

Urban Heat Island Effect in Urban Regeneration Areas: The Case of Saraycık-Ankara

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ABSTRACT

After industrialization, the rapid population growth in cities led to an imbalance in housing supply and demand. As a result, low-income groups constructed their own houses on public lands, introducing the concept of “gecekondu” or squatters into the Turkish planning literature. These squatters, which evolved into socio-economically and spatially problematic urban zones, have become the focus of legal regulations and urban regeneration practices. Although urban regeneration aims to renew deteriorated urban fabric and address the housing needs of low-income groups, the urban form it produces often contradicts these objectives. Today, climate change, rapid urbanization, destruction of natural areas, and high-density, high-rise vertical development models contribute to heat absorption in cities, thereby triggering the formation of urban heat islands. This study is based on the assumption that the Saraycık Urban Regeneration Project has contributed to the formation of an urban heat island. Accordingly, it examines the impact of changing urban morphology on urban heat island formation before and after the regeneration by employing GIS-based remote sensing methods, including LST, NDVI, and NDBI analyses. The findings reveal that, as a result of urban regeneration projects, increased building density and impervious surfaces, the reduction of natural areas, and the proliferation of high-rise structures intensify the urban heat island effect. In the face of climate crises, improving urban quality of life requires that urban transformation be addressed not only in terms of its socio-economic and spatial impacts but also through its environmental dimensions, integrating climate-sensitive and sustainable approaches into project design.

Kentsel Dönüşüm Alanlarında Kentsel Isı Adası Etkisi: Saraycık- Ankara Örneği

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ÖZET

Sanayileşme sonrası kentlerde artan nüfusun konut arzının sağlanamaması, orta ve düşük gelir grubunun hazine arazileri üzerine kendi konutunu inşa etmesi ile sonuçlanmış ve Türkiye planlama literatürüne “gecekondu” kavramı girmiştir. Sosyo-ekonomik ve mekansal olarak kentin sorunlu bölgelerine dönüşen gecekondu alanları, yasal düzenlemeler ile kentsel dönüşüm uygulamalarının konusu olmuştur. Kentsel dönüşüm temelde köhneleşen kent dokusunun yenilenmesi ve düşük gelir grubunun konut sorununu çözmeyi hedeflese de yarattığı kentsel doku temel amacıyla çalışmaktadır. Günümüzde iklim değişikliği, hızlı kentleşme, doğal alanların tahribi, yüksek yoğunluklu ve yüksek katlı dikey yapılaşma modeli, kentlerde ısının emilmesine neden olurken kentsel ısı adası oluşumunu tetiklemektedir. Araştırma Saraycık Kentsel Dönüşüm Projesi’nin kentsel ısı adası oluşumunu tetiklediği varsayımına dayanmakta olup, bu amaçla dönüşüm projesinin öncesi ve sonrası dönemlerde değişen kent morfolojisinin kentsel ısı adası oluşumuna etkisini incelemek amacıyla GIS tabanlı uzaktan algılama yöntemleri kullanılarak LST, NDVI ve NDBI analizleri yapılmıştır. Araştırma bulguları, kentsel dönüşüm projelerinin sonucunda yapı yoğunluğu ve sert zeminlerin artışı, doğal alanların azalması, yüksek katlı yapılaşmanın alanda artmasının kentsel ısı adası etkisini artırdığını ortaya koymaktadır. İklim krizinin karşısında kentsel yaşam kalitesinin artırılması amacıyla kentsel dönüşümün sosyo-ekonomik ve mekansal dokuya etkisi kadar çevresel boyutları ile de ele alınmalı, projeler iklime duyarlı, sürdürülebilir yaklaşımlarla entegre edilmelidir.

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INTRODUCTION

In Türkiye, during the period of planned development following World War II regarded as an indicator of modernity, urban infrastructure and housing investments played a significant role (Tekeli, 1982). With the acceleration of urbanization in the 1950s, imbalances between housing supply and demand led low-income groups to produce housing through informal and illegal means. As a result, a new housing typology known as “gecekondu” (squatter housing) rapidly increased in urban areas, and qualitative problems were added to the quantitative housing deficit (Tekeli, 2012). Unlike global examples, in Turkey, providing housing for the lower-income group has never been a priority for the public sector, and no housing policies have been developed in this context. Squatter areas with unhealthy living conditions provided a temporary solution to the quantitative housing problem, but they raised debates regarding the quality of housing. Subsequent legal regulations, instead of deterring the production of squatter settlements, legitimized this illegal production and transformed it into a tool for profit and investment. Throughout history, the housing problem in Turkey has not been solely related to the level of housing production. The lack of an economically affordable housing stock that meets the needs of different income groups, the inability of production levels to address the needs of all segments of society, and the failure to provide economically accessible housing for the lower-income group have all contributed to the rapid increase in the number of squatter settlements. These areas, which became socio-economically and spatially segregated from the city, have been regarded as problematic zones in the history of Turkish urbanization. With the adoption of neoliberal discourses and a construction-led economic model, squatter housing areas were brought to the center of urban regeneration projects (Balaban, 2011; Korkmaz & Balaban, 2020). During this period, the construction sector was accepted as a core sector of the economy due to its employment-generating capacity, its ability to absorb surplus value, and its strong linkages with other sectors, leading cities to enter a phase of rapid urban development (Balaban, 2016).

In Ankara, the urban regeneration process gained significant momentum particularly after the 2000s as a result of legislative arrangements. Initiated in eight districts with high concentrations of squatter housing areas, such as Çankaya, Altındağ, and Mamak, this process was reinforced by regulations including Law No. 5104 on the Northern Ankara Entrance Project and Law No. 5393 on Municipalities, which expanded the authority of local governments. During the same period, the expansion of the TOKİ¹ powers in planning and land management helped overcome financial and bureaucratic barriers, enabling the number of regeneration projects to double within a short time (Korkmaz & Balaban, 2020). While urban regeneration projects aimed to achieve socio-economic, spatial, and environmental improvement in squatter housing areas, legal transformations and the transfer of authority turned these projects into instruments of rent generation, attracting both public and private sector interest (Uzun, 2006). As housing transformed into an investment tool, environmental impacts were overlooked, and urban space was rapidly concreted. While the pressure of built environment production on the natural environment triggers the formation of urban heat islands, it also negatively affects quality of life. The urban heat island effect, which highlights the temperature difference between urban areas and their surrounding natural environments, is influenced by changes in urban morphology. Although urban regeneration initially sought to address the housing problems of middle- and low-income groups, the sustainability of the newly created urban spaces has been frequently debated in the literature (Acevedo-De-los-Ríos et al., 2025; Korkmaz & Balaban, 2020; Ricciardelli & Raimo, 2023). Today, the success of urban regeneration projects is evaluated not only in terms of social, economic, and spatial improvements but also in terms of resilience to the global climate crisis.

This research evaluates the hypothesis that the morphological changes resulting from the Saraycık

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Urban Regeneration Project have increased the impact of urban heat islands. This study aims to evaluate the urban heat island effect of increasing density and permeable surface and the decrease in natural areas GIS- based methods in Saraycık Urban Regeneration Project. The failure of this capability to function, the progress of the transformation process, and the temporal change analysis are being conducted as percentages. The study examines how a rural area has been transformed into a regular neighborhood through a settlement transformation process. The research analyzes how this transformation process has been superficially affected by changes in land cover and land use. This orientation, the primary aim of which is not to beautifully identify Urban Heat Island improvement by comparing it with an external rural reference area, but rather to reveal the temporal temperature changes of project development growth. Following the introduction, the theoretical background section presents the literature on the relationship between urban regeneration and urban heat islands. The methodology section then describes GIS-based remote sensing methods used to measure the urban heat island effect before and after the Ankara Saraycık Urban Regeneration Project. The fourth chapter presents the findings obtained from the GIS-based analyses, and the evaluation and conclusion section discuss these findings in relation to the literature and offers policy recommendations for making urban regeneration projects climate-sensitive.

THEORETICAL BACKGROUND: THE PROCESS OF SQUATTER SETTLEMENT, URBAN REGENERATION, AND THE URBAN HEAT ISLAND EFFECT

Like all countries in the world after World War II, Turkey underwent a rapid urbanization process due to the impact of industrialization. While countries involved in the war developed housing policies to eliminate the destruction and fill the resulting housing shortage, Turkey, relatively protected from the physical devastation of the war, faced a housing shortage problem due to increased urban population growth through migration. In the 1950s, the failure to balance housing supply and demand resulted in the illegal construction of housing by low-income groups, giving rise to the concept of squatter settlements (Tekeli, 2012). The lack of social housing production by the state, insufficient housing loans, and the inability to provide affordable land and housing finance models resulted in low-income groups solving their housing problems by illegally constructing houses on state-owned lands (Tekeli, 1996). The rapid increase in the number of squatter settlements until 1950 made it necessary for municipalities to take measures to solve the housing problem. Although housing production was included among the mandatory duties of municipalities with the Municipalities Law enacted in 1951, it could not be implemented (Çoban, 2012; Öztop & Şekeroğlu, 2016). Although squatters were seen as a socio-economic and physical problem and efforts were made to prevent, new legal regulations actually legalized squatters, and their number increased day by day. TOKİ, established in the 1980s with the aim of solving the housing problem of low-income groups and creating healthy living environments, has become the sole actor in housing production by being endowed with numerous powers over time. While ensuring social justice, protecting social order, providing equal opportunities, creating healthy living environments, and creating flexible provision options for all income groups are the main aims of housing policies, urban regeneration projects in squatter settlements which are socio-economically and spatially separated from the legally developed parts of the city, have been among the applications that have emerged with this aim. Ankara was the first city to experience urban regeneration in its squatter settlements and in the 1980s, amnesty laws and rehabilitation zoning plan studies for squatter settlements initiated the transformation process (Korkmaz & Balaban, 2020). Established in 1984 with the aim of producing social housing, TOKİ gained the authority to develop and implement transformation projects in squatter settlements. In Turkey, since the year 2000, the public sector has begun to play an active role in housing and built environment production, making urbanization and settlement activities a national policy. Housing and built environment production have been seen as a force that reduces unemployment and ensures economic stability. With the housing production and urban regeneration projects that

became a government policy from the 2000s onwards, the construction of new housing has been supported not only in vacant lots but also in built-up areas, squatter housing regions, and historically significant areas requiring preservation (Özdemir Sarı, 2015). Since the housing sector is seen as a tool for revitalizing the national economy, policymakers are interested in the quantitative aspect of housing, and efforts are made to add more housing units to the existing stock each year (Bölen, 2004). In addition, by the 2000s, TOKİ had acquired unlimited construction rights in many areas, including disaster zones, tourism regions, and infrastructure areas. In the 2000s, when we witnessed the reflections of neoliberal policies in the city, housing began to be presented as a means of generating rent and as a commodity. The allocation of public lands to the private sector for tourism, housing, shopping mall, and urban transformation projects, the distribution of planning powers to different institutions, and the expansion of TOKİ authority have displaced the holistic planning approach, encouraged the production of the built environment and allowed the expansion of cities under the monopoly of capital (Penbecioğlu, 2016). With these practices, urban rent has become a tool for capital accumulation, while housing has been stripped of its fundamental right to shelter and transformed into an investment tool and a commodity. The change in housing finance models supported the production of mega-housing projects in squatter areas, instead of just social housing (Korkmaz & Alkan Meşhur, 2021). Although housing has been at the center of discussions in the literature due to its economic and social dimensions, studies emphasizing the pressure of construction activities on the natural environment have increased in the last twenty years, with the rise of sustainability, climate change, and environmental issues (Landman & Du Plessis 2007; Faraji et al., 2026; Korkmaz & Alkan Meşhur, 2021; Lu & Ke, 2018; Obeng-Odoom, 2014). Contrary to what they claim, housing projects, through the built environments they produce, alienate society from natural life and the land, creating a social order confined to concrete areas (Korkmaz & Alkan Meşhur, 2021).

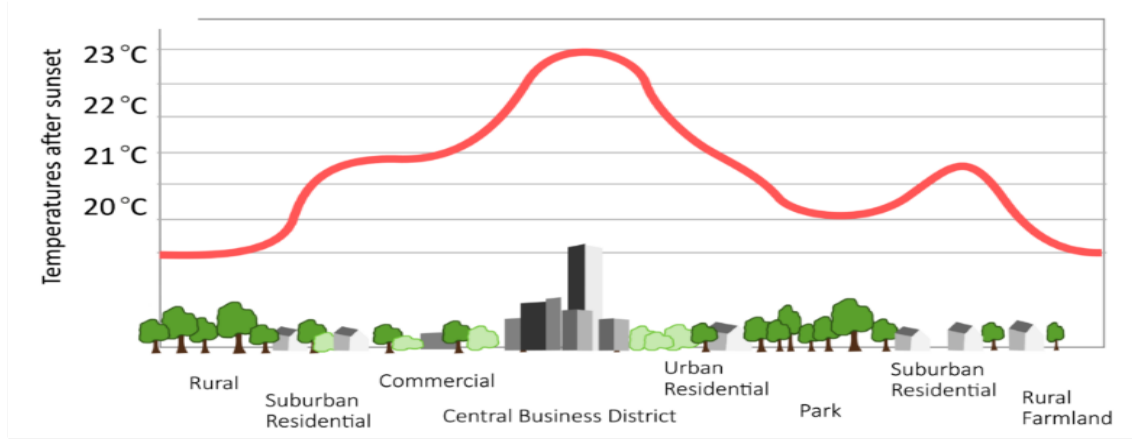
In its most general definition, the urban heat island (UHI) refers to the temperature difference between urban areas and their surrounding natural environments and is classified into four main types. The canopy-layer urban heat island is based on near-surface air temperature measurements; the boundary-layer urban heat island refers to temperature measurements above the average building height; the surface urban heat island involves three-dimensional surface temperatures of urban elements such as ground surfaces, walls, and roofs; and the subsurface urban heat island is based on soil temperatures beneath the ground surface (Stewart & Mills, 2021). Although urban and rural areas receive similar amounts of solar radiation, differences in the heat absorption capacities of their surfaces result in distinct temperature patterns between the two environments. The increase of population and build-environment have triggered the urban heat islands effect. Although socio-economic and spatial problems are being addressed through urban transformation, environmental problems have been relegated to the background. Changes in land-use patterns, transformations in building typologies, an increase in reflective and heat-absorbing surfaces, and heat emitters due to population density have led to the formation of urban heat islands (Canan & Geyikli, 2021).

All these processes have led to the formation of urban heat islands, defined as the average temperature in cities being higher than in rural settlements and the city periphery (Theophilou & Serghides, 2015) (Figure 1). The squatter settlements that have undergone significant spatial and morphological changes through urban regeneration, the question of how the built environment has changed and how the heat island effect can be minimized has become a critical issue requiring research. While informal settlements had a morphological texture dominated by low-density, mostly single-story buildings and permeable surfaces, the transition to a new urban fabric with increased high-rise buildings and hard surfaces has caused significant changes in microclimate conditions. Chandler (1965), who made one of the first climate-based city classifications in the literature, divided London into zones according to its physiographic and structural characteristics, revealing local climate differences. Auer

(1978), who developed this approach, proposed a classification based on land use and cover (Stewart & Oke, 2012). The physical foundations of the urban heat island phenomenon are based on radical changes in the energy balance of urban surfaces.

Figure 1

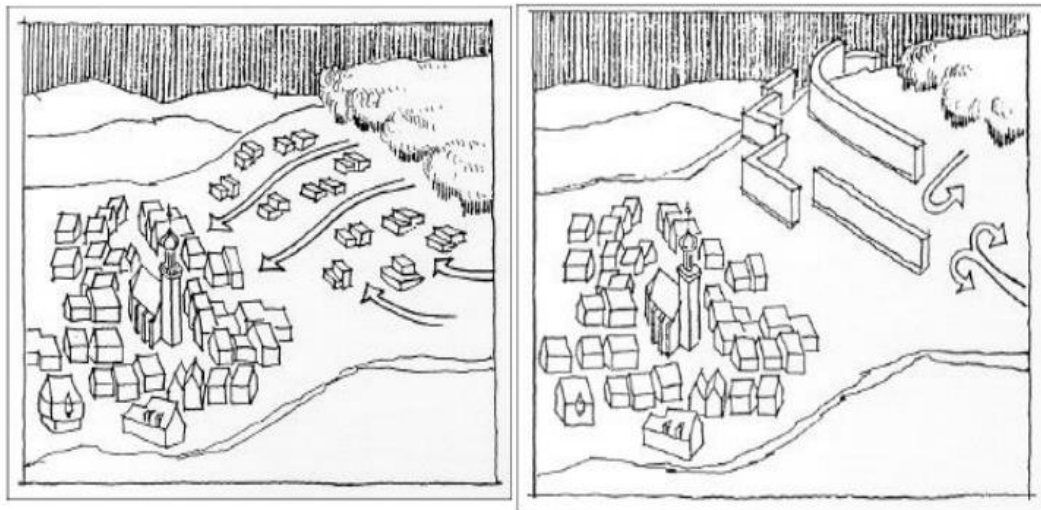
Spatial distribution of the urban heat island (Metlink, 2025)



Urban areas reflect more heat than the natural environment due to building density and the abundance of hard surfaces. As natural areas decrease, urban sprawl and the increase in impermeable surfaces disrupt the microclimatic effect and increase the urban heat island effect (Keogh et al., 2011; Li et al., 2011). Furthermore, rising air temperatures, also influenced by global warming, combine with the heat island effect to negatively impact urban health (Sakar & Çalışkan, 2019; Yasdıman, 2023). Urban typology affects the duration of heat retention in the atmosphere, and increased building heights reduce open skylights, thus increasing the heat island effect. In addition, high-rise construction hinders natural climate control and wind flow, creating a canyon effect and contributing to warming (Canan, 2017) (Figure 2).

Figure 2

Interruption of airflow by high-density development, (Taslima et al., 2015)



High-rise construction, along with the increased open sky ratio, the rise in heat-emitting devices such as cars and air conditioners, the increase in heat-absorbing concrete surfaces, and dark-colored ground surfaces, all contribute to urban warming (Ay, 2024; NIHHIS, 2026). However, increased vegetation reduces urban heat, so the heat island effect is less pronounced in rural settlements and the

outskirts of cities. This is primarily due to the natural cooling function of plants through transpiration and evaporation. In this context, NDVI (Normalized Difference Vegetation Index) analyses provide important data to reveal the effects of changes in vegetation cover on urban warming (Tapçı & Bayer Altın, 2024). The destruction of vegetation cover due to construction directly affects the formation of the urban heat island, while there is an inverse relationship between ground surface temperature (LST) and NDVI values (Polat, 2020). Increased water evaporation from surfaces reduces heat absorption, and vegetation prevents the formation of an urban heat island. Plants cool themselves and their surroundings by releasing water, similar to how the human body cools itself through sweating. Instead of increasing infrared radiation after absorbing solar energy, plants contribute to heat reduction through transpiration. Transpiration in forest cover or large grasslands also increases water vapor in the atmosphere, leading to precipitation and cloud cover, thus preventing heat island formation (NASA, 2026). According to Keith and Meerow (2022), the urban heat island effect is influenced by several interrelated factors. These include the widespread use of low-albedo, heat-storing materials that absorb and retain solar energy, the lack of trees and other vegetation that limits shading and evapotranspiration, urban canyons and urban geometry that reduce air circulation and trap heat, and waste heat generated by human activities such as transportation, industry, and building energy use.

Urban regeneration should not only be a tool for physical renewal but also a part of the climate change adaptation process. When transformation is carried out by considering local dynamics instead of high-density and profit-oriented projects, it is an important tool in reducing greenhouse gas emissions (Tuğaç & Mahdizadeh Dalir, 2023). When looking at the sustainability performance of large-scale projects in Turkey, it is seen that economic concerns taking precedence over ecological goals can make the urban environment more microclimatically vulnerable. In addition, if the increase in urban density is not balanced with social infrastructure and green space values, urban resilience to climate change weakens (Bektaş, 2022). International studies on climate change resilience strategies also support this context. While resilience to climate change is achieved through strong social networks and institutional collaborations, the increase in the built environment due to sprawl increases climate vulnerability.

METHODOLOGY

This research aims to analyze the impact of the built environment created by the Saraycık (Ankara) urban transformation project on urban heat island formation using GIS. So, this research complies with ethical guidelines. It is based on secondary data and publicly available sources, and does not involve human participants or personal data. The selected years were chosen to represent three critical stages of the urban transformation process: the pre-project period (2013), which reflects baseline environmental conditions before the implementation of the urban regeneration project; the project initiation period (2015), marking the beginning of major land-use and construction activities; and the most recent period (2025), representing the current state of development. This temporal framework enables a comparative assessment of environmental changes associated with the project by capturing conditions before, during, and after its implementation. Within the scope of the research, surface temperature (LST), Normalized Vegetation Index (NDVI), and Normalized Difference Built-up Index (NDBI) analyses were performed separately for the years 2013, 2015, and 2025 using GIS data, and the changes were evaluated. For this evaluation, Landsat 8 OLI/TIRS satellite images were selected from the summer months with the highest vegetation cover and cloudless days. For surface temperature analysis (LST), band 10 data obtained from the Landsat 8 satellite during the relevant period were used. The accuracy of the analyses was increased by applying surface emission power corrections, and the obtained values were converted from Kelvin to Celsius. LST is calculated using the formula $LST = BT / (1 + (\lambda \times BT / \rho) \times \ln(\epsilon))$, where BT is the brightness temperature recorded by the satellite, λ is the radiation wavelength, ρ is a constant related to Planck's constant, ϵ is the surface emission, and $\ln(\epsilon)$

represents the emission correction using the natural logarithm function. The values obtained were then converted to °C using the formula $T(^{\circ}\text{C}) = T(\text{K}) - 273.15$.

Next, NDVI analysis, which shows the vegetation density, was performed to evaluate the urban heat island effect of surface changes. The Normalized Difference Vegetation Index adopts the principle of plants absorbing red light (RED) and reflecting infrared radiation (NIR) (Zha et al., 2003). In this context, NDVI is calculated with the formula $\text{NDVI} = (\text{NIR} - \text{RED}) / (\text{NIR} + \text{RED})$. Vegetation creates a cooling effect in the area through transpiration and evaporation mechanisms, and NDVI is an important indicator in measuring vegetation density (Tapcı & Bayer Altın, (2024). In an area, positive NDVI values represent vegetation density, while negative values represent built-up areas.

Finally, the ratio of building density and hard surfaces creating a warming effect in the urban transformation area was examined with Normalized Difference Built-up Index (NDBI) analysis. NDBI is measured with the formula $\text{NDBI} = (\text{SWIR} - \text{NIR}) / (\text{SWIR} + \text{NIR})$, based on the difference between short-wave infrared (SWIR) and near-infrared (NIR) bands. Negative NDBI values indicate an increase in natural areas, while positive values indicate an increase in construction and impermeable surfaces. Within the scope of the research, the effects of NDBI and NDVI analyses on LST were evaluated.

The obtained data was subjected to Geographic Information Systems (GIS) based layer overlay analyses to spatially test the linear correlation between Normalized Difference Built-up Index (NDBI) and surface temperatures (SST). In the following "Findings and Discussion" section, the thermal temperature change in the 2013-2025 projection was examined in relation to microclimatic studies in the existing literature through the generated multi-temporal maps. In particular, the "heat island" hotspots created by extreme temperature values such as 73°C detected in the analyses at the neighborhood scale, and the potential risks of these hotspots on urban sustainability, energy-efficient design, and ecosystem services were explained in detail. In this way, the environmental impact of morphological transformation was presented within a scientific framework

FINDINGS

In this section, the declaration, scope, and implementation process of the Saraycık Urban Regeneration Project are first explained. Subsequently, in order to evaluate the impact of the project on the formation of the urban heat island, pre- and post-transformation periods are analyzed using GIS-based remote sensing methods, including LST, NDVI, and NDBI.

Saraycık (Sincan- Ankara) Urban Regeneration Project

Sincan is located to the west of Ankara, and the Saraycık Urban Regeneration Project is situated on the southern periphery of Sincan district. Saraycık, which gained village status in 1956, was annexed to Sincan when Sincan was declared a district in 1983, and was included within the Sincan municipal boundaries in 1984 (Sincan Belediyesi, 2019). The increased development activities resulting from Sincan's population growth fragmented agricultural lands, forcing the village population, whose livelihoods depended on agriculture and animal husbandry, to abandon their villages. New zoning activities, the division of plots into 300 m² sizes, and the sale of these plots have paved the way for illegal construction, increasing the number of single or two-story illegal buildings in the area (Tekpınar, 2023) (Figure 3). Saraycık, which gained neighbourhood status in the 1980s, suffered from a lack of infrastructure investments due to the absence of zoning plans during this period, and the low quality of life led to the abandonment of the area. In the 1980s, urban regeneration projects began in many squatter settlements in Ankara. The most important of these transformation projects concerning Saraycık was the transformation of the Gültepe (Çınçın) neighbourhood in Ulus. Saraycık, which experienced significant migration from the Çınçın neighbourhood with the commencement of urban transformation

in the region, was declared an urban transformation area in 2011 through a protocol signed with TOKİ to prevent security problems.

The Saraycık Urban Regeneration Project, encompassing a total area of 526.5 hectares within the boundaries of Saraycık and Ulubathı Hasan neighborhoods, was officially launched through a protocol signed between TOKİ and Sincan Municipality. Prior to the Saraycık Urban Regeneration Project, the area contained 1,343 squatter houses and 67 commercial units. Following the project, a new built environment was created consisting of 8–10 storey buildings, along with integrated social and technical infrastructure areas (Tekpınar & Levend, 2024; TOKİ, 2025) (Figure 4). While the population of Saraycık was 6,415 in 2013, it increased to 22,937 by 2025 as a result of the regeneration project and accompanying investment initiatives (TÜİK, 2025). Along with the urban regeneration project, the increase in building density led to a significant rise in housing unit prices. Between 2022, when housing projects began to be completed, and 2025, an increase of 885.75% was observed (Endeksa, 2026). The 2023 Ankara Master Development Plan defined the area as a sub-center serving Etimesgut and Sincan. With the planned connections to the Sincan Organized Industrial Zone and the highway network, rapid population growth in the region is anticipated.

The Sincan Saraycık Urban Regeneration Project, chosen as the study area, has primarily examined issues of quality of life, social cohesion, and spatial change in its literature (Aksoy & Güzey Kocataş, 2017; Tekpınar, 2023; Tekpınar & Levend, 2024). Research on the heat island effect generally focuses on central areas of metropolitan cities or urban density models. However, the impact of urban regeneration areas on the microclimate (comparative before and after) has been addressed in a very limited number of studies.

Figure 3

Saraycık Urban Regeneration Project area: Satellite images and photographs (2013–2025), (Google Earth Satellite Images and Tekpınar, 2023)



Figure 4

Master plan of the Saraycık Urban Regeneration Project, (Prepared by the authors)



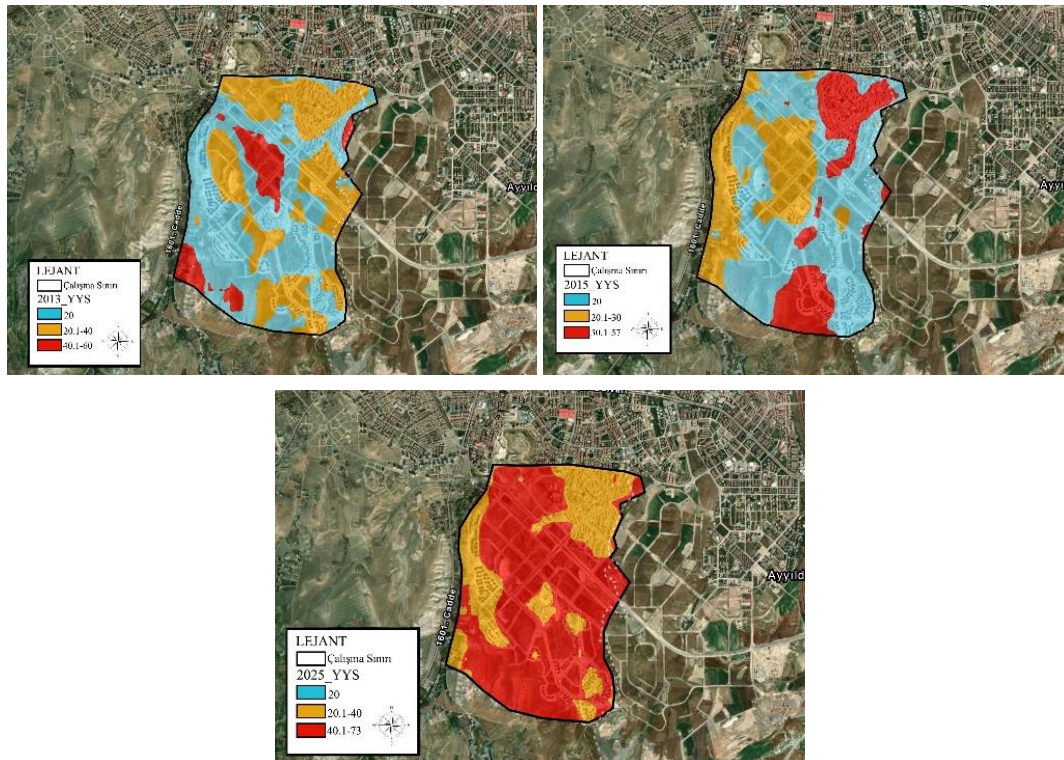
Evaluation of Factors Influencing the Formation of the Urban Heat Island Effect

The Saraycık Urban Regeneration Project's surface temperature analyses reveal that the project significantly contributes to the formation of an urban heat island effect. Prior to the project, in 2013, the neighbourhood was a squatter settlement consisting of low-rise, low-density houses with gardens and detached homes. In 2013, the surface temperature ranged from 20°C to 40°C. By 2015, when the project began and the squatter settlements and gardens were removed, the surface temperature (LTS) had increased to a range of 30.1-57°C due to the soil's high capacity to absorb solar radiation. Surface temperature is a different parameter from air temperature; hard surfaces, especially asphalt and concrete, absorb solar radiation intensely, creating surface temperatures above 60°C. In urban areas, the low solar reflection capacity of building materials and the high percentage of impermeable surfaces drive temperature values to peak levels. Long-term analyses confirm that urban growth directly affects ground surface temperatures, posing a significant obstacle to sustainable urbanization (Figure 5).

In 2025, when the urban regeneration project is largely completed, temperature zones ranging from 40.1 to 73°C covers the entire neighbourhood. This thermal load, particularly on the 8-10 story high-rise blocks constructed as part of the transformation, is a typical example of the "urban canyon" effect described in the literature. The narrowing of building distances between high-rise structures also reduces wind circulation, i.e., its cooling effect, causing heat to become trapped between buildings. It has been determined that the temperature increase in Saraycık is related not only to horizontal concrete construction but also to the vertical building geometry. The maximum heat island effect is observed to peak in densely populated areas where the distance between buildings is reduced and sky visibility is restricted. The 8-10 story, contiguous blocks built in Saraycık have created a heat trap situation by reducing skylight values, causing solar radiation to remain on the surface. When building heights and spacing interrupt wind corridors, the self-cooling potential of the urban area completely collapses. The peak temperatures of 73°C detected in the analyses provide numerical evidence of the cumulative warming created by this urban canyon structure and the narrowing open spaces.

Figure 5

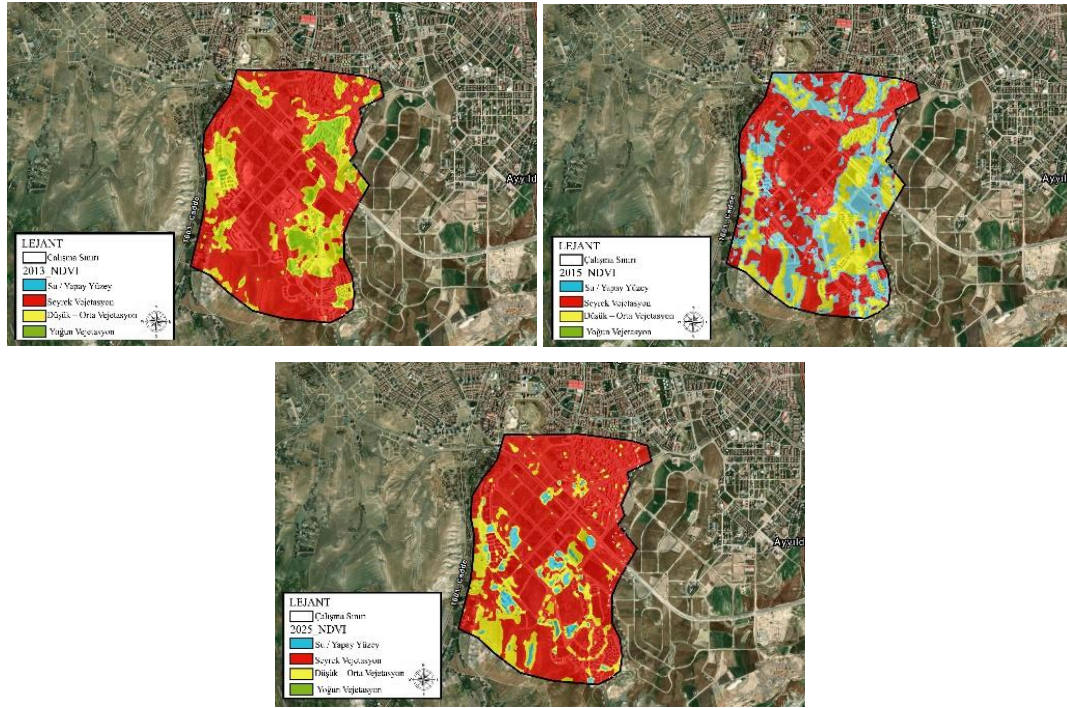
Land Surface Temperature (LST) analysis of the Saraycık Urban Regeneration Project area, (Prepared by the authors)



The change in land cover due to the urban regeneration project has altered the thermal energy balance of the urban ecosystem. There is a strong negative relationship between surface temperature and vegetation density (NDVI), and the destruction of vegetation increases radiation absorption on the surface, triggering a temperature increase. Before 2015, the informal settlements in the area, due to their physical structure consisting of low-rise buildings with high permeable surfaces and abundant green areas, acted as a natural cooler. However, the high-density, high-heat-capacity construction after the project has caused an increase in surface temperature. The increased temperature in the Saraycık Urban Regeneration Project area is not only a result of construction but also a consequence of the destruction of the urban cooling capacity. Before the regeneration, plants balanced the surface temperature through transpiration and evaporation, while large private gardens and open wooded areas between neighbourhoods resulted in positive NDVI values. As emphasized in the literature, thermal stress is lower in areas with high healthy plant density (range 0.3-0.6). Analyses conducted in 2025 revealed that the vegetation in the neighbourhood center had almost completely disappeared. High-rise blocks and concrete floors, replacing private gardens, had reduced NDVI values to 0.1 and below. (Figure 6).

Figure 6

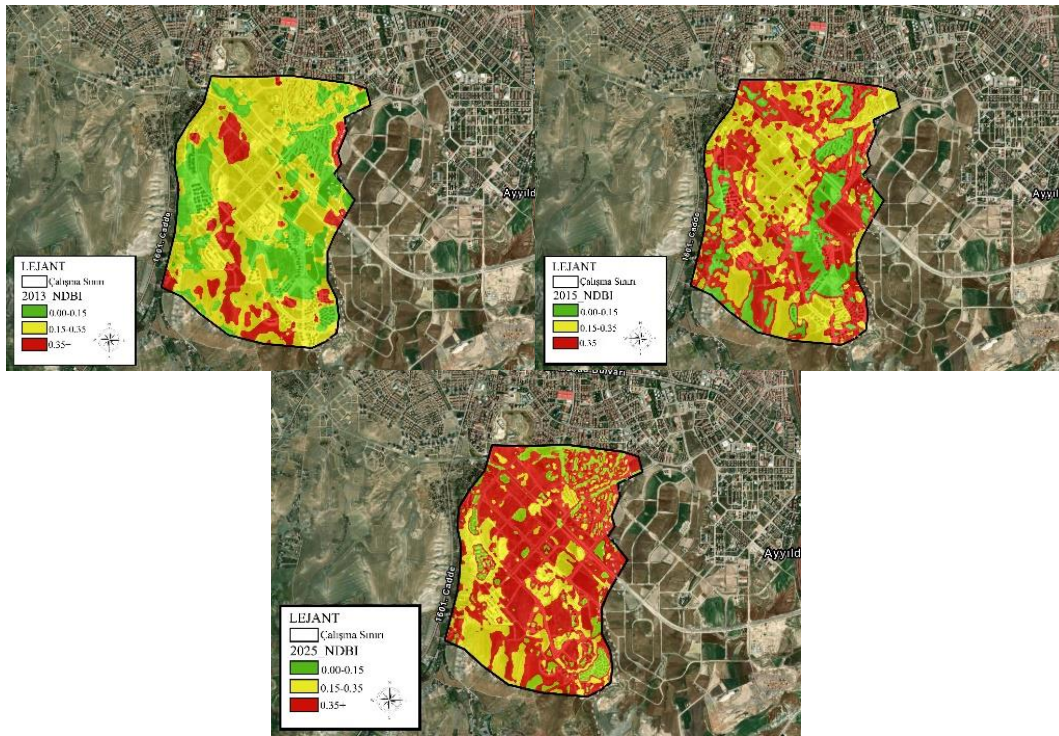
Vegetation Density (NDVI) analysis of the Saraycık Urban Regeneration Project Area, (Prepared by the authors)



The urban regeneration project has led to a decrease in green spaces while simultaneously increasing hard surfaces and building density. Scientific research based on Landsat data has revealed that impermeable surface areas such as concrete and asphalt are a much stronger and more decisive indicator of surface temperature prediction compared to vegetation indexes (NDVI). NDBI analysis is an indicator used to determine the proportion of impermeable surfaces (asphalt, concrete, roofs, etc.) in urban areas, and the soil surfaces in the neighbourhood before 2015 have largely been replaced by concrete and asphalt surfaces by 2025. NDBI values of 0.35 and above (red areas) indicate artificial areas where heat is trapped due to impermeable surfaces. According to the analysis results, the locations of high-rise buildings with the highest NDBI values coincide with the hot spots on the surface temperature (LTS) map. The high NDBI values obtained in the Saraycık example prove that the vertical construction, which replaced the low-density, garden-style old settlement pattern in the region, has transformed into a structure with a high thermal mass that absorbs solar radiation (Figure 7).

Figure 7

Impervious Surface Ratio (NDBI) analysis of the Saraycık Urban Regeneration Project Area, (Prepared by the authors)



CONCLUSION

Urban regeneration is mostly associated with illegal, informal settlement areas and aims at the socio-economic and physical development of aging, risky, and deteriorated urban fabric. This study, which examines the microclimatic impacts of the Saraycık Urban Regeneration Project, reveals that urban regeneration is not limited to socio-economic and physical effects alone. While urban regeneration projects target physical and socio-economic development, the resulting morphological changes can disrupt microclimatic balance. Urban regeneration projects, which exert pressure on the natural environment in urban peripheries or rural areas, tend to urbanize rural fabric while converting urban voids into built surfaces.

The 526-hectare area within the boundaries of Saraycık and Ulubatlı neighborhoods was declared the Saraycık Urban Regeneration Project Area to achieve the socio-economic and physical transformation of existing informal settlements. During the transformation process, the focus was primarily on socio-economic and physical structures, while environmental impacts were overlooked. However, challenges such as climate change, water scarcity, and food security necessitate the integration of sustainability- and environment-focused approaches into planning decisions at all scales.

This study evaluates the impact of the Saraycık Urban Regeneration Project on urban heat island formation using GIS-based analyses, including LST (Land Surface Temperature), NDVI (Normalized Difference Vegetation Index), and Normalized Difference Built-up Index. It discusses the effects of vegetation cover and impervious surfaces on urban surface temperature increases. Findings indicate that the urban regeneration project altered the thermal characteristics of the area and that changes in urban morphology significantly affect local temperatures. In 2013, when informal settlements still existed, building density and impervious surfaces were lower, distances between buildings and vegetation cover

were higher, and surface temperatures ranged from 20°C to 40°C. By 2015, with the removal of squatter housing and loss of existing green spaces, temperatures began to rise, and by 2025, when construction is largely completed, temperatures are projected to range between 40.1°C and 73°C. This change is attributed to higher heat absorption by concrete and asphalt surfaces and the reduction of open spaces due to vertical development. Vegetation, which was dominant in the neighborhood in 2013, also significantly decreased following the regeneration project. Prioritizing ecological values in urban areas is critical for enhancing quality of life and maintaining thermal balance.

This study has certain limitations that should be considered when interpreting the findings. The analysis was based on a single cloud-free Landsat image for each selected year (2013, 2015, and 2025), representing the pre-project, project initiation, and current stages of the urban regeneration process. Although all images were acquired during the summer season to ensure seasonal consistency and facilitate temporal comparison, the use of a single image for each period does not capture daily and seasonal variability in land surface temperature and spectral indices. Therefore, the results should be interpreted as representative snapshots of the selected time periods rather than continuous temporal dynamics. Future research could improve the robustness of the findings by incorporating multi-temporal and multi-season satellite imagery to better account for temporal variability.

The urban heat island effect can be mitigated through a range of strategic planning approaches, from large-scale planning decisions to small-scale interventions. Strategies include planning land use according to climatic conditions, preserving natural areas and increasing vegetation diversity, determining minimum green areas in projects, limiting impervious surfaces, creating natural ventilation corridors, optimizing building orientation and shading strategies, designing urban greenery and green corridors, implementing green roofs and walls to reduce heat-retaining hard surfaces, reducing waste heat from air conditioning, vehicles, and other electronics, applying water-sensitive design to create cooling through evaporation, improving building insulation to enhance energy efficiency and reduce heating and cooling demand, using highly reflective colors and surfaces to prevent heat absorption, increasing shading in public spaces, and preparing heat action plans. Integrating climate-sensitive planning criteria into urban regeneration projects is crucial, as ignoring them may cause environmental costs that negatively affect urban life quality. Incorporating GIS-based analyses into planning processes and assessing environmental impacts before implementation is essential for designing sustainable and resilient urban spaces.

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Ethical Statement

The present study is an original research article designed and produced by the authors.

Author Contributions

Author 1: Conceptualization of the study, data collection and analysis, preparation of the original draft, interpretation of findings, and visualization.

Author 2: Literature review and development of the theoretical framework, planning and coordination of the research process, translation of the manuscript into English and language editing, review and revision of the draft manuscript, and approval of the final version.

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Conflict of interest

The authors declare no conflict of interest for the present study.

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