for filling out and submitting the C40 Risk and Vulnerability Assessment Reporting Framework on a regular basis, as shown in the Appendices section (Figure A.1). The C40 network now comprises over 90 influential cities worldwide, and Antalya was included in the process of participating in the program as of 2021, owing to its pioneering efforts in the field of sustainable environment and clean energy in the country. Accordingly, this advancement plays a significant role when carrying out the next steps of the study, which will be covered in the following chapters.

CHAPTER 3

MATERIAL AND METHOD

This chapter is divided into two sections. The 'material' section contains specific information for the case study area within the borders of Antalya city, and the related tools for obtaining data on this area for further analysis. The ongoing action plans of the city, as introduced in the literature review, served as a foundation for the selection of both the case study area and the specific tools described below. Secondly, there is a 'method' section that explains how the study will be carried out through a strategy set, outcome estimation, simulation, and comparative analysis steps.

3.1 Material

The primary material of the research is one of the action plans of the Antalya Municipality, MatchUP Smart Cities, as introduced in the literature review. This plan includes important pillars such as the urban transformation of Kepez district of Antalya and the right of citizens to participate in the process. According to the MAtchUP Citizens' Engagement Strategies report by Oguz et al. (2020), the contracting firm provided a platform for direct contact in this major transformation project, to collect citizen evaluation. The project has received numerous awards, including the Green Good Design and Sign of the City Awards 2019, as well as being named one of the three smartest projects in Europe, with the Best Regeneration Project by Management Plus (SURYAPI 2020). It was also discussed in the literature review that the most prominent future risk for Antalya was excessive heat as a result of the heat island effect. In this context, the impact of the suburban state of the Kepez project area prior to urban transformation and the renovated state after urban transformation on the formation of urban heat islands is investigated. Applications that provide various extensions, plug-ins, and related source files are also used as research material.

3.1.1 Case Study Area: Antalya Kepez District

Kepez is an inland district located northwest of Antalya. The study area is a low-rise and consecutive houses neighborhood, also known as a suburban settlement. The most recent aerial views of the old neighborhood date from the summer of 2016, and the construction of the urban transformation project can be observed since then. Figure 3.1 depicts the location of the case study area in 2022, while Figure 3.2 demonstrates the before and after states of the area following the planned urban transformation.

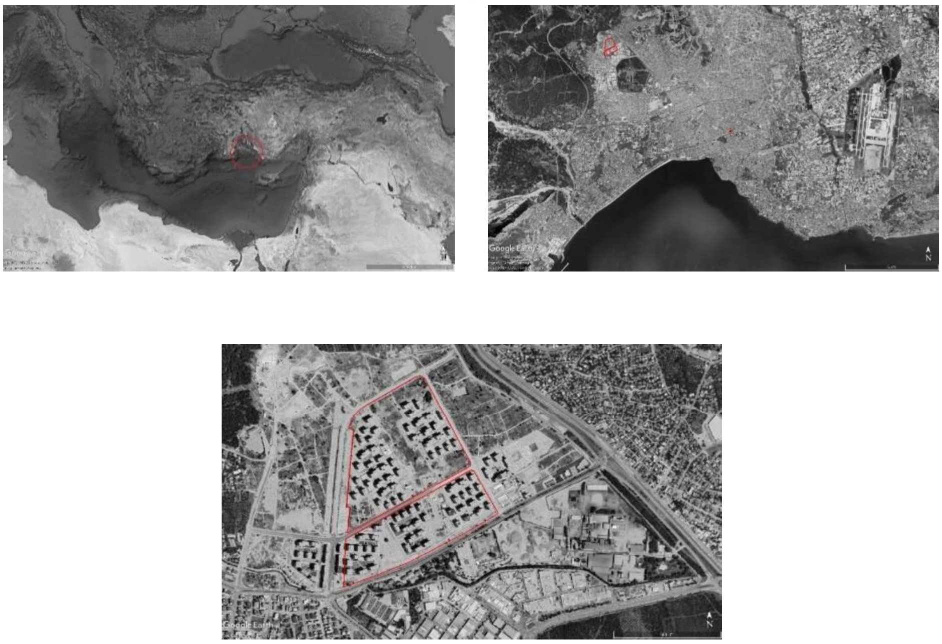

Figure 3.1. Antalya, Turkey in 2022 as study area (Google Earth Pro 2023)

Figure 3.2. Kepez, Antalya in June 2016 (top) and October 2022 (bottom) as study area (Google Earth Pro 2023)

Even though sales have begun, and turnkey deliveries have been made in certain parts of the project, construction is still ongoing due to the scale. To deal with such a large project, it was divided into zones. Figure 3.3 represents the overall approach, with three major zones visible. "Sur Cadde" refers to the street houses zone, "Park" refers to the core of the project, and "Turkuaz (Turquoise)" refers to a smaller-scale replica of the Park zone. The official concept images for each zone are shown in Figure 3.4.

Figure 3.3. The major zones of the Kepez Urban Transformation Project (SURYAPI 2020) [adapted by author]

Figure 3.4. Official concept images of the street, park, and turquoise zone respectively (SURYAPI 2020)

3.1.2 Tools and Databases

The significance of the C40 Cities, both globally and for Antalya, was also discussed in the literature review, and a risk assessment scheme was introduced. The research makes use of two tools provided by C40 Cities: The Adaptation and Mitigation Interaction Assessment (AMIA) tool and the Heat Resilient Cities: Measuring Benefits of Urban Heat Adaptation tool. The only drawback is that the latter tool has a predetermined and limited list of cities for input, which does not include Antalya. The use of Climate Consultant which processes the raw EnergyPlus Weather (epw) data into more understandable visual graphs and its outcome became a material when defining the alternative city as a source for the Heat Resilient Cities: Measuring Benefits of Urban Heat Adaptation tool. The climatic conditions of the case study city Antalya is compared with the conditions of the other cities listed in the interface. From the list, Tel Aviv was determined to have the most similar climate to Antalya, thus, to be used (Figure B.1). Figures B.2-B.7 in the Appendices section reveals the resemblance between the climatic conditions of two cities under the categories of monthly diurnal averages, radiation range, sun chart, sun shading chart, temperature range and timetable plot. On the other hand, Rhinoceros 3D is used to model the before and after urban transformation cases of the study area. The date of June 2016 is used as a reference for the previous case, however, official plan documents were out of reach. Therefore, OpenStreetMap and Google Earth Pro databases are used, as shown in Figure 3.5, while the current condition of the study area as of 2023 is modeled with an additional document from the Antalya Municipality, as shown in Figure 3.6. Lastly, Grasshopper extension of the Rhinoceros 3D is used to code the simulations via Ladybug and Dragonfly plug-ins.

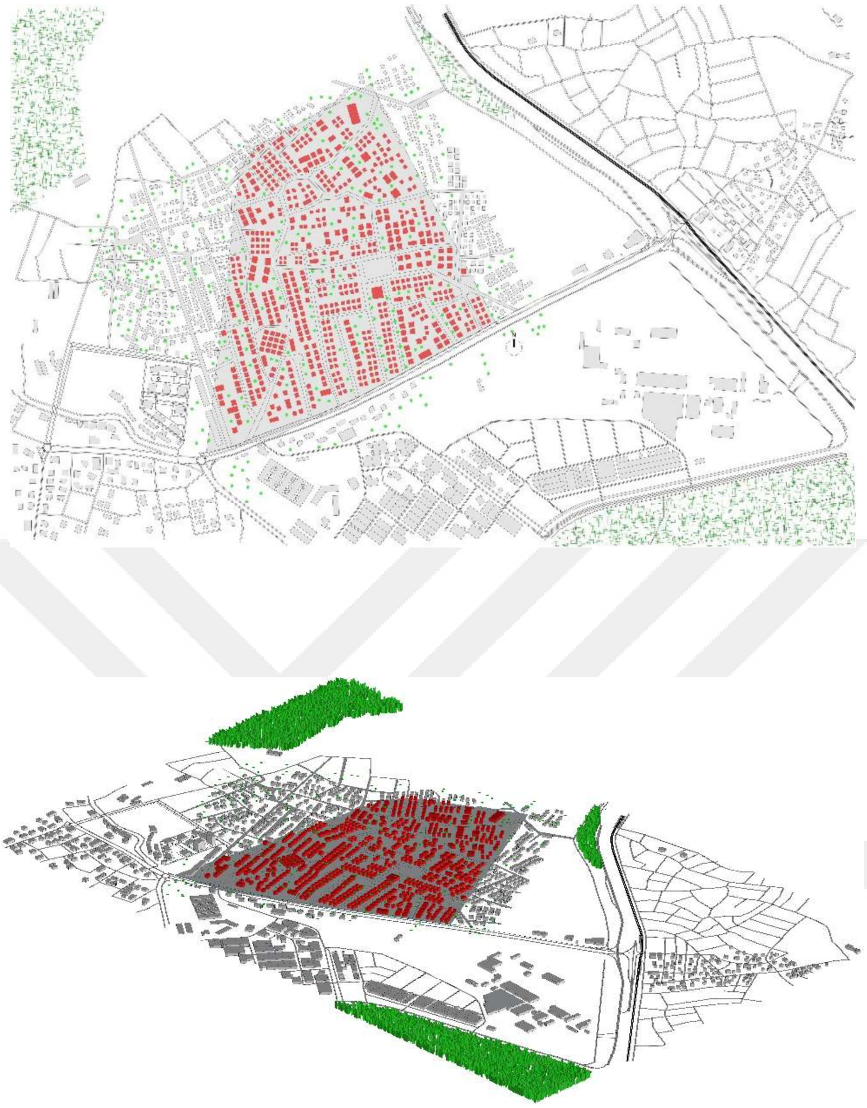

Figure 3.5. Antalya Kepez district plan and 3D model with the old buildings in urban transformation area indicated in red color (Rhinoceros 3D 2023) [prepared by author]

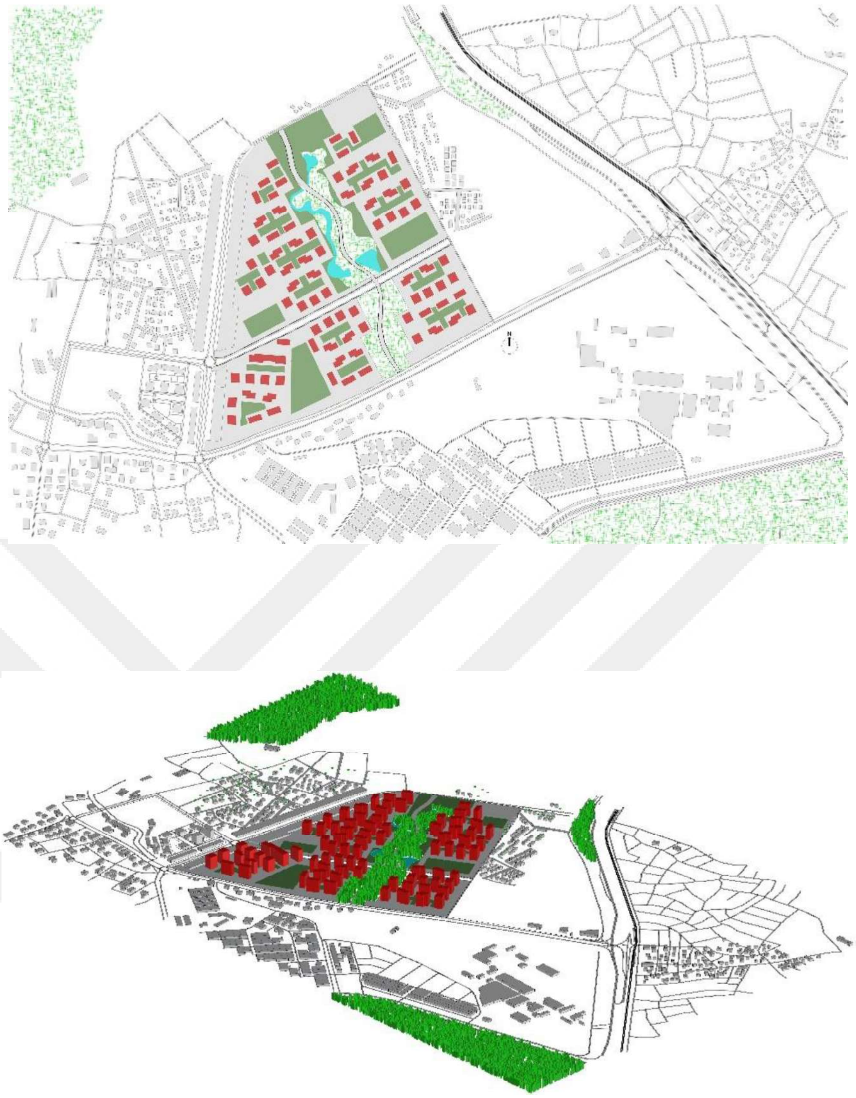

Figure 3.6. Antalya Kepez district plan and 3D model after the urban transformation project of the Antalya Metropolitan Municipality indicated in red color (Rhinoceros 3D 2023) [prepared by author]

3.1.3 EnergyPlus Weather (epw) Files

Both the Climate Consultant and the Grasshopper 3D plug-ins require EnergyPlus Weather (epw) file for accuracy in the simulations. Therefore, the weather file of Antalya became an essential material and it is drawn from the Ladybug epwmap website, as shown in Figure 3.7.

Figure 3.7. epwmap screenshot of available epw files for Antalya (Ladybug Tools 2023)

3.2 Method

As illustrated in Figure 3.8, the first two steps of this study, a literature review and identification of the relevant climatic conditions, were discovered in previous chapters and sections. The remaining steps are divided into two parts: first, a strategy list is produced and their outcomes are estimated, and then the study area containing these strategies is simulated for a comparative analysis.

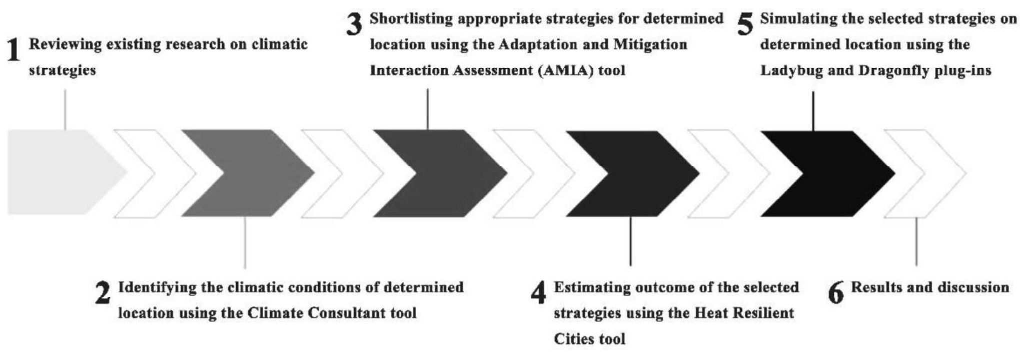

Figure 3.8. Research methodology (prepared by author)

3.2.1 Strategy Set and Outcome Estimation

A strategy set was required as a starting point to generate qualitative data on the decision of which strategies would be estimated, as well as to have a checklist for the studied urban transformation project. The AMIA tool was chosen for this purpose because, as shown in Figure 3.9, it offers a variety of climate hazard category filters under adaptation and mitigation actions, allowing the desired actions to be analyzed. The tool briefly describes the actions under the results tab, then identifies their potential and risk. After generating a strategy set derived from the AMIA tool, four of the most prominent strategies were entered into the Heat Resilient Cities tool to estimate their outcomes. The user input is tailored to the desired location, so that this tool develops quantitative data. Thus, it was used to measure the impact of urban parks, urban water, cool vegetation surfaces, and cool artificial surfaces on the heat island effect. Furthermore, different scales of implementation within the same category were examined. The results were intended to be compared to the following simulations in the study area. The tool, as captured in Figure 3.10, necessitates extensive configuration. Although the city had to be chosen as Tel Aviv due to the previously stated constraints, all other inputs were manually arranged based on Antalya:

- Start year for analysis: 2023
- End year for analysis: 2050
- Climate zone of the chosen city: CSA (Mediterranean hot summer)
- City area size: 1417 km^2
- Population density: 129 people/km^2
- Minimum temperature threshold for mortalities: 35 °C
- The climate scenarios to compare results against: RCP 2.6 and RCP 8.5, where:

RCP 2.6 describes that the global temperature is expected to increase by 0.3 - 1.7 °C
RCP 4.5 describes that the global temperature is expected to increase by 1.1 - 2.6 °C
RCP 6.5 describes that the global temperature is expected to increase by 1.4 - 3.1 °C
RCP 8.5 describes that the global temperature is expected to increase by 2.6 - 4.8 °C by 2081 - 2100

- Albedo of the cool roof surface: 0.8 where approximate albedo values of different roofs:

Conventional roof: 0.3
Green roof: 0.7
Cool roof (light colored materials): 0.8

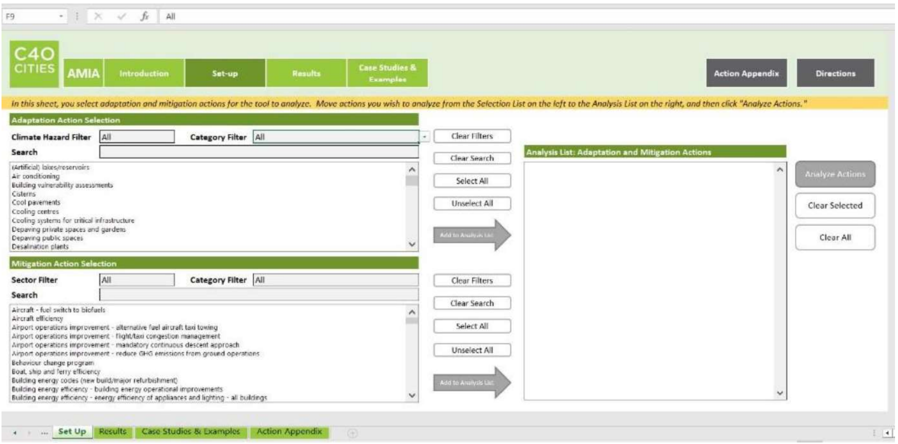

Figure 3.9. AMIA tool interface (AMIA 2023)

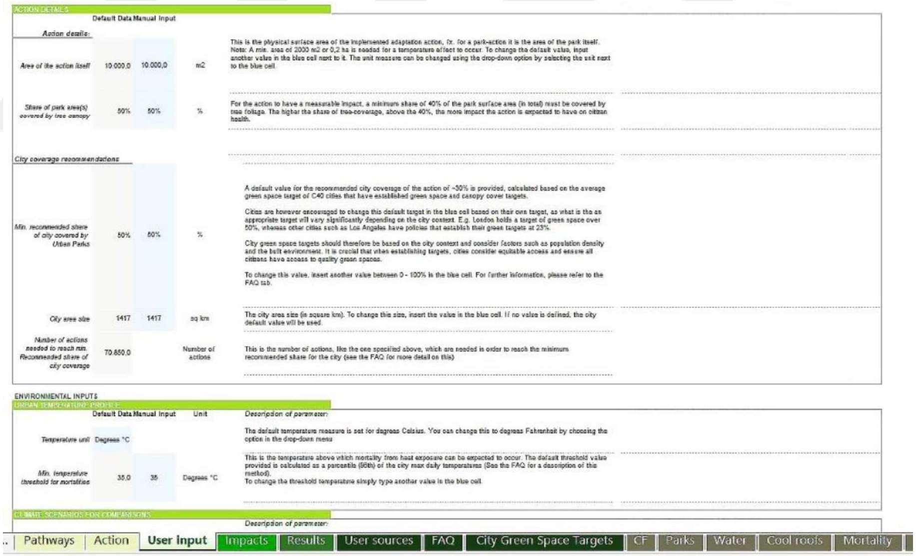

Figure 3.10. Heat Resilient Cities tool interface (Heat Resilient Cities 2023)

3.2.2 Simulation and Comparative Analysis

With the Ladybug plug-in, the before urban transformation, 2016 version and the after urban transformation, 2023 version of the study area were simulated under direct sun hours and incident radiation, as well as determining how the winds affect the area. For the solar simulations, the analysis period was determined to be the month of August, specifically, the first day of the month, considering the peak of excessive heat (Figure B.8). The wind rose, on the other hand, was observed on an analysis period of May to September daily, between 12.00-23.00 o'clock (Figure B.9). For the final step and the main finding, the Dragonfly plug-in is used to obtain comparative graphs between 2016 and 2023. Consequently, estimations of the Heat Resilient Cities tool and the simulation results were also compared. Lastly, one more comparison was made between the Street and Park zones to be discussed further, in terms of different design solutions.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter is divided into four sections to correspond with the steps of the research methodology. The strategy set obtained from the AMIA tool is shared first, followed by the estimation results of the Heat Resilient Cities tool. Later, solar and wind analysis for the 2016 and 2023 cases, as well as the application of different strategies are compared. Finally, further discussions are included in which the scope of the overall study is evaluated

4.1 AMIA Strategy List Results

The C40 Cities Excel-based Adaptation and Mitigation Interaction Assessment (AMIA) tool is used to generate a strategy set that later served as a guide on the research area analysis. The tool provides such a wide range of actions that they had to be prioritized based on their relevance with first the location and then the scale of the area. Therefore, more urban actions for hot and humid climates are compiled. On the other hand, the tool also shares any potential drawbacks of actions. Many actions that have a significant disadvantage are eliminated during the shortlisting process. As a result, the qualitative data contained the description, synergy potential, and piggybacking opportunities of each action category, with a few of them still included despite the mentioned potential disadvantages. Finally, the actions are classified into adaptation and mitigation strategies, as shown in Figures 4.1 and 4.2. The observations are explained below to correlate the selected strategies and applications in the urban transformation project as the research area of Kepez.

From the adaptation strategies (Figure 4.1), “Analysis and mapping” strategy is tested through simulations as a part of this study. The implementation of an urban park and the use of relatively lighter colored building materials are examples of "deflecting and shading" strategies. The placement of the new blocks benefits from urban cooling, through the use of the "Wind corridors" strategy, which is shown in the following solar and wind analysis section. In addition to a new urban park, other "Greening" strategies, such as "Green transitways for public transportation," are found to be implemented, recalling Figure 3.4. "Cool pavements" and "Green roofs and facades" on the other hand, have not been proven to be used, but their effects are discussed in the following sections. In terms of trade-off potential, the tool warns against the "Development of parks and urban forests" due to the risk of increased greenhouse gas emissions from transportation and housing. A significant observation allowed this strategy to remain on the list despite its potential disadvantage, which is the promotion of the use of public transportation. With this project, not only are two of the three main zones (the Park and Turquoise zones from Figure 3.3) designed to be closed to traffic, but a brand new tramline is also introduced to Kepez.

The building scale, rather than the urban scale, is listed as a starting point for mitigation strategies (Figure 4.2). Given that all of the buildings in the urban transformation project will be new, their thermal efficiency is expected to be higher than that of the aged houses in the old suburban settlement. Similarly, "street lighting" strategies are observed to be used, with the transition from old cabled street lights to more efficient and fewer led lightings. In the "Greening" category, the tool notes a mal-investment risk, which is the vulnerability of vegetation to changing climate. However, as indicated by "Xeriscaping" under adaptation strategies in Figure 4.1, selected vegetation species in the project are drought-resistant and thus compatible with the climate of Antalya. Lastly, the "Transportation" category is observed to be used, with the design of a more walkable neighborhood and limited vehicle traffic. In terms of encouraging public transportation, the tool generates another mal-investment risk, which is becoming more vulnerable to disasters due to increased population density. Nonetheless, it is examined in the literature review that the major event that awaits Antalya is the urban heat island effect, rather than any other type of disaster, and the contribution of this project to the urban heat island is analyzed in the following sections.

Category	Action Name	Description	Synergy Potential	Piggybacking Opportunities
Analysis and mapping	Mapping heat island effects to effectively respond	Focuses on the vulnerability of the city to heat and the urban heat island, to seek solutions to minimize heat stress in the city.	Reduce energy demand for cooling and associated GHG emissions by identifying areas of the city most vulnerable to heat and taking steps to minimize heat stress.	
Deflecting and shading	Cool pavements	Cool pavements have a higher albedo, meaning that they reflect solar radiation instead of absorbing it. This makes these roofs and walls cooler than normal (dark) pavement.	Reduce energy use and associated GHG emissions through urban heat island mitigation.	The implementation of transit-oriented mitigation actions, such as bus rapid transit or new bike lanes, may provide the opportunity to integrate cool pavement for a little added cost.
	Shading in public spaces, markets	Shading in public spaces protects citizens from the sun and decreases air temperature.	Improve outdoor amenities, reduce energy demand, improve air quality through urban heat island effect mitigation, and increase walking and cycling.	It is often possible to add additional shading when upgrading transit infrastructure, such as adding electric vehicle charging infrastructure or improving bus or rail stations, or when developing a greening program.
	White roofs and walls	White roofs and walls have a higher albedo, meaning that they reflect solar radiation instead of absorbing it. This makes these roofs and walls cooler.	Reduce energy use and associated GHG emissions through urban heat island mitigation.	If building energy retrofits or distributed energy solutions are already being implemented on local buildings, then painting roofs and/or walls white can be performed at little added cost.
Using and preserving ecosystem services	Wind corridors for urban cooling	Cities can be cooled by the inflow of wind from cool areas, like forests or seas. If you map out the corridors through which wind flows and restrict development there, you can maintain this important source of cool air for your city.	Reduce energy use and associated GHG emissions through urban heat island mitigation.	The development of wind corridors can present opportunities to integrate urban greening, which provides mitigation benefits. When integrated with new neighborhood development, other actions can be added, such as energy codes, compact and connected land-use planning, or transit-oriented development.
Greening	Green roofs and facades	Green roofs and facades - roofs and walls covered with plants - cool down buildings and their direct surroundings. Green roofs, in addition, can absorb rainfall and have a small effect on insulating homes.	Reduce energy consumption and associated GHG emissions from the cooling effect of green roofs, in addition to carbon sequestration and biodiversity enhancement.	When implementing green roofs and facades, there are opportunities to combine energy retrofit actions or distributed energy resources, such as solar PV. Additionally, when new transit infrastructure is developed, green roofs can be piggybacked onto new or retrofitted stations.
	Green transitways for public transport	Trams and light rail tracks do not require a road to drive on. Planting grass or other vegetation around the tracks cools the direct environment and allows for the absorption of rainfall.	Sequester carbon and reduce energy use in buildings via urban heat island effect mitigation, in addition to biodiversity enhancement.	Green transitways present an opportunity to piggyback urban greening initiatives and public transit upgrades and expansions.
	Xeriscaping	Xeriscaping is landscaping designed for areas that are susceptible to drought, usually featuring plants with lower water consumption. Xeriscaping can be applied in public areas, but also be promoted in private areas.	Reduce water, energy, and transport required for managing greenspace and thus lower GHG emissions. The improvement of public spaces with greening also encourages walking and biking.	Xeriscaping presents opportunities to piggyback additional urban greening that provides mitigation benefits or to provide landscaping for distributed clean energy, such as ground-mounted solar PV. If designed at the same time as public spaces and transit, it allows the development of cool and shaded areas/grids/paths for cyclists and pedestrians.
	Depaving public spaces	Depaving public spaces means taking away impermeable asphalt and bricks and replacing it with vegetation or permeable materials, so that rainfall can infiltrate.	Increasing urban permeability and urban greening may enable more walking/cycling and help reduce energy use in buildings through urban heat island effect mitigation, reducing overall energy reliance.	Depaving public spaces and gardens for adaptation purposes can often be combined with urban greening strategies for mitigation purposes. Depaving can also be integrated with a new transportation strategy that replaces roads and parking lots with cycling and pedestrian areas to reduce transport-related emissions.
	*Development of parks and urban forests	Parks and urban forests create cool and green zones in your city. The unpaved surfaces allow for the absorption of rainfall.	Sequester carbon and reduce energy use in buildings via urban heat island effect mitigation, in addition to biodiversity enhancement. The development of parks and urban forests can also encourage cycling/walking.	The development of parks and urban forests can present opportunities to integrate other urban greening initiatives, such as the use of urban compost, which provides mitigation benefits through alternative waste management. The development of alternative transport (cycling and walking lanes) can be also based on a green grid between parks, enabling residents to have comfortable and cool areas to use carbon-free transport.

*Trade-off potential: Preserving space for parks and urban forests could increase GHG emissions from transport and housing by reducing urban density.

Figure 4.1. Adaptation strategies (AMIA 2023) [prepared by author]

Category	Action Name	Description	Synergy Potential	Piggybacking Opportunities
Buildings	Thermal efficiency of new building envelope	Take action to evaluate and improve the physical separation between a building's interior and the exterior environment to reduce air leakage, which can result from a poor design that allows the air to move across the thermal perimeter.	Reduce energy demand/emissions and protect the building from heat and cold while also making it more easily operated in instances of a power outage.	Implementing energy efficiency in new buildings can present opportunities to integrate adaptation measures at the same time, such as stilted buildings, installing water efficiency technologies, green roofs, and painting roofs or walls white.
	Thermal efficiency of the existing building envelope		Retrofit to reduce energy demand/emissions and protect the building from heat and cold while also making it more easily operated in instances of a power outage.	Performing energy efficiency retrofits can present opportunities to integrate adaptation measures at the same time, such as installing water efficiency technologies, adding green roofs or facades, and painting roofs or walls white.
Street lighting	Reduce the number of streetlights	Reduce the number of streetlights operating in a city.		
	More efficient luminaires (e.g., LED)	Convert streetlights to more energy-efficient technologies to reduce electricity use and related GHG emissions.		
	Lighting operational improvements	Lighting operational improvements.	Integrate PV panels with street lighting to reduce emissions and increase resilience during power outages.	
Greening	*Green space protection and expansion through restoration/conservation of natural or semi-natural areas, reforestation, afforestation, or tree planting	Protect and expand areas of grass, trees, or other vegetation in the city.	Sequester carbon, reduce stormwater runoff, mitigate the urban heat island effect, and promote biodiversity.	Green space protection and expansion for carbon reduction can be implemented in combination with measures that provide adaptation benefits, such as xeriscaping, water squares, wind corridors for urban cooling, and river/canal rehabilitation. Green space can also be piggybacked on the development of urban floodplains, water-sensitive neighborhoods, or the renovation of streets or buildings for adaptation purposes.
Transportation	Non-motorized transportation development	Improve the non-motorized transportation system to incentivize increased use of non-motorized transportation that can reduce congestion on roads, reduce the number of individual car trips, and lower overall transportation-related emissions.	Reduce urban heat island effect due to fewer car trips and reduced criteria air pollutant emissions.	New cycle parking can incorporate adaptation measures such as cool or permeable pavement, urban greening, and shading.
	**Transit-oriented development	Transit-oriented development (TOD) is an urban planning principle enabling cities to create vibrant, people-focused neighborhoods with maximum public transport and economic activity access. TOD involves planning for high-density, mixed-use development alongside a robust public transport system.	Reduce urban heat island effect due to fewer car trips and reduced criteria air pollutant emissions.	When promoting and implementing transit-oriented development, there are opportunities to integrate adaptation planning strategies, such as flood-proof, water-sensitive, and heat-sensitive development of new neighborhoods.

*Mal-investment risk: Tree and plant species may not survive climate changes due to vulnerability to increased temperatures or changing precipitation levels.

** Mal-investment risk: Increase in urban heat island effect and potentially larger populations at risk for flooding due to increased population density.

Figure 4.2. Mitigation strategies (AMIA 2023) [prepared by author]

4.2 Heat Resilient Cities Estimation Results

Among the shortlisted strategies shared above, four major categories responsive to urban heat adaptation have been chosen to be closely examined. Another C40 Cities Excel-based tool, Heat Resilient Cities, used the implementation of urban parks, urban water, cool artificial surfaces, and cool vegetation surfaces as input. The goal was to calculate the benefits of each action and then compare them to the actual simulation results. The obtained data is discussed in greater depth below. It is worth reminding that, due to the location constraints of the tool, Antalya was replaced with Tel Aviv after a series of climatic analyses to find the most similar weather patterns. Figures B.1–B.6 in the appendices contain related data.

For the urban parks action, the tool predicted a 1.51 °C decrease in urban heat for both the RCP 2.6 and RCP 8.5 scenarios. However, the reduction in days above the threshold varies, being 4.4 days for RCP 2.6 and 9 days for RCP 8.5. With the start and end years for analysis set to 2023 and 2050, respectively, the tool calculated the total benefits for this period, which ranged from 40 to 86 lives saved from the excessive heat. The economic impact over this period is also depicted in Figure 4.3. These results are based on a 50% tree cover in the project area. To understand the impact of each action, coverage input is gradually increased and gathered for more comprehensible comparisons. Table 4.1 depicts the effect of increasing tree cover from 60% to 90% on potential results. It was discovered that the urban temperature could be reduced by 2.68 to 6.19 °C. According to the RCP 8.5 scenario, an extra 17 comfortable days per year can be gained while up to 160 lives can be saved.

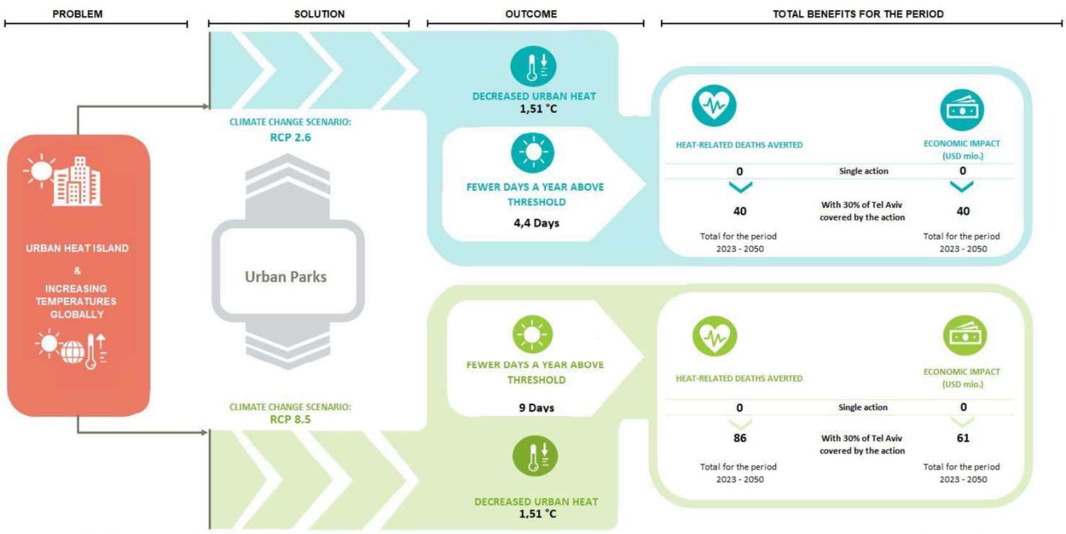

Figure 4.3. Share of project area that is covered by tree canopy as 50%

Table 4.1 Share of project area that is covered by tree canopy from 60% to 90% for further comparison

Share of the project area that is covered by tree canopy:		60%	70%	80%	90%
Climate change scenario: RCP 2.6	Decreased urban heat	2,68 °C	3,85 °C	5,02 °C	6,19 °C
	Fewer days a year above the threshold	5,4 days	7,7 days	8 days	8,3 days
	Heat-related deaths averted	49	69	72	75
	Economic impact (USD mio.)	52	76	77	78
Climate change scenario: RCP 8.5	Decreased urban heat	2,68 °C	3,85 °C	5,02 °C	6,19 °C
	Fewer days a year above the threshold	13 days	15 days	17 days	17 days
	Heat-related deaths averted	128	144	157	160
	Economic impact (USD mio.)	91	109	119	120

For the urban water action, the tool predicted a 1.73 °C decrease in urban heat for both the RCP 2.6 and RCP 8.5 scenarios. However, the reduction in days above the threshold varies again, being 4.6 days for RCP 2.6 and 11 days for RCP 8.5. Unlike the urban parks action, the tool calculated no significant benefits for the urban water action in terms of either lives saved from excessive heat or economic impact between 2023 and 2050. These results shown in Figure 4.4 are based on a water cover of 2000 m^2 in the project area. Table 4.2 on the other hand, compares the effect of increasing water cover from 3000 m^2 to 10,000 m^2 on potential results. It is obtained that the urban temperature could be reduced by 1.91 to 2.44 °C. According to the RCP 8.5 scenario, an extra 13 comfortable days per year can be gained while up to 74 lives can be saved.

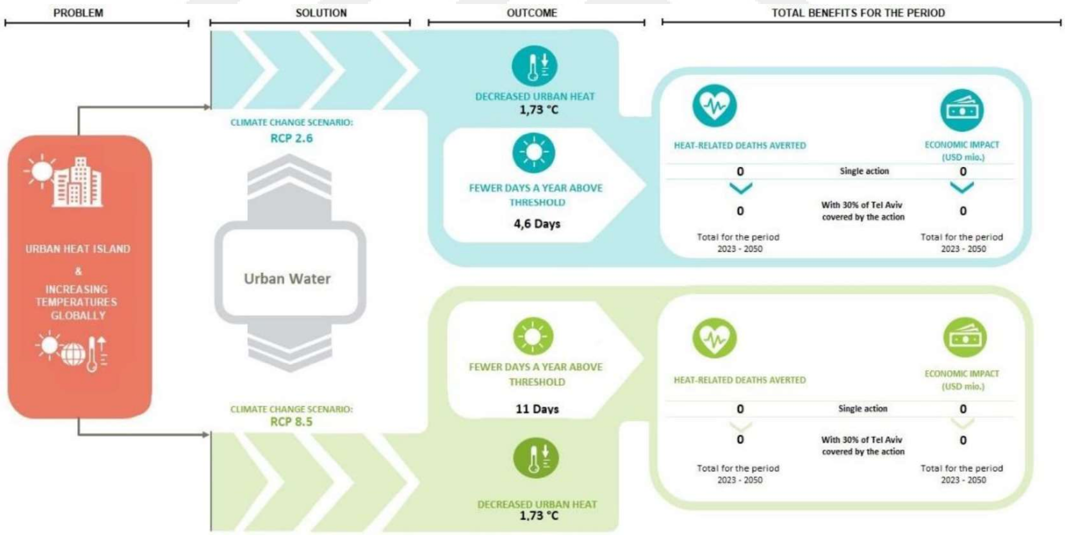

Figure 4.4. Share of project area that is covered by water as 2000 m^2

Table 4.2 Share of project area that is covered by water from 3000 m^2 to 10,000 m^2 for further comparison

Area of the action itself:		3000 m^2	4000 m^2	5000 m^2	10,000 m^2
Climate change scenario: RCP 2.6	Decreased urban heat	1,91 °C	2,04 °C	2,13 °C	2,44 °C
	Fewer days a year above the threshold	5,4 days	5,4 days	5,4 days	5,4 days
	Heat-related deaths averted	10	17	22	30
	Economic impact (USD mio.)	11	18	23	32
Climate change scenario: RCP 8.5	Decreased urban heat	1,91 °C	2,04 °C	2,13 °C	2,44 °C
	Fewer days a year above the threshold	12 days	12 days	12 days	13 days
	Heat-related deaths averted	23	41	52	74
	Economic impact (USD mio.)	17	31	39	54

According to Figure 4.1, the "Cool pavements" action under the "Defeating and shading" category has not yet been proven to be used in the urban transformation project study area. However, because this action and its impact were specifically mentioned in the literature review, it has been included for further investigation. If cool artificial surfaces such as cool pavements were implemented, they would reduce urban heat by 0.78 °C in both the RCP 2.6 and RCP 8.5 scenarios. The number of days above the threshold would be reduced by 2.4 days for RCP 2.6 and 5 days for RCP 8.5. Furthermore, while cool artificial surfaces reduce urban heat by about 1°C less than urban water action, making it appear less effective, it reveals more physical benefits. The tool calculated the total benefits between 2023 and 2050 as 2 to 4 lives saved from the extreme heat. The economic impact over this time period is also shown in Figure 4.5, where the action coverage is 50%. Table 4.3 presents further comparison between 60% and 90% action coverage effects, where the urban temperature could be reduced by 0.94 to 1.4 °C. According to the RCP 8.5 scenario, an extra 8 comfortable days per year can be gained while up to 6 lives can be saved.

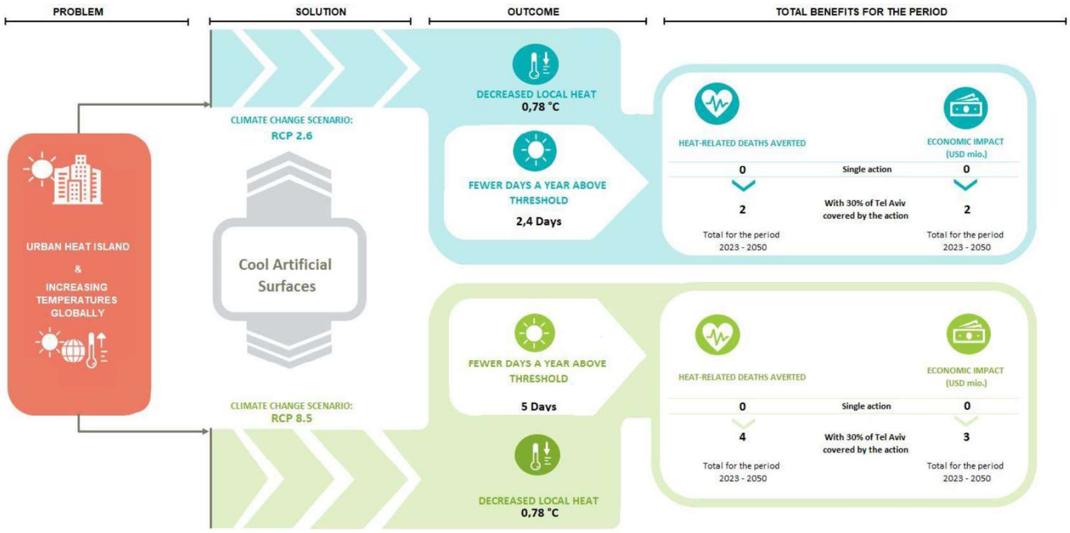

Figure 4.5. Share of project area that is allocated to cool artificial surfaces as 50%

Table 4.3 Share of project area that is allocated to cool artificial surfaces from 60% to 90% for further comparison

Share of the project area that is allocated to cool artificial surfaces:		60%	70%	80%	90%
Climate change scenario: RCP 2.6	Decreased urban heat	0,94 °C	1,09 °C	1,25 °C	1,4 °C
	Fewer days a year above the threshold	2,4 days	2,9 days	2,9 days	3,6 days
	Heat-related deaths averted	2	2	2	3
	Economic impact (USD mio.)	2	2	2	3
Climate change scenario: RCP 8.5	Decreased urban heat	0,94 °C	1,09 °C	1,25 °C	1,4 °C
	Fewer days a year above the threshold	5 days	6 days	7 days	8 days
	Heat-related deaths averted	4	5	6	6
	Economic impact (USD mio.)	3	4	4	4

In the literature review, vegetating surfaces were discussed in addition to the application of cool artificial surfaces in terms of surface types and related albedo values. However, vegetating a surface is possible not only through green walls or roofs, but also by simply introducing grass to the ground level that was previously asphalt or concrete. When Figures 3.6 and 3.7 are compared, it is clear that the design of the urban transformation project promises a significant increase in grass ratio, independent of the main urban park. Similarly, as previously discussed, leaving the new tramline grass rather than filling with gravel is an example of cool vegetation surfaces. Therefore, the last action decided to be estimated is the impact of cool vegetation surfaces on urban heat. Unlike the previous actions, the coverage area input starts at 65% because lower input does not make a difference, as the tool suggests. For this action, the estimation is a 1.06 °C decrease in urban heat for both the RCP 2.6 and RCP 8.5 scenarios. The reduction in days above the threshold on the other hand, are 4.4 days for RCP 2.9 and 6 days for RCP 8.5. With the start and end years for analysis set to 2023 and 2050, respectively, the tool calculated the total benefits for this period, ranging from 2 to 5 lives saved from the excessive heat. The economic impact over this period is also depicted in Figure 4.6. Table 4.4 summarizes the effect of increasing vegetated surface cover from 70% to 90% on potential results. It was discovered that the reduction in urban temperature can vary between 1.15 to 1.47 °C. According to the RCP 8.5 scenario, an extra 8 comfortable days per year can be gained while up to 7 lives can be saved.

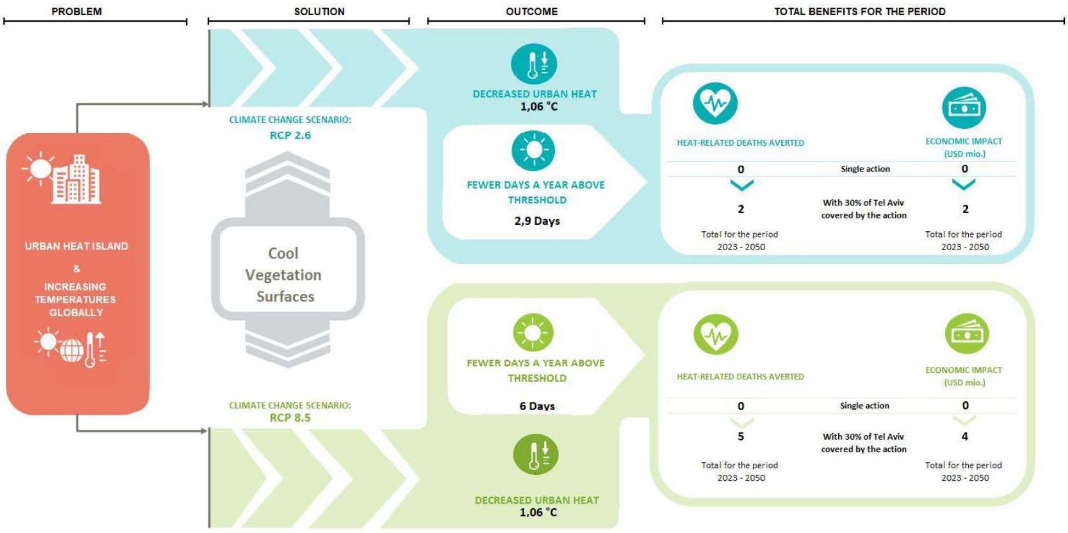

Figure 4.6. Share of project area that is allocated to cool vegetation surfaces as 65%

Table 4.4 Share of project area that is allocated to cool vegetation surfaces from 70% to 90% for further comparison

Share of the project area that is allocated to cool vegetation surfaces:		**70%**	**80%**	**90%**
Climate change scenario: RCP 2.6	Decreased urban heat	1,15 °C	1,31 °C	1,47 °C
	Fewer days a year above the threshold	2,9 days	3,6 days	4,4 days
	Heat-related deaths averted	2	3	3
	Economic impact (USD mio.)	2	3	3
Climate change scenario: RCP 8.5	Decreased urban heat	1,15 °C	1,31 °C	1,47 °C
	Fewer days a year above the threshold	6 days	8 days	8 days
	Heat-related deaths averted	5	6	7
	Economic impact (USD mio.)	4	4	5

In summary, the estimation step of this study yielded a number of overall results. According to shared figures and tables, while the presence of urban water plays a larger role in decreasing urban heat in terms of coverage performance, as the share of their coverage increases, urban parks provide significantly more effective results. Furthermore, the presence of urban parks saves far more lives from heat-related causes than the presence of urban water. Regarding the surface types, cool surfaces have slightly higher albedo values than vegetated surfaces, but vegetated surfaces provide slightly better results in reducing urban heat because it depends on more factors than just albedo values, as discussed in the literature review. Although vegetated surfaces are more expensive than cool surfaces, they are more profitable in the long run for a variety of reasons. Some of these benefits include their increased durability, insulation advantage in colder seasons when cool surfaces increase heating demand, and contribution to stormwater management. Table 4.5 summarizes the results of each action in a RCP 8.5 scenario, for their worst-case performances.

Table 4.5 Performance comparison of each action in a RCP 8.5 scenario

Action name and coverage rate	Urban Parks (50%)	Urban Water (2000m^2)	Cool Artificial Surfaces (50%)	Cool Vegetation Surfaces (65%)
Decreased urban heat	1,51 °C	1,73 °C	0,78 °C	1,06 °C
Fewer days a year above the threshold	9 days	11 days	5 days	6 days
Heat-related deaths averted	86	0	4	5
Economic impact (USD mio.)	61	0	3	4

4.3 Solar and Wind Analysis Results

Following the collection of both qualitative and quantitative data based on selected strategies, their actual implementation on the study area had to be measured for a comparative analysis with the preliminary findings. Before-and-after cases of the urban transformation area, titled as the year 2016 and 2023 cases, are compared using the Grasshopper extension of Rhino 3D computer software. Ladybug plug-in was used for simulations, and Dragonfly plug-in was used for explanatory graphs. Additionally, two different zones in the design, the Park and Street zones mentioned earlier, are compared in terms of the use of different strategies.

4.3.1 Comparison of Simulation Results of the 2016 and 2023 Cases

Based on the data reports for the 2016 and 2023 conditions of the study area, as shown in Figure 4.7, average building heights increased to 40 meters in 2023 from an average of 7.5 meters in 2016, and the facade to site ratio increased accordingly to a ratio of 79% from 50%. On the other hand, the introduction of a major urban park as part of the urban transformation project increased tree coverage from 2% to 11%. Again, by converting the asphalt and concrete ground into greenery, the grass area ratio increased from 5% to 20%. Therefore, the footprint density decreased from 28% to 11% as the number of building blocks decreased and vegetation coverage increased. In light of these two reports, three simulations were conducted on both cases, namely direct sun hours, incident radiation, and wind direction. As a brief definition, direct sun hours is used to measure the average number of hours that a surface is exposed to direct sunlight, by utilizing the specific sun chart of the location. It is generally produced for shadow analyses in urban scale, as well as for measuring glare in building scale. Incident radiation, however, is essentially used to calculate the solar energy strikes on a particular point in the long run.

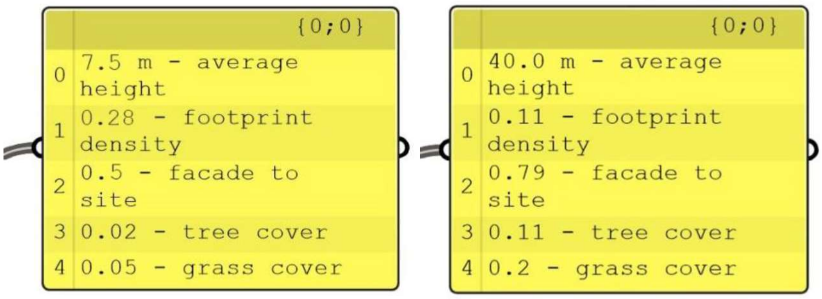

Figure 4.7. Data reports of the 2016 and 2023 cases of the same study area respectively

Figure 4.8 depicts the direct sun hours simulations for both the 2016 and 2023 cases. The implementation of an urban park with water elements clearly reduced the hours of sunlight exposure to a large extent, from 22-28 hours interval to 2-14 hours interval, and even partially 0 hours considering the green corridor that is supposed to be the urban park. When it comes to paths between buildings, it is observed that remarkably fewer buildings achieve the same shade level due to their increased height. For a more detailed and specific understanding, corresponding energy potential on the same area is illustrated in Figure 4.9 through the incident radiation simulation. Solar energy is extremely valuable as a renewable source, and the 2016 case has a high potential for its use. However, as the focus of this study, the sun also causes discomfort, which goes worse with excessive heat waves. A sufficient period of comfortable hours is important for a livable neighborhood, and it is realized that the 2023 case managed this with increased storeys and the green corridor. The urban park with water elements reduced incident radiation from 14.19 kWh/m^2 to less than 4.26 kWh/m^2. The surrounding buildings and paths also provided more comfort, with a solar energy interval of 4.26-9.93 kWh/m^2.

Finally, as the role of cool vegetated surfaces was discussed in Heat Resilient Cities tool estimations, its effects were observed. The change in grass cover from 5% to 20% (Figure 4.7) is not even close to the argued estimations above, but there are still visible changes in the simulations. As shown in Figure 4.8, the ground in the 2016 case was more yellow, indicating 28 hours on the scale, whereas the ground in the 2023 case is paler yellow, indicating less hours, with an interval of 25-28 hours on the scale. Similarly, as shown in Figure 4.9, the 2016 case had a radiation of 14.19 kwh/m^2, whereas the 2023 case has a paler shade of orange, indicating an interval of 11.35-12.77 kwh/m^2 based on the scale.

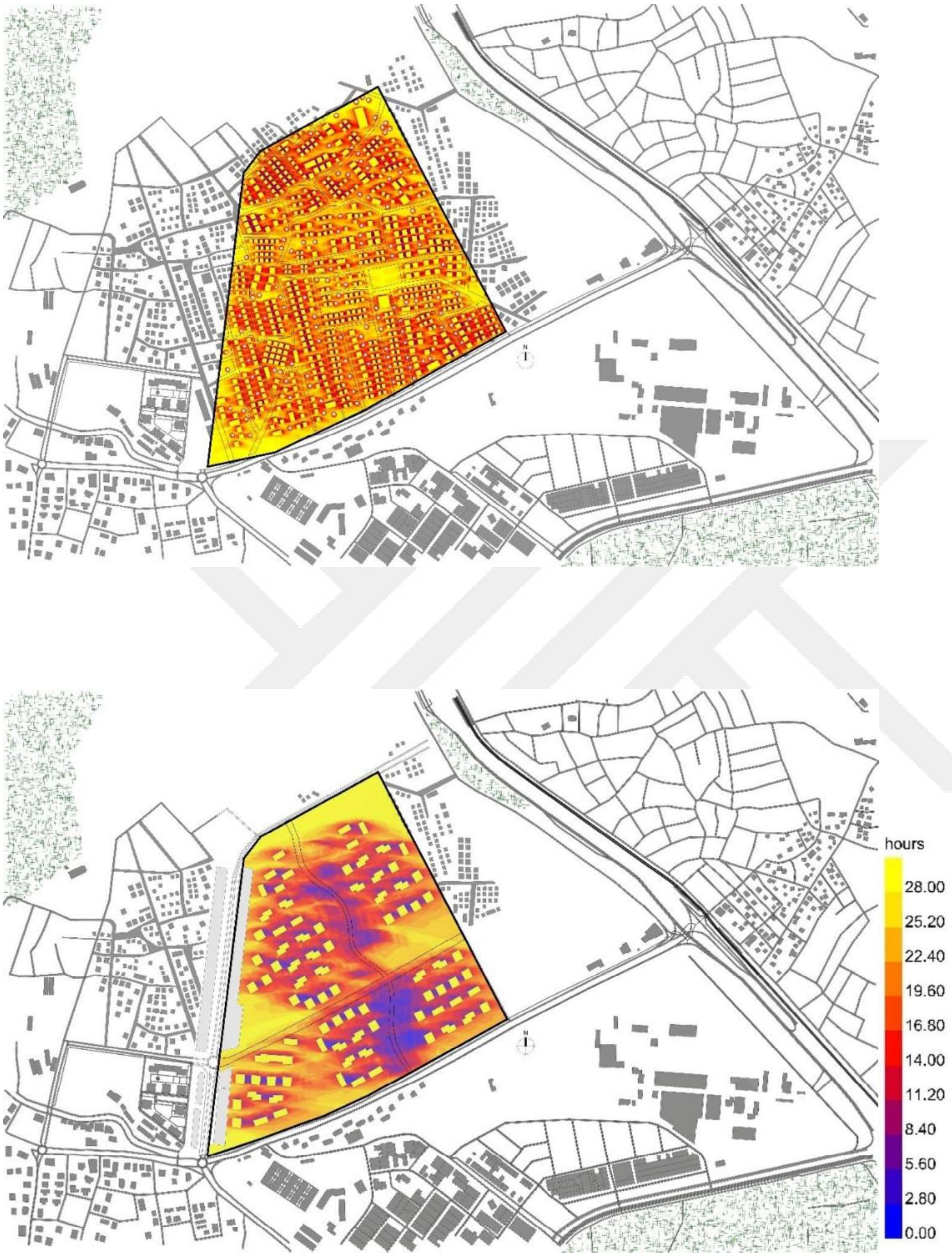

Figure 4.8. Direct sun hours before urban transformation in 2016 and after urban transformation in 2023 (top view)

Figure 4.9. Incident radiation before urban transformation in 2016 and after urban transformation in 2023 (top view)

Recalling Figure 4.1, "Using and preserving ecosystem services" was a critical component of urban heat adaptation strategies. Thus, it was decided to investigate whether the "Wind corridors for urban cooling" action was taken into account during the design process of the urban transformation project. The EnergyPlus Weather (epw) files were used as input once more to generate wind diagrams of the study area, and Figure 4.10 depicts the wind direction as well as wind speed on the 2016 case. The dominant winds are observed to be in the north and southeast directions. However, the grid of the old neighborhood does not appear to benefit from natural cooling opportunities. In the case of 2023, the gap between the blocks defines the main axis of the circulation path within the Park Zone of the urban transformation project. This axis was chosen to align with the northwest-southeast axis shown in Figure 4.11, as well as the placement of a vast urban park at the heart of the project, as its decreased heat maps are discussed above. While defining the main axes and locating the blocks, the design reveals that it considered wind analysis, hence benefitted from natural wind corridors. It undoubtedly helps to cool the new settlement and reduce the urban heat.

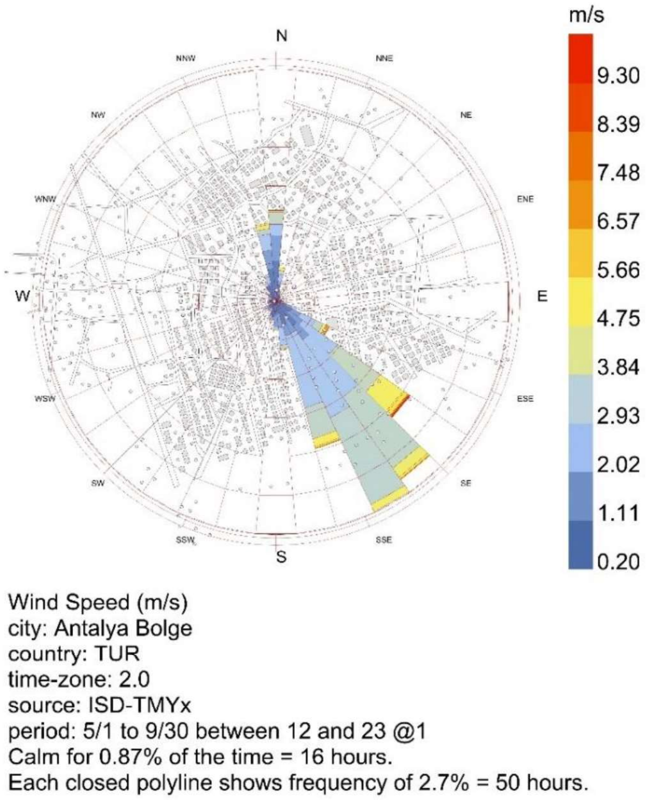

Figure 4.10. Wind rose of the study area shown on 2016 case (top view)

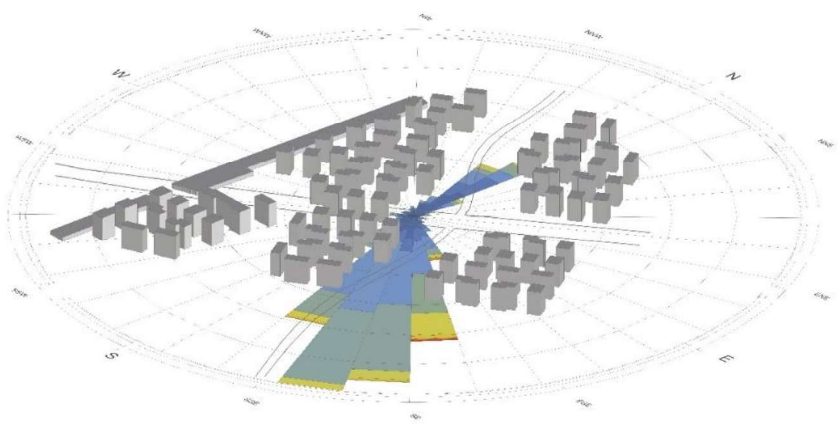

Figure 4.11. Intended green corridor of the urban transformation project following the main wind direction shown on 2023 case (southeast view)

As explained in the literature review, analyses of direct sun hours and solar energy play a significant role in measuring urban heat. Hence, as the next step in the research, the Dragonfly plug-in generated graphs tracking the dry bulb temperatures in the 2016 and 2023 cases. The secondary goal was to compare the temperature differences in these graphs to the results obtained from the Heat Resilient Cities tool above. Dry bulb temperatures were measured in three categories: daily data, monthly data, and monthly per hour data, as shown in Figures 4.12, 4.13, and 4.14.

Prior simulation analysis periods were chosen for the month of August, when excessive heat peaks, temperature values break records, and thermal discomfort is most likely an issue. In this regard, Figure 4.13 confirms that the urban heat island effect had a significant impact on the 2016 case when compared to the other months of the year. When comparing the two years, there is an irregular decrease from the same figure, but months like May or June may initially appear to be unchanged. Figure 4.14, on the other hand, shows the main difference in detail for these months. Monthly per hour data is generated for a more detailed understanding, as shown in Figure 4.14. This type of data can be used to track changes within a day as well as preserving the overall month data. While reading this graph, it is important to remember that a new day begins at midnight, and that the sunrise and subsequent daylight hours are drawn from the vertex to the end of the line for each month. Accordingly, it has been confirmed that in hot climates, such as the studied city Antalya, there are large diurnal swings in temperature, which reflect on both nighttime and daytime temperatures. Figure 4.14 also shows that dry bulb temperatures in 2016 and 2023 are fairly close in the morning hours, with the red and blue lines almost intersecting at the vertex; however, when the peak of the day arrives, which is in the afternoon hours, the separation is read more clearly. The 2016 case with the blue lines takes much longer to cool down, whereas the 2023 case with the red lines drops very quickly, implying that the new urban transformation area takes much less time to cool down.

As for the results comparison of estimations and simulations, Figure 4.13 shows a minus 2.5 °C change from 30.5 to 28 °C in August, the peak month for the reasons explained above, whereas the Heat Resilient Cities tool predicted a reduction of 1.51°C for the implementation of urban parks with 50% coverage, and 1.73 °C for the urban water. The Excel-based tool estimated the impact of each action separately, whereas both actions are implemented in the focused urban transformation area. Therefore, it can be argued that simulation analysis produced close results to the Heat Resilient Cities tool estimations. More importantly, the implementation of the subjected actions demonstrated that the urban heat island effect was indeed mitigated. The shift between 2016 and 2023 is significant also in terms of economy, with lower cooling costs on the bill. On the contrary, the 2023 scenario may raise heating costs during the winter months. In this regard, it should be noted that Antalya has a cooling dominant climate due to its hot and humid weather patterns. The city has a rather consistent climate, and many residents have never seen snow due to the relatively mild winters of the city. Even with the lower temperatures in 2023, Figure 4.12 shows that no day of the year falls below zero. As a result, the reduced energy use during the warmer seasons appears to already compensate for the increased energy use during the colder seasons.

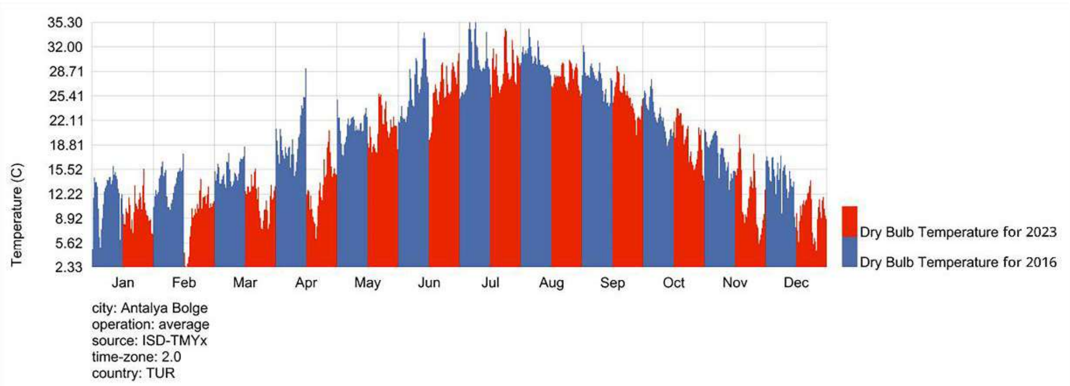

Figure 4.12. Daily data of the comparative analysis where blue indicates 2016, and red indicates 2023 condition of the study area (Dragonfly plug-in 2023) [prepared by author]

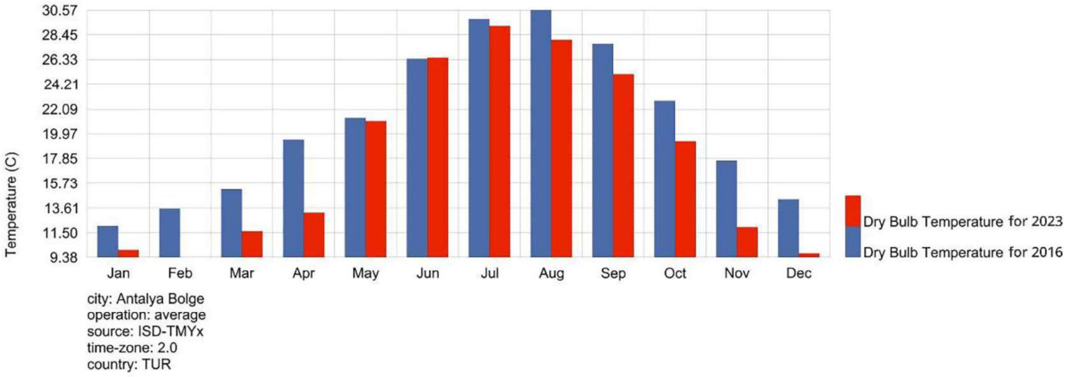

Figure 4.13. Monthly data of the comparative analysis where blue indicates 2016, and red indicates 2023 condition of the study area (Dragonfly plug-in 2023) [prepared by author]

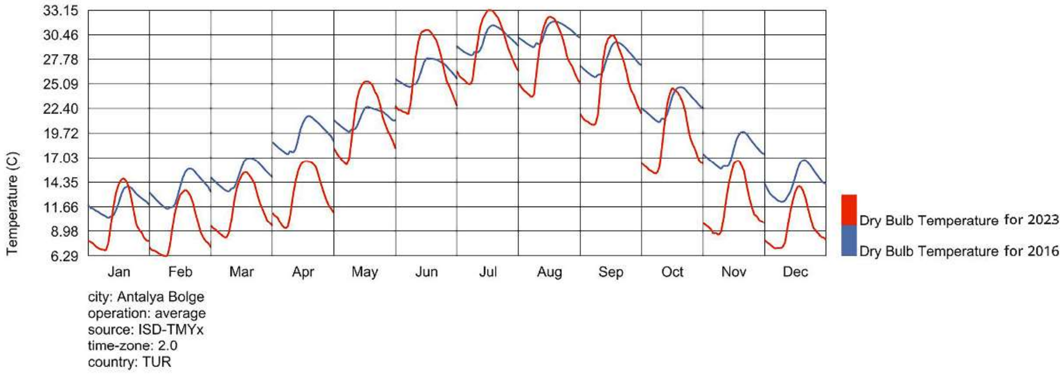

Figure 4.14. Monthly per hour data of the comparative analysis where blue indicates 2016, and red indicates 2023 condition of the study area (Dragonfly plug-in 2023) [prepared by author]

4.3.2 Comparison of Simulation Results of the Park and Street Zones

As the last focus of this study, the impact of different design strategies on the urban heat island effect are compared. For this purpose, the existing three zones of the new urban transformation project are reviewed, as shown in Figure 3.3 and 3.4 from the previous chapter. It was also explained in the same chapter that the Turquoise zone was designed like a smaller scaled replica of the main Park zone. Thus, two zones showcase the same strategies. However, the Street zone takes a completely different approach than the others. The blocks are attached on each side of a new street proposed as a part of the transformation project. Consequently, the area is much narrower and buildings are expected to provide sufficient shadow instead of vegetating the zone. The Park zone, on the other hand, is spread out over a larger area. The buildings have enough distance from one another, and a specific amount of vegetation covers the area, as analyzed above. On account of these major differences, the Street and Park zones have been chosen to be discussed in this section.

Figures 4.15 and 4.16 show the inclusion of the Street zone in the direct sun hours and incident radiation analyses. The Street zone, which is located next to the Park zone, is contoured separately with black lines on the left side of the simulation visuals. The design challenge in both zones remained the same, which was to provide adequate shading for thermal comfort. The findings in Figures 4.15 and 4.16 imply that, at first, both zones successfully managed the problem. Figure 4.15 depicts the direct sun hours analysis of both zones, and it is seen that the Street zone has reduced the hours of sunlight exposure to 5.60 on the scale. The Park zone results were previously shared, with a drastic decrease from 22-28 hours to an interval of 2-14 hours with the help of the new urban park. In terms of incident radiation analysis, Figure 4.16 shows that the Street zone produced results ranging from 4.26 to 7.09 kWh/m^2, which are quite similar to the previously shared Park zone.

Despite the fact that two zones share the same project type with equal building heights, material use, and facade applications, the difference in strategies at the urban scale results in different outcomes. Firstly, the scales of the two zones are not equal. Because of its narrow area, the Street zone is much easier to shade, even with existing building blocks, but the Park zone achieves the same level of thermal comfort through the use of natural elements. Furthermore, whereas the attached blocks of the Street zone are for this purpose, the use of a different strategy in the Park zone works as a multifunctional strategy, bringing additional benefits. Residents of the Park zone have access to a natural setting thanks to the urban park that runs through the heart of the new urban transformation project, whereas the Street zone is more limited and neighbors across the street cause privacy issues. Likewise, the Park zone provides common spaces for socialization through the urban park, and a safe environment for the young and elderly populations is realized by controlling the entrances to the zone, unlike the busy Street zone. Such a busy zone also brings with it a number of pollution issues. Light pollution, while a common issue in modern cities, is not considered a problem in the Street zone, because the new project follows the mitigation strategies on improved street lighting shared in Figure 4.2 with a reduced number of more efficient luminaires. Nevertheless, noise pollution is still a particular issue differentiating the Street zone from the Park zone. As a final remark, the simulations show the direct sun hours and incident radiation, accordingly solely the solar analysis. Yet, in terms of CO_2 emissions and the urban heat island effect, the fact that the Street zone has a significantly more vehicle traffic flow, whereas the Park zone has restrictions towards vehicle entry, must be considered.

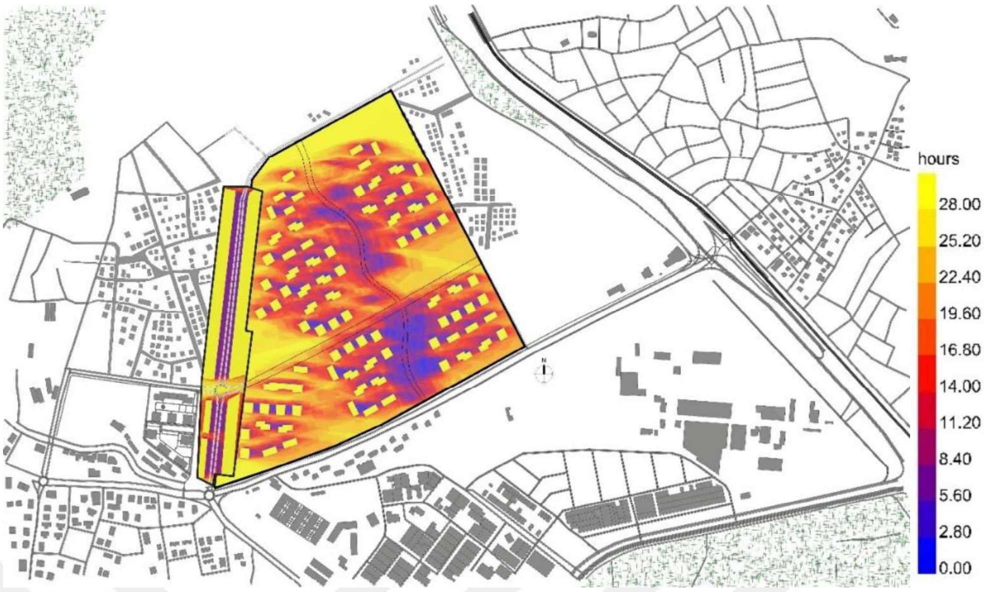

Figure 4.15. Direct sun hours for the integrated Park Zone (right) and Street Zone (left) after urban transformation in 2023 (top view)

Figure 4.16. Incident radiation for the integrated Park Zone (right) and Street Zone (left) after urban transformation in 2023 (top view)

4.4 Further Discussions

Certain topics in this paper are not covered for various reasons, and they can be discussed further to improve the current state of this research and to guide future studies. To begin, the simulation results of the study already represent the solar energy potential of the chosen area. Hence, the optimal placement of solar energy devices for maximum efficiency can be derived. Secondly, one of the categories estimated by the Heat Resilient Cities tool was the impact of cool artificial surfaces to the urban heat island effect. However, due to the unfinished state of the urban transformation project at the time this research was conducted, this category could not exceed an estimation level. Further research may investigate the properties of various building surfaces and materials in order to better understand the impact of cool artificial surfaces on the urban heat island effect. Similarly, to the cool artificial surfaces category, the Heat Resilient Cities tool was used to generate estimates for cool vegetation surfaces. As previously stated, the urban transformation project made room for several greening applications from the shortlisted adaptation strategies via the AMIA tool, such as green transitways and increasing the grass surfaces ratio. Nonetheless, there was no sign of green roofs or living facades. A related case study may look into the cooling effect of such applications.

Aside from material selection, different building forms and city planning schemes can be examined with the simulations used in this study. The case study area of this research compared a low-rise and dense suburban planning scheme to an urban transformation project with increased storeys and a less dense planning scheme. Separate zones with different design approaches were also compared, despite the fact that the building typologies were the same, and the only comparison criteria became the placement of the blocks and thus the shading solutions. In terms of shading solutions, neither the previous nor current versions of the case study area had an artificial shading device implementation. Shade devices such as urban canopies are widely preferred in cases where vegetating is not feasible. This study helped to understand the impact of vegetation as a mitigation solution to the urban heat island effect, but future research may compare the efficiency of artificial shading devices to natural elements, such as the application of an urban park in this study.

Lastly, if the difficulties in obtaining source data are overcome, another aspect that may be discussed further is how location difference changes strategy efficiency. It is assumed that the cooling effect would be different if the district was chosen differently than Kepez, where the urban transformation project is being built, and located closer to the seashore. For a different inland city of the country, where the change between summer and winter seasons is more dramatic with a more inconsistent climate, the methodology of this research can still be used but a completely different scenario would be captured.

CHAPTER 5

CONCLUSION

A variety of options for urban areas to develop climate resilience in different future scenarios have been explored in this paper. Most of the options were presented with real-life applications within the literature review. Yet, being one of the extreme events that requires preparedness, the urban heat island effect contains a knowledge gap on how the theories and innovations may be integrated to construct a holistic vision for heat-resilient communities or capitals. Expanding the adaptation and mitigation strategies over the boundaries of individual structures became a major area of study recently. Individual smart houses are unable to fight the urban heat island effect on a city scale. While modern theories with the developing technology appear to lead hot cities to become more resilient, their applications are confined to minor projects with minor contribution to the urban cycle. Thus, greater awareness of the necessary abilities, qualifications, and improvement techniques is required for cities to effectively respond to extreme heat and drought.

When conducting research, the primary source is the data that should be found on the subject of the study. Looking at the existing literature, it is clear that most research in Turkey, as in the rest of the world, is focused on popular cities. While it is not difficult to find data in cities such as Istanbul and Ankara, the source data and existing studies on Antalya, despite being a large city, are very limited. In addition to the location, the urban heat island effect has only recently been studied throughout the country. Correspondingly, the goal of this research was to contribute a useful case study to the literature in terms of both location and topic selection.

Based on a series of key sustainability methods for extreme events and their estimated performance, the effects of four implementations on urban heat island formation, three of which are present in the studied urban transformation project, were demonstrated as the main focus of this research. It is revealed that many lives can be saved with proper yet simple applications, such as increasing green coverage, and the reduced temperatures with these applications are proven in the urban transformation project. Given that Antalya has a remarkable aging population ratio, the findings on fatalities are expected to emphasize the importance of designing climate-resilient cities for future scenarios.

Additionally, different strategies used at the different zones of the investigated project were compared. Various adaptation and mitigation strategies were discussed, revealing the distinction between natural and artificial intervention in design. When the current state of the study area is compared to the previous state, a situation contrary to popular belief was established. Most urban transformation projects generate controversy because they transform friendly neighborhoods with few floors and gardens into multi-story building estates. Although horizontal architecture has become overused as a term for sustainability, this study also proved that multi-story complexes can perform better under the right conditions.

Overall, this paper established that, like the effects of other extreme events, the urban heat island effect can also be mitigated through proper analysis and mapping for an effective response. Nevertheless, dreaming and striving for a brighter and more secure future is not a task limited to designers alone. It requires the active participation and support of all citizens of all professions. In order to achieve this, individuals should reconsider their lifestyles and make necessary changes on the way to minimize the potential risks associated with climate change. Similarly, governments play a crucial role in fostering this change by adopting a receptive approach and implementing policies that align with the needs and concerns of the public. Most importantly, environmental awareness should become a core component of education, ensuring that future generations are equipped with the knowledge and understanding to make environmentally conscious decisions. As the twig bends, so grows the tree.

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APPENDICES

A. C40 Reporting Document

Table 2. Please identify and describe **the [5-10] factors** that will **most greatly** affect your jurisdiction's adaptive capacity. (m)

FACTOR *(grouped under headers, can report on multiple across the table)*	Description (m)	Degree to which this factor presents a challenge for your jurisdictions adaptive capacity (m)
Services		
Access to basic services	[open field]	○ High ○ Moderate ○ Low ○ No concern[23] ○ Do not know
Access to healthcare	[open field]	[dropdown as above]
Access to education	[open field]	[dropdown as above]
Public health	[open field]	[dropdown as above]
Socio-economic		
Cost of living	[open field]	[dropdown as above]
Housing	[open field]	[dropdown as above]
Poverty	[open field]	[dropdown as above]
Inequality	[open field]	[dropdown as above]
Unemployment	[open field]	[dropdown as above]
Migration	[open field]	[dropdown as above]
Economic health	[open field]	[dropdown as above]
Economic diversity	[open field]	[dropdown as above]
Governmental		
Political stability	[open field]	[dropdown as above]
Political engagement / transparency	[open field]	[dropdown as above]
Government capacity	[open field]	[dropdown as above]
Budgetary capacity	[open field]	[dropdown as above]
Safety and security	[open field]	[dropdown as above]
Land use planning	[open field]	[dropdown as above]
Access to quality / relevant data	[open field]	[dropdown as above]
Community engagement	[open field]	[dropdown as above]
Physical &Environmental		
Rapid urbanization	[open field]	[dropdown as above]
Resource availability	[open field]	[dropdown as above]
Environmental conditions	[open field]	[dropdown as above]
Infrastructure conditions / maintenance	[open field]	[dropdown as above]
Infrastructure capacity	[open field]	[dropdown as above]
Other		
Other ________	[open field]	[dropdown as above]

Table 4. If available, please provide more information on your jurisdiction's climate adaptation plan(s)[21]

Title (m)	Short Description (m)	Year adopted (m)[22]	Nature of climate adaptation plan (m)	Scope/Boundary [23] (m)	Primary author (m)	Update/revision process (opt)	Upload file (m)[24]
[open field]	[open field]	[dropdown of years] ○ Not adopted	○ Standalone climate adaptation plan ○ Addressed in combined adaptation and mitigation climate action plan± ○ Addressed in general city plan ○ Addressed in city sector plan(s) ○ Other ________	○ Same, covers whole jurisdiction and nothing else ○ Smaller, covers part of the jurisdiction ○ Larger, covers the whole jurisdiction and adjoining areas ○ Partial, covers part of the jurisdiction and adjoining areas	○ Local government ○ Consultant ○ International organization ○ Community group ○ Regional / state / provincial government ○ National / central government ○ Other ____________	○ Formal schedule for update ○ Yes ○ No ○ Do not know ○ If yes, what is the time period for update? (years): ______ ○ Status of current update ○ Currently Exists; ○ In Progress ○ Does not exist but intending to undertake in the future; ○ Do not know	

Table 1. Please identify **the most significant** climate hazards faced by your jurisdiction (m) and complete the questions to the right for each one.†		
HAZARDS [16] *(grouped under headers, can report on multiple across the table)*	CURRENT hazard **RISK** level (*dropdown for each hazard selected)*	
	Probability of Hazard [17] (m)	Consequence of hazard (m)
Extreme Precipitation		
Rain storm	○ High ○ Moderate ○ Low ○ Do not know	○ High ○ Moderate ○ Low ○ Do not know
Monsoon	[dropdown as above]	[dropdown as above]
Heavy snow	[dropdown as above]	[dropdown as above]
Fog	[dropdown as above]	[dropdown as above]
Hail	[dropdown as above]	[dropdown as above]
Storm and wind ∨		
Severe wind	[dropdown as above]	[dropdown as above]
Tornado	[dropdown as above]	[dropdown as above]
Cyclone (Hurricane / Typhoon)	[dropdown as above]	[dropdown as above]
Extra tropical storm	[dropdown as above]	[dropdown as above]
Tropical storm	[dropdown as above]	[dropdown as above]
Storm surge	[dropdown as above]	[dropdown as above]
Lightning / thunderstorm	[dropdown as above]	[dropdown as above]
Extreme cold temperature ∨		
Extreme winter conditions	[dropdown as above]	[dropdown as above]
Cold wave	[dropdown as above]	[dropdown as above]
Extreme cold days	[dropdown as above]	[dropdown as above]
Extreme hot temperature ∨		
Heat wave	[dropdown as above]	[dropdown as above]
Extreme hot days	[dropdown as above]	[dropdown as above]
Water Scarcity ∨		
Drought	[dropdown as above]	[dropdown as above]
Wild fire ∨		
Forest fire	[dropdown as above]	[dropdown as above]
Land fire	[dropdown as above]	[dropdown as above]
Flood and sea level rise ∨		
Flash / surface flood	[dropdown as above]	[dropdown as above]
River flood	[dropdown as above]	[dropdown as above]
Coastal flood	[dropdown as above]	[dropdown as above]
Groundwater flood	[dropdown as above]	[dropdown as above]
Permanent inundation	[dropdown as above]	[dropdown as above]
Chemical change ∨		
Salt water intrusion	[dropdown as above]	[dropdown as above]
Ocean acidification	[dropdown as above]	[dropdown as above]
Atmospheric CO2 concentrations	[dropdown as above]	[dropdown as above]
Mass movement ∨		
Landslide	[dropdown as above]	[dropdown as above]
Avalanche	[dropdown as above]	[dropdown as above]
Rock fall	[dropdown as above]	[dropdown as above]
Subsidence	[dropdown as above]	[dropdown as above]
Biological hazards ∨		
Water-borne disease	[dropdown as above]	[dropdown as above]
Vector-borne disease	[dropdown as above]	[dropdown as above]
Air-borne disease	[dropdown as above]	[dropdown as above]
Insect infestation	[dropdown as above]	[dropdown as above]

Please indicate how you expect climate change to affect the intensity and frequency of each hazard and when you FIRST expect to experience those changes† [18]			Please describe the overall impact of FUTURE hazards in your jurisdiction and the sectors, assets, and/or services that will be most affected (up to 5). [19]			Please indicate which vulnerable population groups will be most impacted by FUTURE hazards. † [20]
Expected change in frequency (m)	Expected change in intensity (m)	Timescale [21] (m)	Description of expected impact (r)	Impacted sectors, assets, and services (m) (c) [22] *(select up to 5)* and the magnitude of those impacts (m)		Impacted vulnerable groups † (r) (c) *(can select multiple for each hazard)*
○ Increase ○ Decrease ○ No change ○ Not known	○ Increase ○ Decrease ○ No change ○ Not known	○ Immediately ○ Short-term ○ Medium-term ○ Long-term ○ Not known	[open field]	○ Transport ○ Energy ○ ICT (Information and Communications technology) ○ Water supply and sanitation ○ Waste management ○ Public Health ○ Law & Order ○ Emergency Services ○ Land use planning ○ Education ○ Food & Agriculture ○ Environment, Biodiversity, Forestry ○ Commercial ○ Industrial ○ Tourism ○ Residential ○ Society/community & culture ○ Other ____	< Magnitude of expected impact ○ High ○ Moderate ○ Low ○ Do not know	*[List of vulnerable groups, e.g.* *Women* *Youth* *Elderly* *Indigenous population* *[Other etc.]*
[repeat as above, for all hazards]	[repeat as above, for all hazards]	[repeat as above, for all hazards]	[repeat as above, for all hazards]	[repeat as above, for all hazards]	[repeats, for all hazards and s/a/s]	[repeat as above, for all hazards]

Figure A.1. C40 Risk and Vulnerability Assessment Reporting Framework (C40 Cities 2018)

B. Weather Analysis and Simulation Period

Figure B.1. Heat Resilient Cities: Measuring Benefits of Urban Heat Adaptation tool city selection interface (Heat Resilient Cities 2023)

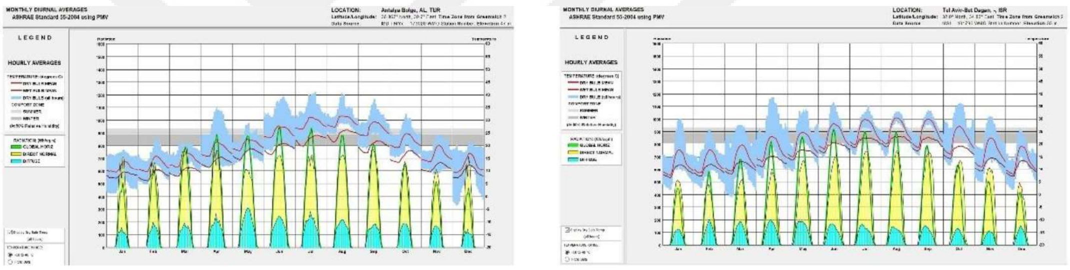

Figure B.2. Antalya, Turkey (left) and Tel Aviv, Israel (right) monthly diurnal averages comparison (Climate Consultant 2023) [prepared by author]

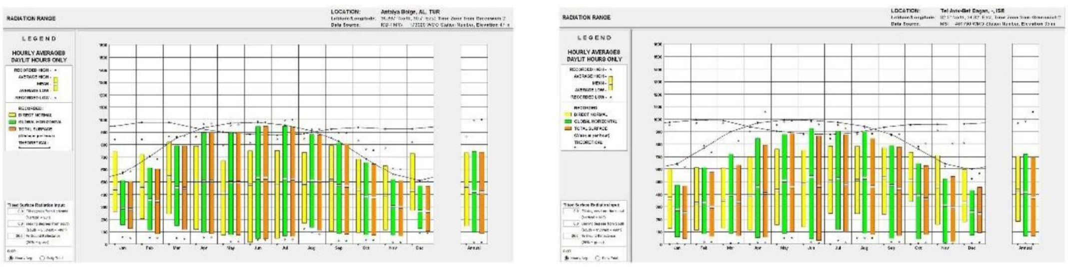

Figure B.3. Antalya, Turkey (left) and Tel Aviv, Israel (right) radiation range comparison (Climate Consultant 2023) [prepared by author]

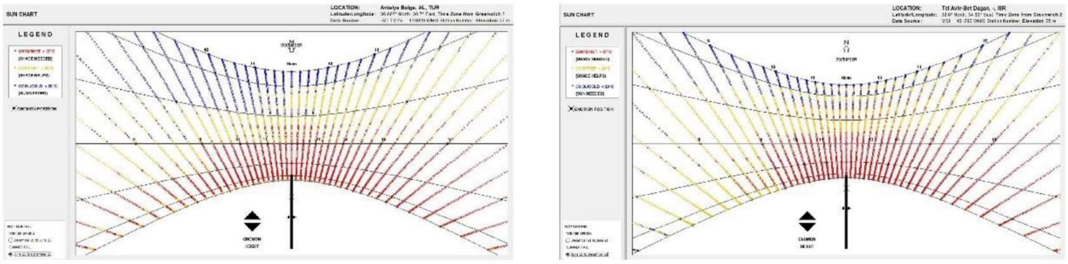

Figure B.4. Antalya, Turkey (left) and Tel Aviv, Israel (right) sun chart comparison (Climate Consultant 2023) [prepared by author]

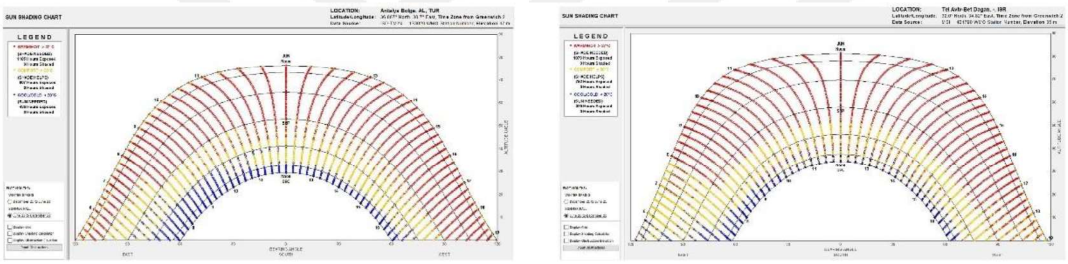

Figure B.5. Antalya, Turkey (left) and Tel Aviv, Israel (right) sun shading chart comparison (Climate Consultant 2023) [prepared by author]

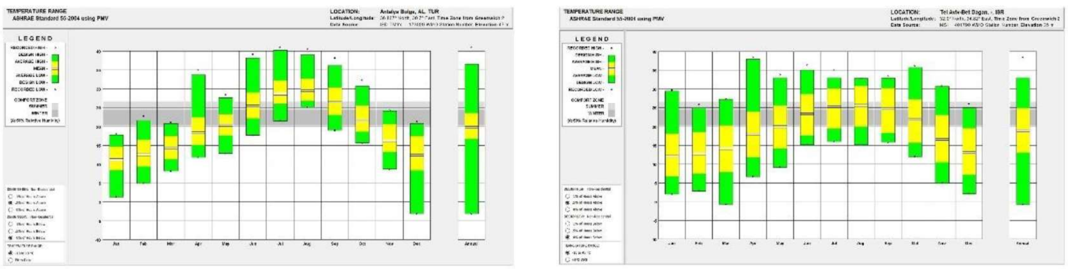

Figure B.6. Antalya, Turkey (left) and Tel Aviv, Israel (right) temperature range comparison (Climate Consultant 2023) [prepared by author]

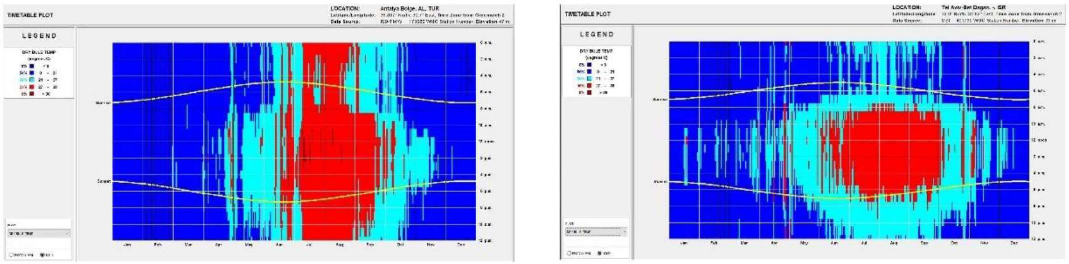

Figure B.7. Antalya, Turkey (left) and Tel Aviv, Israel (right) timetable plot comparison (Climate Consultant 2023) [prepared by author]

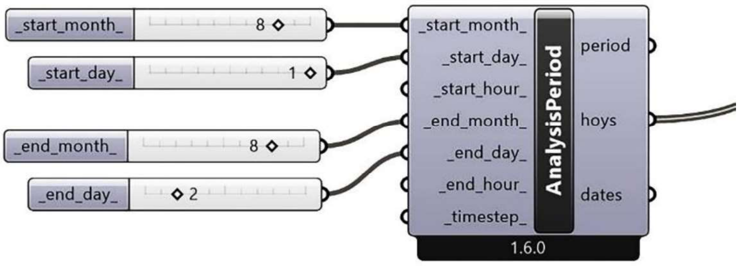

Figure B.8. Analysis period for the direct sun hours and incident radiation simulations

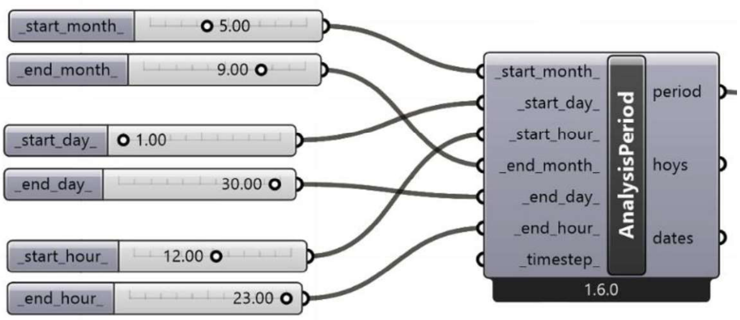

Figure B.9. Analysis period for the wind simulations