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IMPACT ASSESSMENT OF URBAN REGENERATION PRACTICES ON MICROCLIMATE IN THE CONTEXT OF CLIMATE CHANGE

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ABSTRACT

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The annual ever-increase in population, urbanization, industrialization, and CO_2 or greenhouse gas emissions brings with it important environmental crises. Climate change and urban heat islands (UHI) are crucial environmental crises that have serious consequences on the performance of the built environment and the comfort and health of users. Moreover, mass migrations from the urban areas and unhabitable cities are envisaged as a result of climate change. To minimize the impacts of climate change and ensure the resilience of urban environments, mitigation and adaptation strategies such as reshaping urban form, modifying the land-use structure, retrofitting existing buildings, maintaining infrastructure systems, and improvement of urban services should be adopted. In this context, urban regeneration is inherently to contribute to the implementation of sustainable development by 'recycling' land and buildings, reducing demolition waste, and reducing demand for urban growth. However, in Turkey, the potential of urban regeneration in terms of sustainability is not embraced yet. This study analyses the combined impacts of climate change and UHIs on urban environments before and after urban regeneration. An existing regeneration practice in Doğanbey, Bursa, is selected as a case study to evaluate the selected performance indicators, including outdoor temperatures, outdoor thermal comfort, and daylighting. The results show that a decrease is observed in urban performance with regard to climate change and UHI after urban regeneration. It has been concluded that it is necessary to adopt a holistic perspective that covers all of the sustainable development dimensions.

Keywords: Climate Change, Urban Heat Island, Urban regeneration, Outdoor Microclimate, Outdoor Thermal Comfort

ÖZ

İKLİM DEĞİŞİKLİĞİ BAĞLAMINDA KENTSEL DÖNÜŞÜM UYGULAMALARININ MİKRO İKLİM ÜZERİNDEKİ ETKİ DEĞERLENDİRMESİ

Gizem, Akköse
Yüksek Lisans, Yer Sistem Bilimleri
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Nüfus, kentleşme, sanayileşme ve CO_2 veya sere gazı emisyonlarındaki yıllık sürekli artış, önemli çevresel krizleri de beraberinde getirmektedir. İklim değişikliği ve kentsel ısı adası (KIA), yapılı çevrenin performansı ve kullanıcıların konforu ve sağlığı üzerinde ciddi sonuçları olan çok önemli çevresel krizlerdir. Ayrıca bu krizler sonucunda kent alanlarından kitlesel göçler ve yaşanamaz şehirler öngörülmektedir. İklim değişikliğinin etkilerini en aza indirmek ve kentsel çevrelerin değişimle başa çıkmasını sağlamak için kentsel formun yeniden şekillendirilmesi, arazi kullanım yapısının değiştirilmesi, mevcut binaların güçlendirilmesi, altyapı sistemlerinin bakımı ve kentsel hizmetlerin iyileştirilmesi gibi azaltma ve uyum stratejileri benimsenmelidir. Bu bağlamda kentsel dönüşüm, doğası gereği arazi ve binaları 'geri dönüştürerek', yıkım atıklarını azaltarak ve kentsel büyümeye yönelik talebi azaltarak sürdürülebilir kalkınmanın uygulanmasına katkıda bulunmaktır. Ancak Türkiye'de sürdürülebilirlik açısından kentsel dönüşüm potansiyeli henüz benimsenmemiştir. Bu çalışma, kentsel dönüşüm öncesi ve sonrası iklim değişikliğinin ve KIA'nın kentsel çevreler üzerindeki birleşik etkilerini analiz etmektedir. Varolan bir kentsel dönüşüm uygulaması olan Bursa Doğanbey projesi, dış ortam sıcaklıkları, dış ortam ısıl konforu ve günışığı dahil olmak üzere seçilen performans göstergelerini değerlendirmek amacı ile vaka çalışması olarak seçilmiştir. Sonuçlar, kentsel dönüşüm sonrası iklim değişikliği ve KIA açısından kentsel performansta bir düşüş gözlemlendiğini göstermektedir. Tüm sonuçlar ışığında, sürdürülebilir kalkınmanın tüm boyutlarını kapsayan bütüncül bir bakış açısının benimsenmesi gerektiği sonucuna varılmıştır.

Anahtar Kelimeler: İklim Değişikliği, Kentsel Isı Adası, Kentsel Dönüşüm, Dış Mekan Mikroklima, Dış Mekan Isıl Konfor

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CHAPTER 1

INTRODUCTION

1.1 Background and Problem Statement

In the 21st century, humanity is faced with many environmental, economic, and financial crises, including climate crisis, pandemic crisis, and financial crisis. These crises have many causes and consequences that constantly affect each other. It is aimed to balance social, economic, and environmental sustainability and to create a sustainable future for everyone. Among these crises that are trying to cope with, climate change has become a compelling, threatening, and devastating global crisis. Many negative and vital impacts on human health, the Earth's ecosystem, economy, and society have begun to be experienced. Anthropogenic causes, a huge amount of CO_2 and other gas emissions based on industrial, agricultural, and transportation activities, and human settlement, are mostly responsible for this change. In this context, the built environment or urban areas are a key contributor to climate change. Urban areas and buildings consume more natural resources and more energy than any other human activity, and they generate substantial amounts of greenhouse gases, toxic air, CO_2, and water pollutants (Smith, 2005). The rapid increase of the population living in cities, significant changes in the land cover, migration from rural areas to cities, and more industrial, commercial, and transportation services trigger warming in cities increases with the effect of the urban heat island. Moreover, the urban heat island (UHI) effect stimulates global climate change on a local scale and creates negative effects on the health of people and other living things, quality of life, energy consumption, extreme weather, etc. The key and emerging global climate risks are concentrated in urban areas, and a high proportion of the world's population most affected by extreme weather events is concentrated in urban centers. Extreme weather has severe impacts, including high mortality. In line with these facts, it is explicit that the cities are part of the climate crisis, both affecting and affected factors.

In order to minimize these effects, adaptation and mitigation strategies are followed in line with the perspective of sustainable development at the urban level. Fundamentally, urban regeneration is a way to mitigate the combination impacts on climate change and UHI with its aspect of retrofitting and improvement in existing settlements rather than planning the new ones. In other words, urban regeneration can provide an opportunity to make cities more climate-friendly and less vulnerable through rehabilitation, recycling, and renewal (Balaban, 2011). It has been observed that effective transformations improve not only social, economic, and physical conditions but also reduce environmental effects (Andreucci et al., 2021; Balaban & Puppim de Oliveira, 2014a; Gaspari & Fabbri, 2017). However, in Turkey, this is not exactly the case. Urban regeneration is the government policy in Turkey. In other words, urban regeneration policies, as an extension of political philosophy in Turkey, have been restructuring urban areas for recent years. As a result of this extension, it can be said that the implemented regeneration projects do not take environmental issues into account and also limit social relations, isolate people, and cause economic and social fluctuations (Miray Gür, 2018).

1.2 Aims, Objectives, and Research Questions

The main aim of this study is to evaluate the impacts of climate change and UHIs on cities and to predict how poorly implemented urban interventions amplify these impacts. In this regard, the Doğanbey neighborhood in Bursa, Turkey, which is the focus of many positive and negative criticisms, is chosen as a case study. The effects of the urban regeneration project implemented in Doğanbey on microclimate, outdoor temperature, outdoor thermal comfort, and daylighting are conducted a comparative analysis with the situation before regeneration. The study seeks to answer the following questions:

1. What is the relationship between climate and the built environment?
2. How do the varying future climatic conditions and urban heat island (UHI) influence the outdoor temperature?
3. What are the most effective adaptation and mitigation strategies for climate change and UHI at the urban level? and What is the role of urban regeneration?
4. To what extent have current urban regeneration projects addressing climate change?
5. What are the current and future effects of urban regeneration projects implemented without considering a sustainable future?

1.3 Method

This research is based on a systematic methodology that is underpinned by microclimate analysis through quantitative simulation. A simulation-based computational method is adopted to examine and contrast the situation of urban context before and after urban regeneration in terms of temperature, thermal comfort, and daylight quality. The research presented in this study consists of a few steps, as follows:

a) An extensive literature review on climate and the built environment, urban heat island effect and its relationship with climate change, adaptation and mitigation strategies, urban regeneration in the context of climate change, and Tukey's urban regeneration approaches;

b) The development of a simulation model to analyze the before and after situation of an urban context;

c) The assessment or analysis of current and future climate data with UHI effect;

d) The evaluation of the results.

CHAPTER 2

LITERATURE REVIEW

This chapter presents an extensive overview related to climate change and its interaction with the urban environment, urban heat island (UHI) effect and its relationship with climate change, approaches as mitigation and adaptation strategies in the urban environment to cope with the changing climate and UHI effect, and urban regeneration concept in the context of changing climate.

2.1 Climate Change and Urban Heat Island Effect

The climate and built environment are always in a complex, dynamic and bidirectional interaction. The built environment creates unique and site-specific microclimatic conditions as well as modifies the climate. With the climate crisis, the dialogue of the built areas with the environment has become a focus issue. This section addresses climate change, its relationship with the built environment from an urban perspective, and UHI effects.

2.1.1 Climate Change and Built Environment

In the 21st century, humanity is faced with many environmental, economic, and financial crises. These crises have many causes and consequences that constantly affect each other. Among all these, climate change has already become a compelling, threatening, and devastating global crisis. Many negative and vital impacts on human health, the Earth's ecosystem, economy, and society have begun to be experienced (NASA, 2021; Pachauri et al., 2014). Climate change can be driven by natural and/or human-induced factors. However, anthropogenic causes, a huge amount of CO_2 and other gas emissions based on industrial, agricultural, and transportation activities, and human settlement, are mostly responsible for this change (Priyadarshi R. Shukla et al., 2019). In this context, the urban environment is one of the main contributors to climate change. The urban environment is responsible for the consumption of more natural resources and more energy, substantial amounts of greenhouse gas emissions, generation of construction and demolition waste, indoor air pollution, and water pollutants (Dimoudi & Tompa, 2008; Field et al., 2014; Smith, 2005). As cited in the AR5 report of IPCC, it is reported that

> "Urban energy-related CO_2 emissions at 19.8 Gt or 71% of the global total for the year 2006. This corresponds to 330 EJ of primary energy, of which urban final energy use is estimated to be at 222 EJ. The Global Energy Assessment provides a range of final urban energy use between 180 and 250 EJ with a central estimate of 240 EJ for the year 2005. This is equivalent to an urban share between 56% and 78% (central estimate, 76%) of global final energy use" (Pachauri et al., 2014, p.935).

Population size, land use, rapid urbanization, and density are the main factors of anthropogenic climate change and accelerate this change. Climate change has an impact on urban areas as well as the built environment's impact on climate.

It is obvious that climate change will continue for an extended period of time. Although there are various emissions scenarios from low to high, at current rates of temperature increase, it is presumed that many cities will become uninhabitable because of extreme weather events, and this causes mass migration (Murray, 2019). A striking change in climate conditions will be experienced by 77% of the cities around the world (Bastin et al., 2019). The temperature of urban areas will be 3.5°C hotter in summers 4.5°C in winters throughout all of Europe (Figure 1) (Bastin et al., 2019). These assessments clarify that the assembled climate will be strongly influenced by climate change. In addition to increases in temperature, psychological and social health are affected through flood and drought impacts on housing, food security, and livelihoods around urban areas.

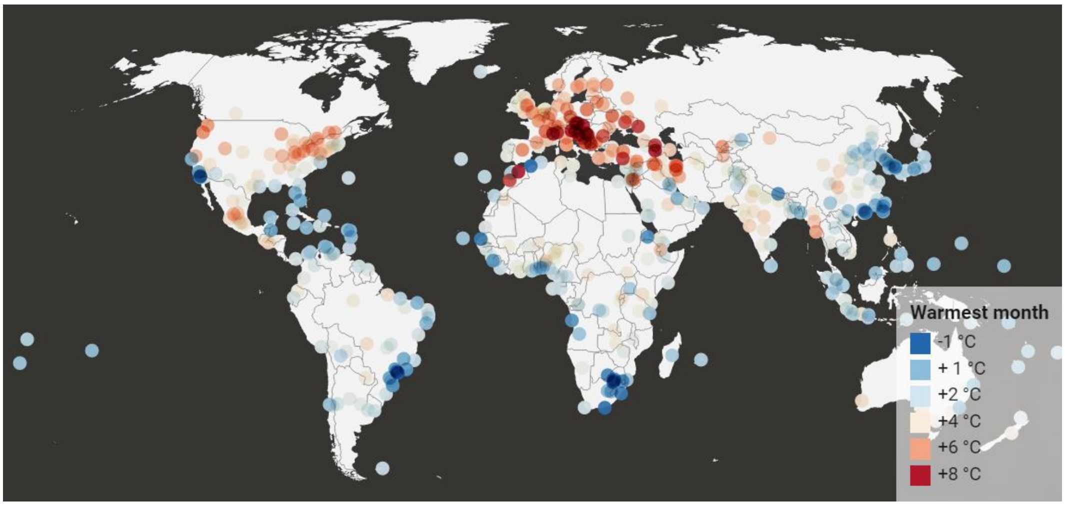


Figure 1. increase in temperature of the warmest month in capital cities (Bastin et al., 2019)

2.1.2 Climate context and climate change in Turkey

Turkey is in the Mediterranean geographical region that has quite temperate climatic conditions; however, there are significant differences in climatic conditions from one region to the other in there. In compliance with the Köppen system of climate classification, one of the most widely used climate classification systems and combines measurements of average temperature and precipitation, as well as seasonal variations, the climate of the Turkey is divided into several different climate zones (Figure 2).

The coastal areas of the Mediterranean Sea and the Black Sea have a Csa Climate, a warm temperate Mediterranean climate with dry, warm summers and moderate, wet winters with the warmest month above 22°C over average. The mountainous regions of Anatolia have a Dsa Climate, a snow climate with a dry summer and the warmest month above 22°C, and the coldest month below -3°C. The climate of the central Anatolian plateau can be classified as Csb Climate, a cold, dry climate with a dry summer and annual average temperatures under 18°C.

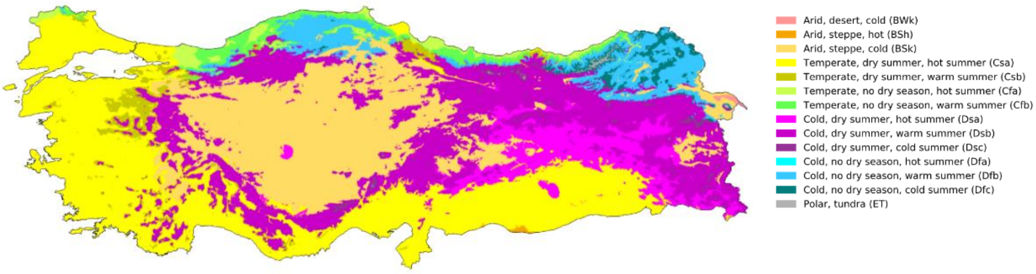


Figure 2. Köppen-Geiger climate classification map for Turkey (Beck et al., 2018, p. 3).

As compared to the global change in temperature, the impacts of climate change in Turkey reflect global patterns, but Turkey is projected to be one of the regions that are most vulnerable to climate change in the Mediterranean basin (IPCC, 2014). The impacts are projected to continue and can be summarized as follows:

- Temperature increases, causing warmer winters with less snow
- Heatwaves and greater droughts frequency
- Reduction in surfaces and freshwater resources
- Greater frequency of floods due to sudden and heavy rainfall
- The gradual shifting of the seasons.

The major causes of these impacts are incorrect agricultural activities and implementations, a fast-growing population, and rapidly and faultily increasing urbanization.

2.1.3 Urban Heat Island (UHI) Effect

Although urban areas cover a very small portion of the Earth's surface, their adverse impacts on climate change were discussed in the previous section, and it was highlighted that cities are affected in a strong way by climate change (UN-Habitat, 2020). Moreover, there is one more environmental problem facing all urban areas, the urban heat island (UHI) effect. The air temperature tends to be significantly higher in cities compared to their surrounding rural areas, and the phenomenon is called the UHI effect (Figure 3).

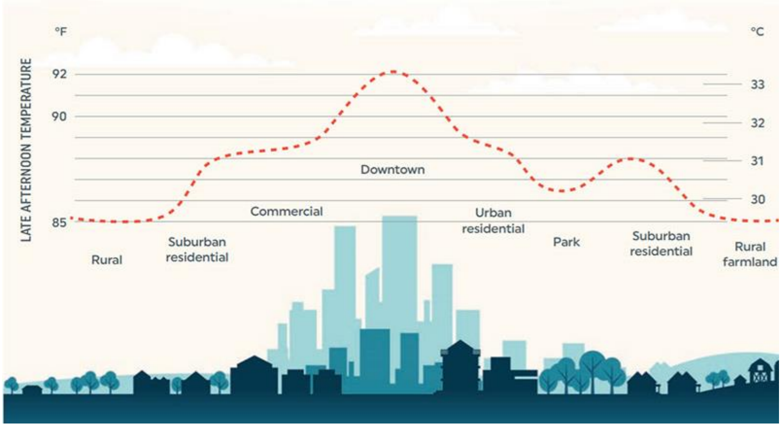


Figure 3. Generalized cross-section of a typical UHI

The formation of UHIs is one of the most effective evidence of the anthropogenic impact, and it is a form of local anthropogenic climate change. It is pointed out that "even a single building may create a measurable disturbance to the land in its natural state." (Erel et al., 2011, p.70).

The factors that caused UHI can be categorized as controllable and uncontrollable. Wind speed, cloud cover, anticyclone conditions, diurnal conditions, and season are rooted in nature, and for this reason, they are uncontrollable variables. They show temporary effects (Hong et al., 2020; Rizwan et al., 2008). Urban form, building density, sky view factors, impervious surfaces, vegetation, properties of urban materials, and anthropogenic heat sources, including the cooling and heating of buildings, are the major factors that intensify UHIs. They are controllable but permanent variables related to the built environment. In addition to these factors, transportation, manufacturing, and lighting also intensify UHIs effect in an instant and direct way.

Although the UHI effect is known as local climate change, it has a much broader role in a global sense. In point of fact, urban heat islands and climate change affect each other consistently. UHIs are expected to trigger the interaction between climate change-related risks and vulnerability, especially in terms of excessive heating, while temperature increases resulting from climate change have a high potential to impact the urban heat island (UHI) effect exacerbatingly (Corburn, 2009; Erell et al., 2011).

As stated, the UHI effect causes a major increase in outdoor temperature. However, the climatic data are generally collected in rural areas outside of the urban belt, and the UHI effect and its possible impacts on the temperature are neglected in general. Therefore, UHIs should be taken into consideration for taking proper measures on climate change, accurate predictions for future climatic variables, and the improvement of human thermal comfort.

2.2 Adaptation and Mitigation Strategies

Managing impacts and future risks of climate change and UHIs is possible in two approaches; mitigation and adaptation. Basically, mitigation is to "*reduce the impacts of climate change"*, and adaptation is to "*cope with the impacts of climate change"* (Laukkonen et al., 2009, p.288). The purpose of the reduction is to balance the level of anthropogenic CO_2 emissions in a specific time period and to observe rapid recovery. It is easily applied to different areas from the global to the individual level, including technical and infrastructural investments, renewable energy implementation, and increasing energy efficiency (Laukkonen et al., 2009). There should be a synergy or simultaneous support between mitigation and adaptation to achieve a sustainable future. Sustainable future or development requires managing many threats and risks, including climate change, and this is possible with both mitigation and adaptation strategies. These strategies can be implemented at many levels and in many sectors or fields. However, regarding the aim of this study, the strategies only for urban areas or cities are focused.

2.2.1 Strategies for Urban Areas

Cities represent an integral part of both low-carbon and sustainable future, and both mitigation and adaptation strategies, therefore, have become crucial issues for the urban environment. Mitigation and adaptation within the urban areas aim to provide reducing impacts on the environment, successfully manage the risks of changing climate, optimize and extend the life cycle of the urban environment, and healthier and more comfortable living conditions for the users. The strategies differ depending on the scale, from regional to neighborhood to building scale. At the regional level, the development of sustainable spatial forms that focused on the geometric and configurational ordering of space in the city "provides essential merits for mitigation and adaptation" (Balaban, 2011, p. 4). With the effective positioning of buildings and streets, extra heat gain from the sun can be reduced. The form and placement of buildings and streets can be designed to provide passive ventilation. Moreover, the role of green and blue infrastructure is undeniable. They considerably help to cool the environment by evaporation and transpiration and passively by shading surfaces that otherwise would have absorbed short-wave radiation (Kleerekoper et al., 2012). High-quality green spaces, made up of a linked network of well-irrigated open spaces, can provide channel breezes into buildings and enhance natural ventilation. Also, they have additional ecological, recreational, and flood storage benefits. Green infrastructure in urban areas includes open spaces, woodlands, street trees, fields, parks, outdoor sports facilities, community gardens, village greens, private gardens, Urban services, and infrastructure including "*extensive public transportation systems, renewable energy consumption and generation, renewed infrastructure utilities, sustainable solid waste management"* can be considered as a response for climate change (Balaban, 2011, p. 3). At the building level, retrofitting the existing building stock is also a valid way to combat climate change. Passive and active strategies in existing buildings provide energy efficiency, better air quality, thermal comfort, and visual comfort, healthy and productive occupants, less vulnerability, and less negative impacts on the environment (Ma et al., 2012). Also, urban regeneration practices have the potential for climate change mitigation and adaptation in accordance with their purpose and nature. In the next part, the topic is discussed in detail.

2.3 Urban Regeneration in the Context of Changing Climate

Urban areas continuously evolve and face new challenges as a part of a dynamic and complex system. These challenges include underutilized lands or physically and/or socio-economically distressed and decaying urban areas. These areas are often the result of changes in urban and population growth patterns. Urban regeneration has become an important tool of urban policy to revitalize underutilized and urban decay areas and transform them into places where people want to live, work, and play in (Korkmaz & Balaban, 2020). The concept of urban regeneration can be defined in various ways. Thomas (2003) defines the concept as a comprehensive vision and action that provides a solution to urban problems and tries to provide a permanent solution to the economic, physical, social, and environmental conditions of a region undergoing change (Thomas, 2003). In parallel with this definition, urban regeneration is defined as a comprehensive and integrated vision and action that seeks to bring permanent improvements to the economic, physical, social, and environmental conditions of the region in question and provides solutions to urban problems (Roberts & Sykes, 2000). Contrary to these definitions, Keleş (2006) states that urban transformation emerges as a result of external interference with the use of urban parts for purposes that can reach social, economic, cultural, and even political dimensions (Ruşen Keleş, 2021).

With climate change and growing concerns, the concept of urban regeneration has evolved from the approach of physical changes to an approach that takes the environment, economy, social and physical parts as a whole (Korkmaz & Balaban, 2020). In other words, urban regeneration actions comprise economic, social, physical, and environmental improvement measures in the areas under intervention. Urban regeneration is considered at its most basic to contribute to the implementation of sustainable development by 'recycling' land and buildings, reducing demolition waste, reducing demand for urban growth, and facilitating the intensification and compactness of existing urban areas (Turcu, 2012). This brings up the concept of sustainable regeneration. Sustainable urban regeneration is regeneration actions, policies, and processes within a city that address interrelated technical, spatial, and socio-economic problems in order to reduce environmental impact, mitigate environmental risk, and improve the environmental quality of urban systems, lifestyles, and assets. As stated previously, cities are the main contributors to GHG emissions, and they are responsible for a significant part of environmental issues. Therefore, sustainable urban regeneration can play a crucial role in climate change adaptation and mitigation strategies.

Newly designed buildings are not sufficient to deal with the climate crisis because they constitute only around 1.0-3.0% per annum compared to the existing buildings (Ma, Cooper, Daly, & Ledo, 2012). It is an undeniable fact that existing buildings are an effective way to minimize the negative impacts of the warming climate, considering that buildings have a relatively long life cycle. Sustainable urban regeneration can minimize the environmental impacts, mitigate environmental risk, and improve the environmental quality of urban systems, lifestyles, and assets by transforming and enhancement of existing built environments (Balaban & Puppim de Oliveira, 2014b).

2.3.1 Urban Regeneration Approaches in Turkey

In Turkey, one of the most important results of urbanization, which can be associated with industrialization and migration in the 1950s, has been the proliferation of illegal housing in the peripheries of the cities. In other words, extensive migration to the large cities, rapid urbanization, increase in population, economic insufficiencies, legal gaps, and planning issues resulted in squatter settlements in the major Turkish cities (Kuyucu, 2018; Uzun & Celik Simsek, 2015). Over time, these settlements have become an important and integral part of the cities.

This situation continued, and urban regeneration, which can be considered as a relatively new phenomenon for Turkey, did not receive the necessary attention due to reasons of the local and central governments' financial weakness and no legal framework until the 2000s (Korkmaz & Balaban, 2020; Kuyucu, 2018). After 2000, urban regenerative initiatives gained momentum with public, private interest, and legal frameworks. After these progresses, the squatter settlements became the main focus of urban regeneration. In line with this, while there is an increasing focus on sustainability in international urban regeneration practices, the motivation and scope of urban regeneration practices in Turkey are different. The regeneration projects carried out in Turkey consist only of physical, social, and economic improvement. The regeneration approach, which has been criticized in many ways, has not yet gained the sustainable dimension (Korkmaz & Balaban, 2020).

CHAPTER 3

METHOD

This study introduces a simulation-based method for the urban regeneration project under climate change and the UHI effect. The proposed method involves the following steps: (a) site analysis and generation of 3D geometries, (b) the generation of climate change and UHI-modified weather datasets, and (c) obtainment and comparative analysis of outdoor microclimate, thermal comfort, and natural lighting after and before urban regeneration (Figure 4).

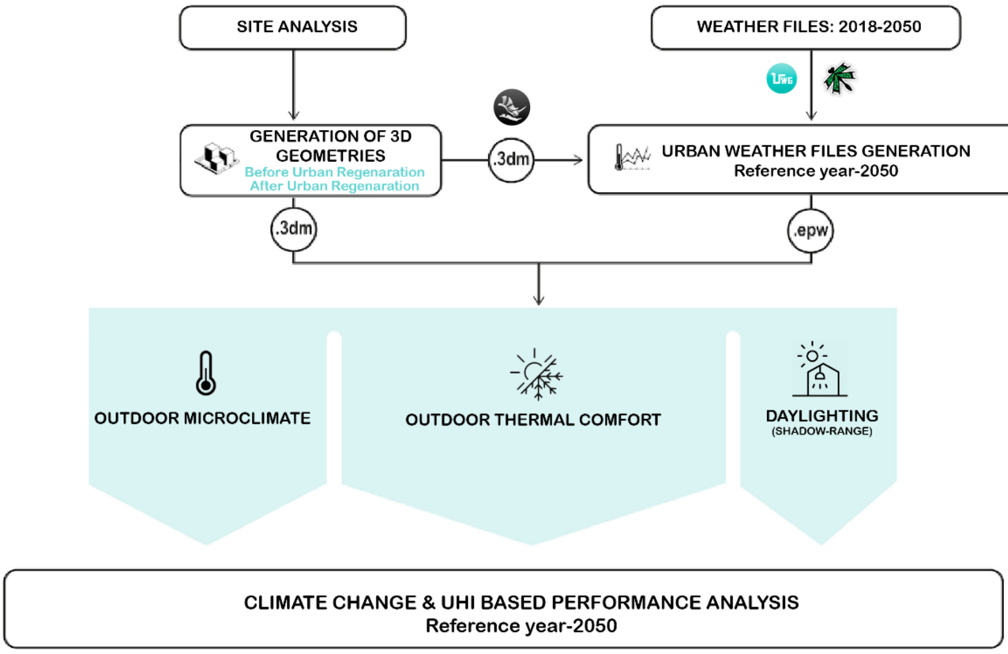


Figure 4. The proposed analysis approach

As a first step, understanding the site through research from various sources is an important step for this study. Detailed information about the site, including building and city parameters, is needed to obtain better and more accurate results. In line with this information and understanding, a 3D model can be developed. In this study, two different models are created as before and after regeneration situations are compared. The second step is the generation of climate change and UHI-modified weather data. Future weather data projections are essential to generate to be able to make predictions and comparatively analyze the climatic conditions. The future data are produced over the reference year by using different models, methods, and tools. In this study, only 2050 weather data is generated using a morphing model coupled with CCWorldWeatherGen[1]. UHI-modified data is generated with the help of the 3D site models and Urban Weather Generator (UWG)[2]. As the last step, outdoor dry bulb temperature and outdoor thermal comfort results are obtained using climate change, and UHI-modified data and comparative analyzes are made for the conditions before and after. Moreover, the daylight analysis based on a shadow range of the urban context, which changes with urban regeneration, is conducted.

[1] For further information refer to https://energy.soton.ac.uk/ccweathergen/

[2] "Urban Weather Generator [UWG] estimates the hourly urban canopy air temperature and humidity using weather data from a rural weather station. It takes a rural epw file and the *.xml (or *.xlsm) input file, which describes your urban canyon. The output is a morphed weather file [epw] that captures urban heat island effect and is compatible with many building performance simulation programs."

CHAPTER 4

CASE STUDY

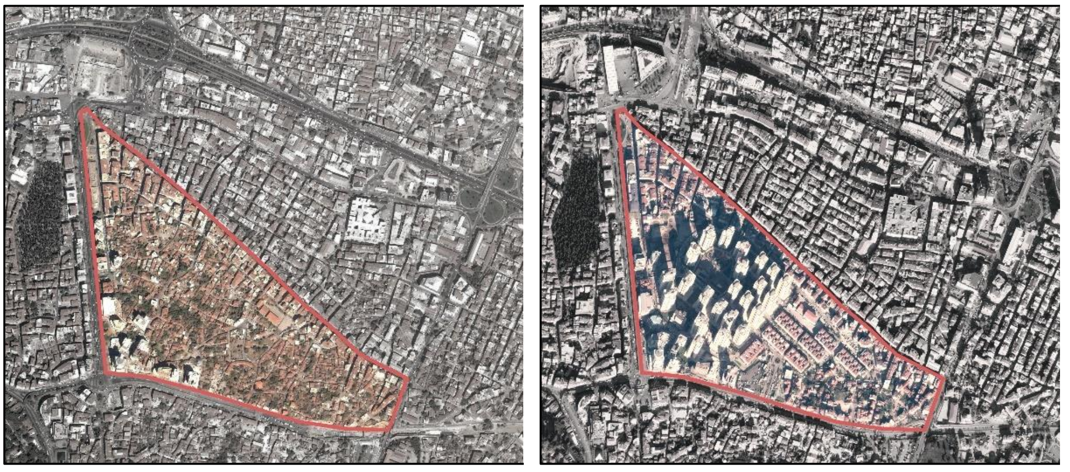
In the previous chapter, the method for an urban transformation project was presented. This chapter aims to present a demonstration of the proposed method by means of its application on a case study in Doğanbey, Bursa.

4.1 The Description of Case Study

A case study was selected to investigate the current and future effects of urban transformation projects implemented in Turkey on the environment. In this study, the urban regeneration project located in Doğanbey, Bursa, is discussed as a case study.

The project area is located in Bursa city center and constitutes one of the oldest known settlements of Bursa in the north of the historical city center. Also, it is located at the intersection of roads that have great importance in the history and development of Bursa.

The city of Bursa did not go through a very bright period in terms of urban planning. On the contrary, new master and improvement plans were prepared for the city in order to meet the constantly inadequate housing needs due to its commercial identity and immigration, but unplanned urbanization could not be prevented. Therefore, transformation projects have been started in order to save the city from the existing depression areas, to gain a new vision, and to increase the living conditions for the citizens. Doğanbey within the territory of the district of Osmangazi is one of the renewal areas. Doğanbey Urban Regeneration Project is planned for four neighborhoods of 282.000m^2 called Doğanbey, Tayakadin, Kırcaali, and Kiremitçi, within the framework of the decisions given by the relevant administrations and the revised zoning plans. In Figure 5, the project area is illustrated as aerial images before and after regeneration. The nonfunctional and noneconomic infrastructure of the region, social and health problems are the basis of this project. Before the project, the settlement consisted mostly of detached houses with 1-2 floors with gardens, and it provided poor living conditions to lower-income occupants (Figure 6).



(a) (b)

Figure 5. Aerial images (a) before urban regeneration and (b) after urban regeneration from Google Earth

Figure 6. Doğanbey neighborhood before regeneration

In 2006, the Bursa Metropolitan Municipality, the Bursa Osmangazi Municipality, and the Mass Housing Development Administration (TOKI) agreed on the Bursa Osmangazi Doğanbey Urban Regeneration Project. Figure 7 shows the neighborhood plan where the urban regeneration was applied. It has been decided to build 2500 residences and 50000 m^2 open area in the above-mentioned neighborhoods. In 2007, the regeneration process started. Figure 8 (a) shows the site plan of the project, and Figure 8 (b), (c), and (d) represents the overall image of the project. There are 70 A blocks, 9 B blocks, 9 C blocks, and 5 D blocks, consisting of two stages (See Appendix A).

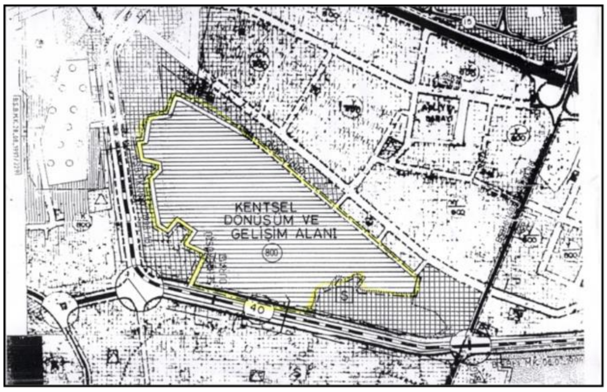
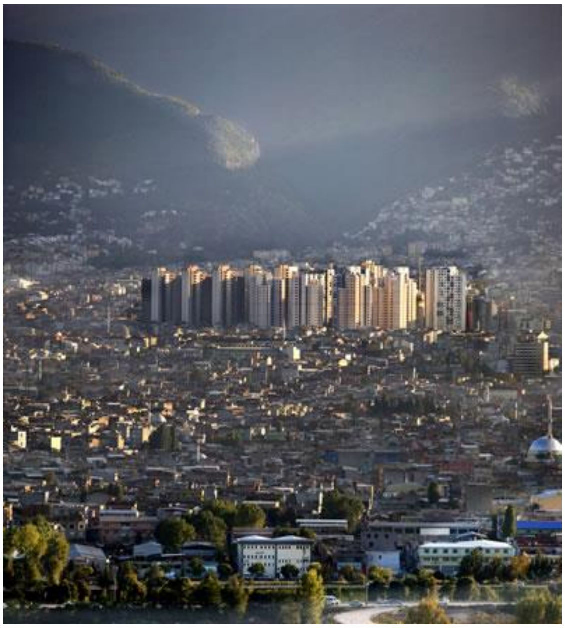


Figure 7. The neighborhood plan where the urban regeneration was applied (Cubukcuoglu, 2013)

(a)



(c)

(b) (d)

Figure 8. Doğanbey neighborhood after regeneration (a) the site plan of the project, (b), (c), and (d) the general view of the completed project (Cubukcuoglu, 2013)

Doğanbey is a project that is at the center of negative criticism. First of all, as promised, the houses were not completed and delivered in 18 months (Eren & Tökmeci, 2012). Moreover, the area is close to the historical center, which has a unique urban texture. For this reason, it had to be taken account the social, cultural, and geographical characteristics of the neighborhood. However, the project in Doğanbey has ignored all these aspects as well as urban sustainability and focused on high-rise monotype buildings.

4.2 Future Weather File

CCWorldWeatherGen is used to generate future weather files. CCWorldWeatherGen that is a future weather file generation tool modifies statistical 8760-hour weather files (in .epw format) representing a typical meteorological year using the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report model summary data of the Hadley Centre Coupled Model, version 3 with

A2 emission scenario (HadCM3 A2) experiment ensemble (Jentsch et al., 2012). HadCM3 A2 predicts future climate change for the medium emission scenario as a general circulation model. The tool is based on the standard morphing method developed by Belcher et al., which can predict the future weather in a given year by modifying a reference weather file by combining morphing procedures (Belcher et al., 2005). CCWorldWeatherGen calculates the mean temperature, relative humidity, solar irradiance, wind speed, atmospheric pressure, and precipitation variables. In this study, future weather files for 2050 were generated for Bursa in Turkey.

4.3 Simulation Inputs and Settings

As pointed out previously, the current weather data does not explicitly take into account weather data differences between the location of the building and the airport where the weather data is collected because of the UHI effect. In this section, the 3D modeling, simulation tools, and the development of simulation model are explained.

The area approximately 0.5 km^2 area was modeled. In order to calculate UHI-modified climate data, the following datasets were used: geometric and non-geometric properties of buildings and the information of weather.

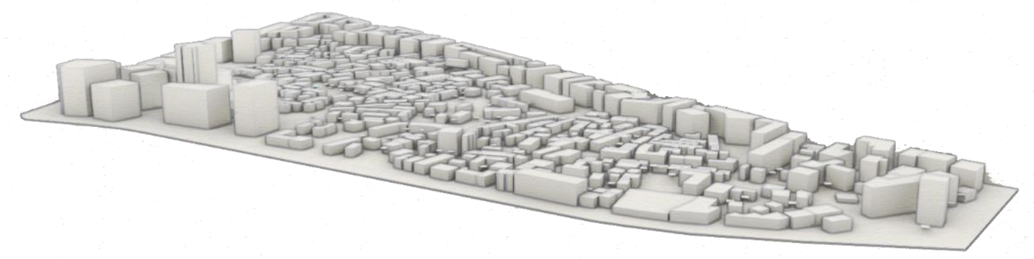
The geometric data of buildings, including shape, footprint area, envelope characteristics such as window-wall ratio, and the number of floors, were extracted from Gismo[3], Cadmapper[4], and Google maps. These are only 2D geometric data, but a 3D model is needed. Massing 3D models are generated with the Rhinoceros 3D CAD environment, which "can create, edit, analyze, document, render, animate, and

[3] Gismo enables automatic generation of urban environment and terrain geometry based on location's latitude-longitude coordinates/or address and radius. This includes connection with openstreetmap website and generation of buildings, trees, roads, rivers and other map elements. https://www.grasshopper3d.com/group/gismo, February 2022.

[4] Cadmapper transforms data from public sources such as OpenStreetMap, NASA, and USGS into neatly organized CAD file. https://cadmapper.com/, February 2022.

translate Non-Uniform Rational B-Splines (NURBS) curves, surfaces, and solids, point clouds, and polygon meshes[5]." Building heights in the model were based on data from site drawing, the feature of Google Earth Street view, and information from the literature. It is modeled in 2 ways as before and after urban regeneration.

As shown in Figure 9, the 3D model is just volumetric representations of buildings as a box according to their heights and geometrical characteristics. Structural components and internal divisions within zones were not modeled. Moreover, their slope roofs were also excluded and modeled with a flat roof. The city elements, including trees, roads, all kinds of pavements, and soil areas, were also modeled as surfaces. There are two main reasons for the simplification of the components. The first reason is that the simulation program used in this study cannot overcome more geometric detail. Secondly, the simple model provides to reduces the calculation time, and thus, it enables more alternatives to be tested.



(a)

(b)

Figure 9. 3D models (a) before regeneration and (b) after regeneration

[5] https://www.rhino3d.com/6/features, February 2022.

4.4 Urban Weather File

To calculate for the urban microclimate or the UHI modified weather file, Dragonfly plugin is used. Dragonfly is open-source and free, which "is a graphical algorithm editor tightly integrated with Rhino's 3-D modeling tools[6]". Dragonfly can be used to model and estimate large-scale climate phenomena, such as urban heat islands, future climate change, and the influence of local climate factors such as topographic variation. UHI creates with the help of the Urban Weather Generator (UWG). UWG calculates the variations in urban canyons compared to measurements taken at a weather station in an open area outside the city belt and the hourly values of urban air temperature and humidity by modeling UHI on a neighborhood scale.

To produce a weather file modified by UHI in dragonfly, a set of criteria are required to be met, which are as follows:

Building Parameters: Geometric and non-geometric properties of buildings are needed to generate large-scale phenomena. Geometric data of buildings include information of envelope shape, area, glazing, and the number of floors, while non-geometric data includes the year of construction and program of buildings. The envelope properties such as glazing ratio, solar heat gain coefficient (SHGC), wall, and roof albedo can be defined by the user.

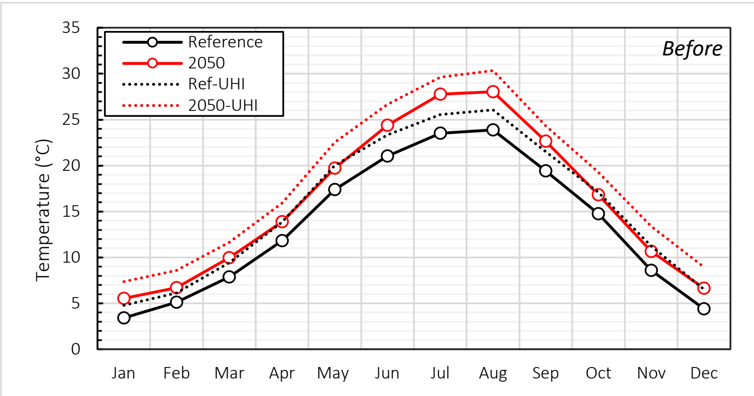
City Parameters: Not only are buildings typology needed, but also the surrounding context, including traffic, vegetation, and pavement information, are needed to generate the UHI-modified weather file.

4.5 Results

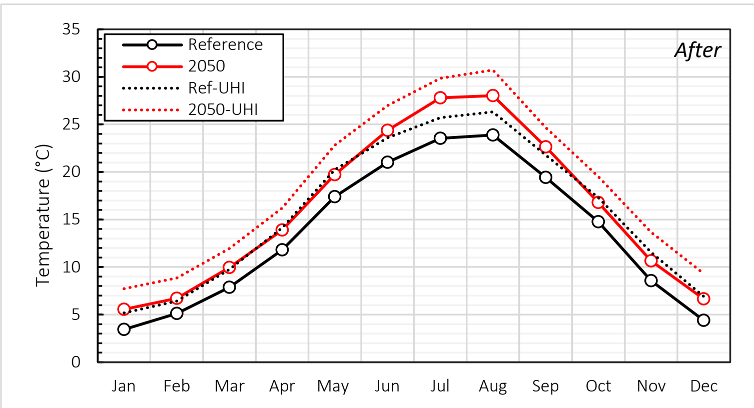
This section presents results and comparative analysis of outdoor temperature, outdoor thermal comfort, and natural lighting based on a shadow range.

[6] https://www.grasshopper3d.com/, February 2022.

Figure 10 illustrates a comparative analysis of the annual dry bulb temperature of base and UHI-modified weather data for the reference year 2050. In Figure 10 (a), pre-urban regeneration data are summarized, whereas Figure 10 (b) summarizes the post-urban regeneration data. A consistent increase with climate change and UHI is observed. The annual average temperature values are calculated as 13.43°C, 15.46°C, 16.06°C, and 18.22°C for reference year, reference with UHI, 2050 and 2050 with UHI respectively before regeneration whereas the temperature values with UHI effect are 15.74°C for the reference year and 18.52°C for 2050 after regeneration. Table 1 summarizes the annual temperatures and differences.



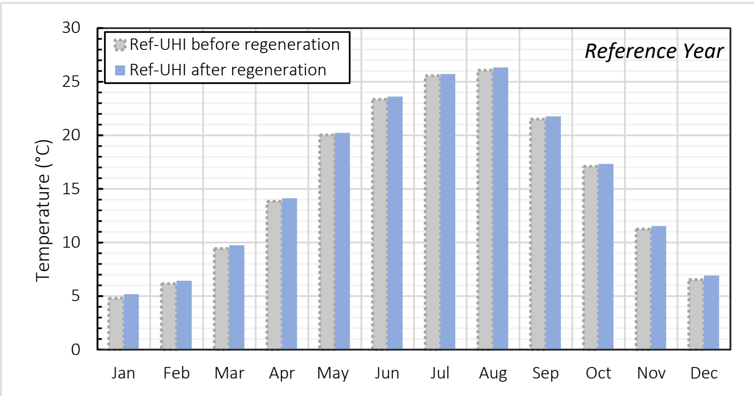
(a)



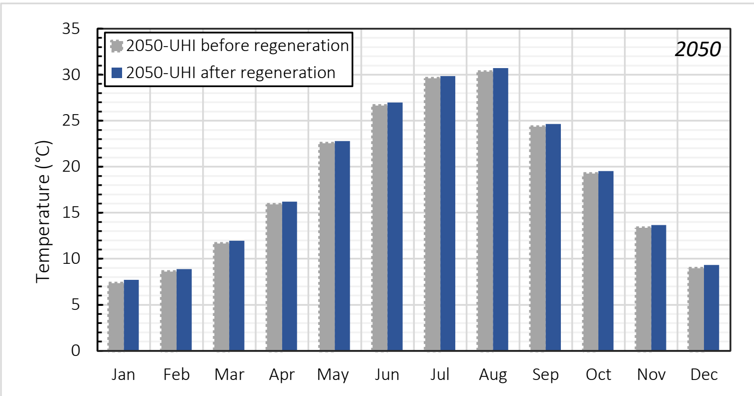
(b)

Figure 10. The annual dry bulb temperature (a) before urban regeneration and (b) after urban regeneration.

Figure 11 compares the annual dry bulb temperature after and before regeneration for the reference year and 2050 with the UHI effect. The average differences are 0.28 and 0.30 for the reference year and 2050, respectively (Table 1). In terms of temperature, it is seen that there is not a strong difference in the conditions before and after urban transformation. However, the necessity of improving the UHI effect with the intervention is a requirement brought about by the climate crisis, and this project cannot meet this requirement. Moreover, as mentioned in the case description part, the project cannot meet the social, cultural, and geographical requirements. In consideration of the results and criticism, it can be easily said that it is an environmentally and socially unsuccessful practice.



(a)



(b)

Figure 11. the annual dry bulb temperature after and before regeneration for the reference year and 2050 with UHI effect

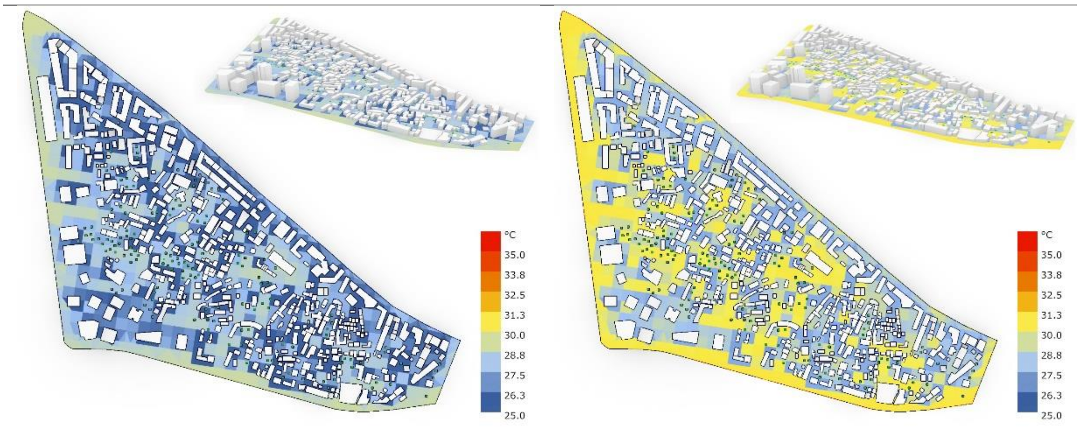
Table 1. The summary of annual outdoor dry bulb temperature

			Difference (Ref-2050)
	Reference 13.43	**2050** 16.07	2.63
	Ref-UHI before regeneration 15.46	**2050-UHI before regeneration** 18.22	2.76
	Ref-UHI after regeneration 15.74	**2050-UHI after regeneration** 18.52	2.78
Difference (UHI effect)	2.03	2.15	
Difference (before-after)	0.28	0.30	

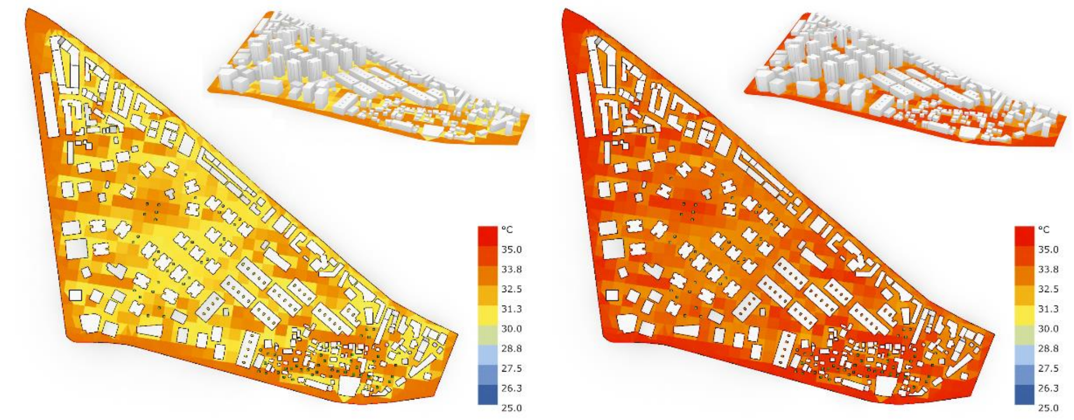
The concept of thermal comfort is mostly applied to the indoor environment, but it has been increasingly started to apply to outdoor environments. As stated and observed previously, UHIs cause warmer outdoor temperatures, and as a consequence of UHI, outdoor thermal comfort is affected in a negative manner. In this study, the UHI impact on outdoor thermal comfort was calculated, represented as Universal Thermal Comfort Index (UTCI). UTCI is "measures the outdoor thermal comfort of humans by considering the effects of such factors as air temperature (T_a,°C), radiation temperature (T_{mrt}, K), relative humidity(RH, %) and wind speed (m/s)" (Xu et al., 2019, p. 8). UTCI includes ten thermal stress levels, as shown in Table 2. The outdoor thermal comfort is calculated as the average UTCI for extreme cold and hot weeks that are in February and August, respectively. UHI-modified data are used to conduct the analysis. As shown in Figure 12, the average UTCI varies 25-30°C for the reference year and 27-31°C for 2050 before urban regeneration. These variation ranges refer to no thermal and moderate heat stress. The average UTCI range is 31.3-33.8°C for the reference year and 33.8-+35°C for 2050 after urban regeneration. This means that means people are being exposed to strong heat stress in current situation and future. Moreover, human well-being is adversely influenced due to the urban regeneration implemented without considering environmental issues. For the extreme cold week, the case is similar to the extreme hot week. The cold stress after regeneration is stronger than the situation before regeneration. While slight cold stress is observed for both cases with increasing temperatures in 2050, cold stress shifting from slight to moderate cold stress is observed after urban transformation for the reference year (Figure 13).

Table 2. Stress classification of the outdoor thermal comfort following the UTCI ranges (Xu et al., 2019, p. 8)

The Range of UTCI (◦C)	**Stress Classification**
>46	Extreme heat stress
+38 to +46	Very strong heat stress
+32 to+38	Strong heat stress
+26 to+32	Moderate heat stress
+9 to+26	No thermal stress
0 to+9	Slight cold stress
−13 to 0	Moderate cold stress
−27 to−13	Strong cold stress
−40 to−27	Very strong cold stress
<−40	Extreme cold stress

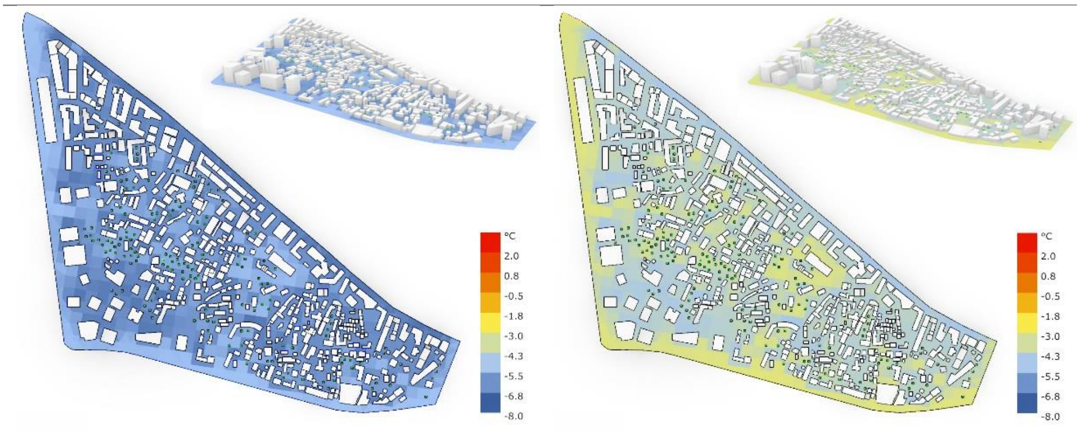


Before-reference year | Before-2050

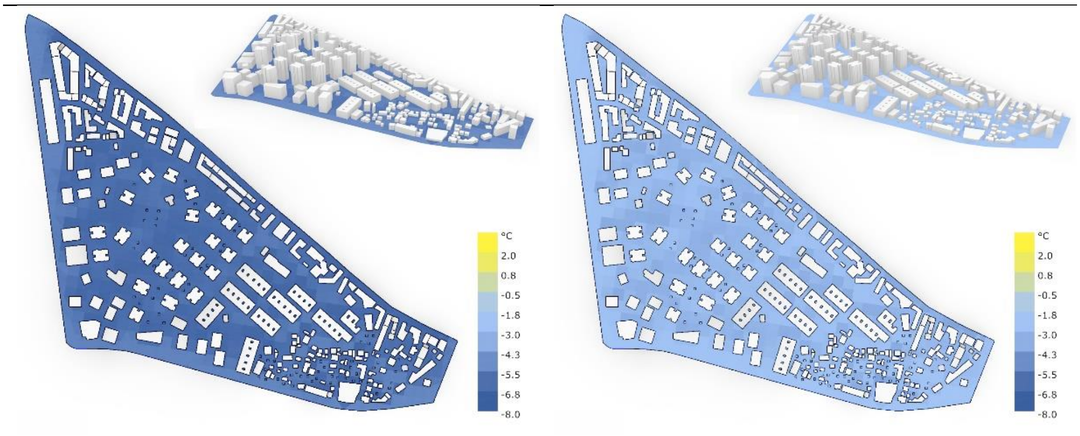


After- reference year After-2050

Figure 12. Outdoor thermal comfort for extreme hot week in August



Before- reference year Before-2050

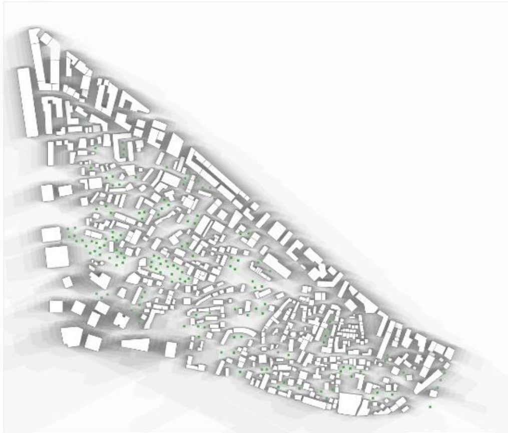


After- reference year After-2050

Figure 13. Outdoor thermal comfort for the extreme cold week in February

As can be seen in Figure 14, the implemented project was not designed in a framework that is compatible with the context of its environment. It is anticipated that this situation affects daylight in general. The purpose of performing a daylight analysis based on the shadow-range study is to examine how phenomena other than temperature are affected by the projects implemented without considering their environmental effects. The analysis is limited to the days with the most and least hours of daylight, June 21 and December 21. As can be observed in Figure 15, high-rise buildings constructed with the regeneration cut off the daylight to a great extent and cause an increase in heating demand by preventing the solar gain required, especially in winter months. Although the shading rate in summer months provides relief in terms of thermal comfort, it reduces the rate of daylight benefit.

Figure 14. The general view of Doğanbey neighborhood and TOKİ dwellings



Before- December 21 Before-June 21

After- December 21 After-June 21

Figure 15. Daylight analysis based on a shadow-range

CHAPTER 5

DISCUSSION AND CONCLUSION

In this study, an environmental analysis of the Doğanbey Urban Regeneration Project was conducted by approaching it from 3 different perspectives. The main findings for the case study neighborhood are listed below:

- Before urban regeneration, the annual average temperature increase is calculated 2.03°C (13.43°C→15.46°C) for the reference year and reference with UHI whereas in 2050 and UHI-modified in 2050, the temperature increase is 2.14°C (16.06°C→18.22°C).
- After urban regeneration, the annual average temperature increase is calculated 2.31°C (13.43°C→15.74°C) for the reference year and reference with UHI whereas the temperature difference between 2050 and UHI-modified in 2050 is 2.44°C (16.06°C→18.50°C).
- The average differences between after and before urban regeneration are 0.28°C (15.46°C→15.74°C) and 0.30 (18.22°C→18.52°C) for the reference year and 2050 with UHI effect respectively.
- The outdoor thermal comfort is calculated as the average UTCI. For the evaluation before and after regeneration situations, the average UTCI shifted from moderate heat stress to strong heat stress in the extreme hot week, whereas slight to moderate cold stress in the extreme cold week.
- Closely spaced multi-story buildings that are incompatible with the context have been observed to block daylight and sunlight, especially in winter.

When all the results are evaluated, it is obvious that the project was implemented without consideration of environmental impacts. In the pre-regeneration situation, the necessity of an improvement was observed due to infrastructure inadequacies and unhealthy living environment, but the projects implemented without combining the three major dimensions of sustainability, including economy, social, and environment, create living spaces that are not satisfactory under no circumstances. Doğanbey project has already been at the center of negative criticism, apart from environmental aspects. In this project, instead of focusing on the rehabilitation of the proposed site to eliminate the causes of urban collapse, the main was to destroy the existing one and build the new one. The cleaning of the construction site was the starting point. In addition, the project does not correspond to the general principle of urban renewal, which should aim at a long-term solution focused on the needs of the original residents of the area, thus urban sustainability, displacing most of the original residents of Doğanbey neighborhoods due to economic and socio-cultural factors. Therefore, the project causes an interruption in urban sustainability because it ignores the main features of sustainability;

- it does not encourage social participation and cultural interaction among its parts;
- it does not support cultural and social diversity among the members of the society;
- it does not focus on all environmental impacts at all.

In conclusion, the urban regeneration practices in Turkey have various problems. One of these problems is the lack of a sustainable approach, and it is necessary to insert the environmental concerns into the traditional urban regeneration concept, which provides viability, equality, prosperity, and a sustainable future. In the urban regeneration practices in Turkey, it should be aimed to increase harmony with both urban context and nature, user engagement, and social equality. For this purpose, short-term plans should not be created since the process and action to be carried out is future-oriented. Regeneration practices should be planned considering the long-term benefits, and feedback should be received regularly after use.

Further Studies: This study focuses only on outdoor temperature, outdoor thermal comfort, and daylighting before and after urban regeneration. In other words, it examines the existing conditions. For further studies, the hypothetical scenarios with the concept of sustainable urban transformation can be determined and evaluated. Urban design strategies for climate adaptation measures such as solar control, green and blue infrastructure, natural ventilation, and replacement or selection of cool urban materials and their impacts on buildings' performance can be investigated in future studies.

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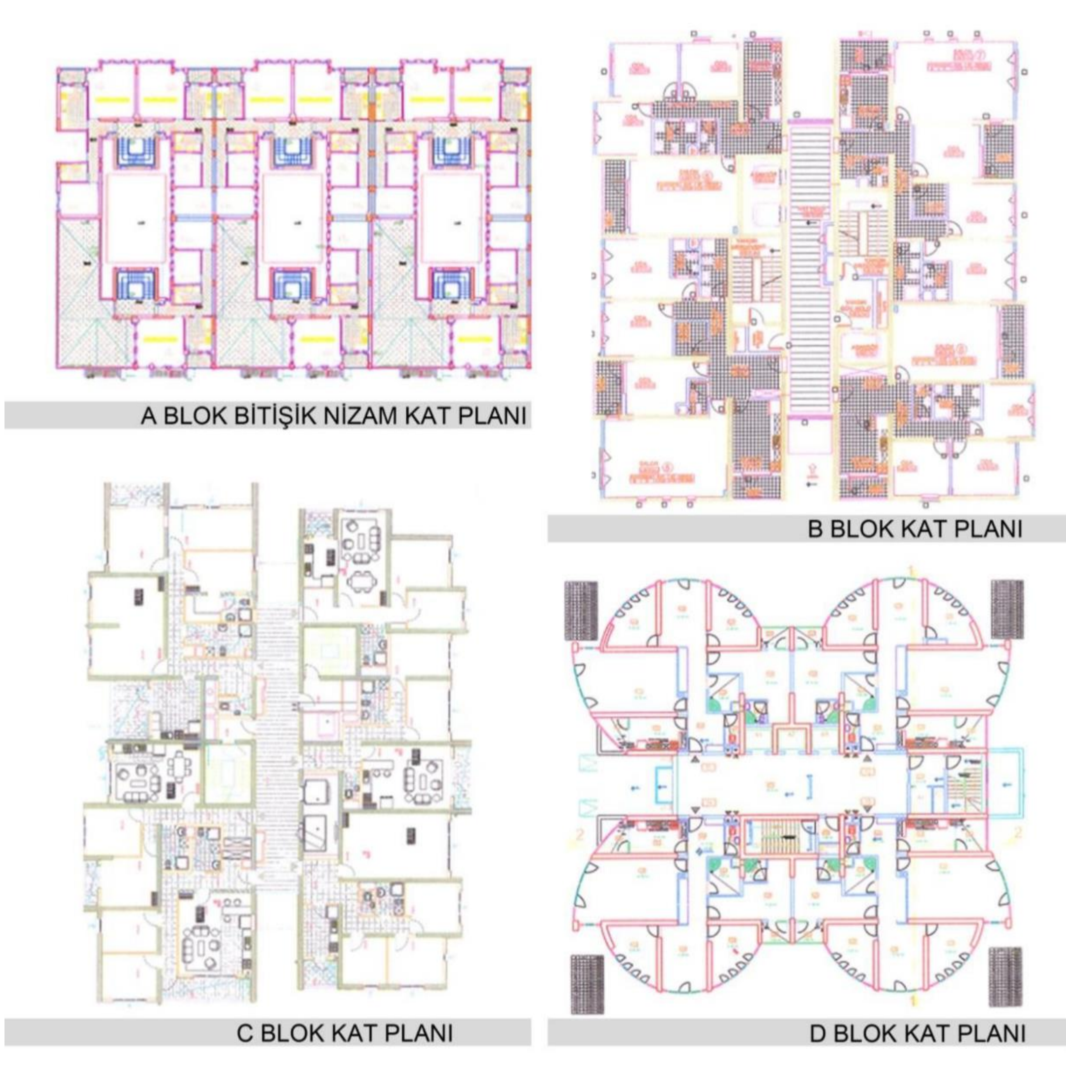
APPENDICES

A. Blocks Floor Plans in Urban Regeneration Project



A- B- C- D Blocks floor plans