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Smart Planning Tool Based on Future Predictions for Sustainable Cities

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ABSTRACT

Spatial planning for the future must be data-driven. This study aims to predict future trends by analyzing the connections between construction area increases, changes in humidity and green space, and extreme summer temperatures. Within the scope of the study, the "smart planning system" designed for this purpose is detailed. This system aims to form the foundation of resilient cities. The research involves collecting and analyzing data from four neighborhoods in the Etimesgut district of Ankara, Türkiye, which experienced the highest increases in construction area between 2012 and 2021. In the second phase of the study, a Python-based software tool called the "smart planning system" was developed, which uses the relationships between construction area increases, changes in humidity and green space, and extreme summer temperatures to make future predictions. This tool demonstrated that the outcomes of various urban interventions and the impacts of construction activities in expanding urban areas can be predicted. Thus, the research contributes to the development of sustainable cities. In conclusion, this study emphasizes the importance of data-driven planning.

Sürdürülebilir Şehirler için Gelecek Tahminlerine Dayalı Akıllı Planlama Aracı

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ÖZET

Geleceğe yönelik mekânsal planlama, veriye dayalı olmalıdır. Bu çalışmada, inşaat alanı artışı, nem ve yeşil alan miktarındaki değişiklik ile aşırı yaz sıcaklıkları arasındaki bağlantıların analiz edilerek gelecekteki eğilimlerin tahmin edilmesi amaçlanmıştır. Çalışma kapsamında, buna yönelik kurgulanan "akıllı planlama sistemi" detaylandırılmaktadır. Bu sistem, dirençli şehirlerin temelini oluşturmayı amaçlamaktadır. Araştırma, Türkiye'nin Ankara iline bağlı Etimesgut ilçesinde, 2012-2021 yılları arasında en yüksek inşaat alanı artışı gözlenen dört mahallesinden elde edilen verilerin toplanması ve analiz edilmesini kapsamaktadır. Çalışmanın ikinci aşamasında; inşaat alanı artışı, nem ve yeşil alan miktarındaki değişiklik ile aşırı yaz sıcaklıkları arasındaki ilişkileri gelecekteki tahminler için kullanan Python tabanlı bir yazılım aracı olan "akıllı planlama sistemi" geliştirilmiştir. Bu araç, çeşitli kentsel müdahalelerin sonuçlarının ve genişleyen kentsel alanlardaki inşaat faaliyetlerinin etkilerinin öngörülebileceğini göstermiştir. Araştırma böylece sürdürülebilir şehirlerin gelmesine katkıda bulunmaktadır. Sonuç olarak, bu çalışma, veri odaklı planlamanın önemini vurgulamaktadır.

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INTRODUCTION

By 2030, it is estimated that there will be 43 megacities with populations exceeding 10 million, highlighting their crucial role in helping the world limit dangerous climate change. These cities have the potential to offer substantial environmental benefits. However, it has been observed that new residential areas built to accommodate population growth contribute to increased urban temperatures (Sikkema et al., 2023).

Urban land consumption is expanding at a rate that outpaces population growth by up to 50%, with an additional 1.2 million km² of new urban built-up area expected within the next thirty years. As built-up areas increase, the hydrological cycle is disrupted (Meng et al., 2020), reducing latent heat usage and exacerbating more variable temperature conditions (Liu et al., 2022; Oke, 1973).

Different meteorological conditions prevail in various land-use areas within cities (Liu et al., 2022), creating distinct environments within the urban landscape. Parks, pools, newly developed areas, and areas with dense low-rise buildings tend to have lower temperatures compared to the urban average (Meng et al., 2020).

Cities face increasing risks as a result of climate change. A certain amount of climate risk is already locked in due to current emissions, and if actions to mitigate climate change fail to achieve the target of limiting warming to 1.5°C, the risks will increase significantly (Lu et al., 2023). To protect the lives and livelihoods of urban residents, cities must enhance their resilience to current and future climate impacts.

The problem addressed by this research is that traditional planning is not informed by urban data, which is necessary to ensure environmental resilience against the negative impacts of future urbanization.

The issue addressed by this research is that traditional planning methods, which are still prevalent, do not provide future projections based on urban data parameters that ensure environmental resilience against negative impacts. Citizens do not know how much inhabited space the projected population will need or how much this inhabited space will increase summer temperatures. The aim of this study is to design a "smart planning system" to predict future trends by analyzing the connections between construction area increase, humidity, changes in green space, and extreme summer temperatures.

This study aims to predict future trends by analyzing the connections between construction area increases, changes in humidity and green space, and extreme summer temperatures. For this, I have focused on four neighborhoods in Ankara Province for this article. In these four neighborhoods, which experienced the highest increases in construction area between 2012 and 2021.I examined the increases in construction area, the amount of green space, summer temperatures, and humidity levels between 2011 and 2022. In the first phase, data on construction area increase, humidity, and green space changes, along with extreme summer temperatures, were collected and analyzed from four neighborhoods in the Etimesgut district of Ankara, Türkiye, which experienced the highest construction area increase between 2012 and 2021. The relationships among these variables were identified. In the second phase of the study, a Python-based software tool, named the "smart planning system," was developed based on these identified relationships. This smart planning system relies on these relationships to make future predictions. According to the system, if no precautions are taken, these future predictions will hold true. The smart planning system facilitates the development of solutions to prevent climatic and environmental negative effects, making sustainable cities more attainable.

The software allows for the identification and implementation of suitable alternatives to reduce temperature and humidity. The software is suitable for use by architects, planning offices, urban planners, and other relevant stakeholders.

THEORETICAL BACKGROUND

By 2060, the global building floor area is expected to double (Lu et al., 2023). To accommodate the largest wave of urban growth in human history, citizens anticipate adding 230 billion square meters of new floor area to the global building stock every month. This is equivalent to adding an entire New York City to the world every month.

The future growth of cities, along with the allocation of land and natural resources, will determine the success of an environmentally sustainable future (Mousavinia et al., 2019). In some cities, unplanned or poorly managed urban expansion, coupled with unsustainable production and consumption patterns, leads to rapid sprawl, pollution, and sharp increases in temperature and humidity. Today, the demand for population and the built environment is rapidly increasing (Sutradhar et al., 2024). Urban development, along with the accompanying increase in urban population, accelerated towards the end of the 18th century and became almost unstoppable in the 19th and 20th centuries. In the future, the global urban land area will continue to increase up to 2030 (Chen et al., 2020).

Urban temperature and humidity are influenced by urbanization, resulting from changes in land use and the impacts of human activities (Arnfield, 2003; Foley et al., 2005; Grimm, 2008; Kalnay & Cai, 2003; Rizwan et al., 2008). Ecosystems, energy and water demands, and human well-being are negatively impacted by these changes. Urban temperature and humidity affect not only the quality of indoor air but also outdoor air quality and even regional atmospheric pollution (Sarrat et al., 2006).

The rising energy demands for cooling indoor temperatures (Santamouris, 2014) result in increased consumption of global resources. Additionally, the impact on local meteorology, such as wind patterns and cloud formation, directly affects human comfort and health (Taha, 1997). Heat-related illnesses and deaths are becoming more frequent and are expected to worsen with continued urbanization (Hajat et al., 2014).

Taking action to improve human well-being and achieve sustainability is an urgent task. Implementing strategies to lower urban temperatures during the planning and design phases provides a practical approach to urban management. According to the study framework proposed by Oleson (Oleson et al., 2013), it is essential to relate one factor to others. Establishing the "phenomenon-formation mechanism" relationship is fundamental to finding effective strategies.

Urban Planning Perspective

To assist urban planners and decision-makers in effectively utilizing research findings, it is more advantageous to connect climate issues with planning parameters rather than relying solely on geographic or morphological factors. From an urban planning standpoint, the expansion of built-up land surface area affects urban temperatures. It has been demonstrated that more construction area leads to higher temperatures (Perini & Magliocco, 2014; Petralli et al., 2014). Increasing vegetation cover is a practical way to reduce urban heat and humidity effects (Duarte et al., 2015; Fan et al., 2015; Perini & Magliocco, 2014). There is substantial literature supporting the idea that increasing urban greenery can reduce heat (Correa et al., 2012; Erell et al., 2012; Gartland, 2008; Heaviside et al., 2017; Oke, 2006; Sarrat et al., 2006). At the same time, numerous studies have been developed to investigate the impact of urban factors, such as vegetation, on urban temperatures (Oke, 1982; Arnfield, 2003; Chakraborty, A., & Lee, 2019; Zhao et al., 2014; Karydis & Georgopoulos, 2018; Li & Bou-Zeid, 2013).

At the microscale, this heat reduction occurs in two ways: firstly, through vegetation metabolism that uses solar energy and photosynthesis, and secondly, through evapotranspiration (evaporative cooling) in response to ambient temperature on the surface of leaves, similar to human skin. Therefore, green infrastructure can resist heat effects by cooling air and surface temperatures at the microscale. Various forms of greenery in urban areas, including parks, gardens, green roofs, vertical greenery, urban farming, nature reserves, and extensive vegetation planting, help to reduce urban temperatures by distributing absorbed solar radiation as latent heat (Wong, 2009). Recent research indicates that vegetated areas can be several degrees cooler than their surroundings (Bi & Little, 2022).

Current studies have primarily focused on the relationship between urban sprawl driven by population growth and climate change, but there hasn't been enough focus on the interrelationships of parameters and future scenarios for resilient settlement planning. Additionally, simulating urban interventions through the lens of new-generation planning concepts is of paramount importance. In this context, the aim of the study is to use software named the "smart planning system" to foresee the outcomes of different interventions in the city and the impacts of construction in growing urban areas through future predictions, thereby generating solutions to avoid climatic and environmental negative impacts.

STUDY AREA

Determination of the study area

One of the most crucial stages of this study was identifying rapidly urbanizing areas on the outskirts of the city to demonstrate the necessity of incorporating smart planning parameters. The research involves collecting and analyzing data from four neighborhoods in the Etimesgut district of Ankara, Türkiye. Additionally, access to data on construction growth, climate, temperature, and humidity was essential for the selected locations. In the initial phase, I calculated the increase in construction across all neighborhoods of Ankara through a preliminary research effort lasting one year.

Ankara, historically known as Ancyra and Angora, has a rich history dating back to the Bronze Age. It was an important cultural and political center for several civilizations, including the Phrygians, Lydians, Persians, Greeks, Romans, Byzantines, and Ottomans (Yılmaz, 2018). Ankara became the capital of Türkiye in 1923. Situated in the central Anatolian region, the city serves as a key geographical hub. Ankara experiences a continental climate, with hot, dry summers and cold, snowy winters. Summer temperatures can reach up to 35°C (95°F), while winter temperatures often drop below freezing, accompanied by significant snowfall (Kaya & Yilmaz, 2017). With a population exceeding 5 million residents, Ankara plays a pivotal role in Türkiye's political, cultural, and economic life, balancing its historical heritage with modern development (Eker & Duman, 2016).

Based on the data obtained within the scope of this study and observable trends, I identified that the city is expanding towards the west (keos, 2024). I selected four neighborhoods with the highest rates of construction on the western side of the city. To ensure meaningful results, I used the period from 2012 to 2021 as a reference. In this study, I aimed to explore the future of cities in the face of climatic risks by examining the relationship between construction growth and temperature, rainfall, and humidity in these four conventionally planned neighborhoods. Additionally, using the data obtained from these neighborhoods, I aimed to develop smart planning system software using the Python programming language. This software considers climate and environmental risks to minimize their impacts, allowing for the anticipation of environmental and climatic consequences resulting from various construction scenarios and enabling necessary revisions to be made in advance.

The impact of urbanization-related climate change in Ankara has been noticeable since the 1970s, with its effects on the city's surroundings intensifying, particularly in the mid-1990s, as the city amalgamated with nearby settlements (Çalışkan & Türkoğlu, 2014). The number of days with heavy rainfall has been increasing in the city, and as the urban area expands, both temperature and humidity levels rise (Çiçek, 2004). Unlike other major cities in Türkiye, which are generally near the sea, Ankara is situated at an average elevation of 850 meters, roughly at the 40th parallel, and experiences a semi-continental climate in the Central Anatolian Region. Topographically, Ankara is located in a basin enclosed on three sides (Yüksel & Yılmaz, 2008).

In the first stage of the study, I collected data from four neighborhoods in Ankara where rapid urbanization and uncontrolled urban sprawl have led to increased construction. (See Figures 1, 2, 3, 4, 5, 6, 7).

In the study, four neighborhoods in the Etimesgut District of Ankara, the capital of Türkiye, with the highest construction increase, have been analyzed. The selection of the Etimesgut District is due to the more organized and diverse nature of the data collected in this district compared to others. In the figure below, the location of Ankara within Türkiye is shown (Figure 1).

Figure 1
Ankara's location on the map of Türkiye (source: https://www.vientex.com/en/product/ankara-il-harita-tablosu-cty151)

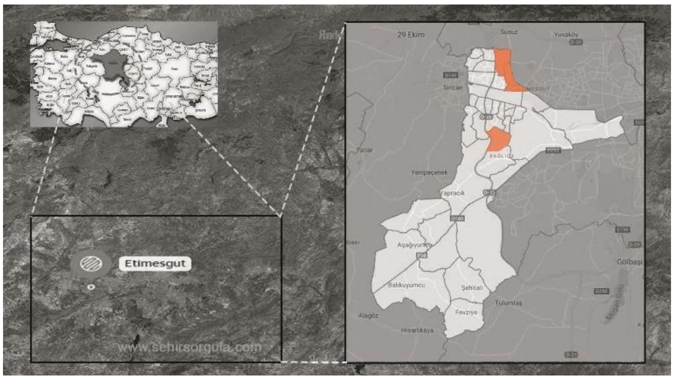
Below, the districts of Ankara Province are shown. The Etimesgut District is highlighted to indicate its location within Ankara Province (Figure 2).

Figure 2
The location of the discussed neighborhood in Ankara
(source: https://www.vientex.com/en/product/ankara-il-harita-tablosu-cty151)

Below, the locations of the neighborhoods analyzed within the scope of the study (Figure 3).

Figure 3

The location of the discussed neighborhoods Etimesgut
(source: https://www.vientex.com/en/product/ankara-il-harita-tablosu-cty151)



Bağlıca Neighborhood, one of the four neighborhoods in Etimesgut District with the highest construction increase, is shown below (Figure 4).

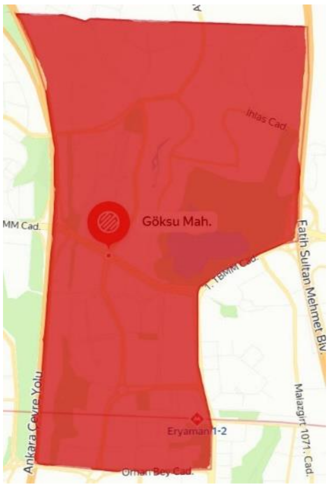
Figure 4

Baglıca neighborhood (source: http://keos.etimesgut.bel.tr/keos/)

Goksu Neighborhood, one of the four neighborhoods in Etimesgut District with the highest construction increase, is shown below (Figure 5).

Figure 5

Göksu neighborhood (source: http://keos.etimesgut.bel.tr/keos/)



Seker Neighborhood, one of the four neighborhoods in Etimesgut District with the highest construction increase, is shown below (Figure 6).

Figure 6

Seker neighborhood (source: http://keos.etimesgut.bel.tr/keos/)

Sehit Osman Avci Neighborhood, one of the four neighborhoods in Etimesgut District with the highest construction increase, is shown below (Figure 7).

Figure 7

Sehit Osman Avcı neighborhood (source: http://keos.etimesgut.bel.tr/keos/)

I collected data on construction area, humidity, changes in green space, and summer temperatures for the mentioned neighborhoods. These data were obtained through a year-long effort involving aerial photographs, neighborhood municipalities, and the Ministry of Environment, Urbanization, and Climate Change. Based on the data collected and prepared for analysis, I developed a smart planning system using the Python programming language. This software provides future projections illustrating the negative impacts of urban construction on cities.

MATERIALS AND METHODS

The aim of this study is to design a "smart planning system" to predict future trends by analyzing the connections between construction area increase, humidity, changes in green space, and extreme summer temperatures.

In the first phase, data on construction area increase, humidity, and green space changes, along with extreme summer temperatures, were collected and analyzed from four neighborhoods in the Etimesgut district of Ankara, Türkiye, which experienced the highest construction area increase between

2012 and 2021. The relationships among these variables were identified. In the second phase of the study, a Python-based software tool, named the "smart planning system," was developed based on these identified relationships. This smart planning system relies on these relationships to make future predictions. According to the system, if no precautions are taken, these future predictions will hold true. The smart planning system facilitates the development of solutions to prevent climatic and environmental negative effects, making sustainable cities more attainable.

The software aids in evaluating various urban design scenarios and predicting future urban heat and humidity due to increased population and construction. This allows for the identification and implementation of suitable alternatives to reduce temperature and humidity. The software is suitable for use by architects, planning offices, urban planners, and other relevant stakeholders.

Phase 1: Data Collection and Analysis

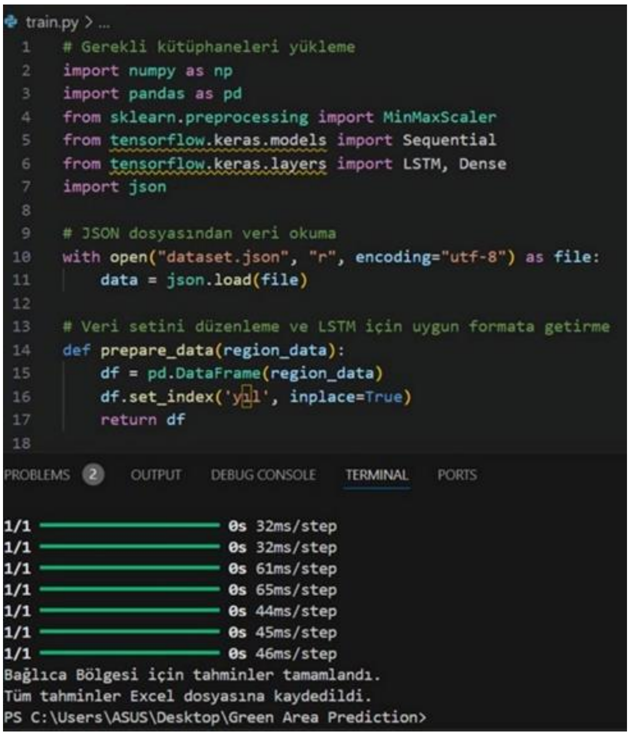
In the first phase, data on construction area increases, humidity, green space changes, and extreme summer temperatures were collected and analyzed from four neighborhoods in the Etimesgut district of Ankara, Türkiye. These neighborhoods experienced the highest construction area increases between 2012 and 2021. Relationships among these variables were established through detailed data analysis.

Phase 2: Development of the Smart Planning System

In the second phase, a Python-based software tool, named the "Smart Planning System," was developed based on the identified relationships. This system utilizes these relationships to make future predictions. The predictions are based on the assumption that if no precautionary measures are taken, the forecasted trends will continue to hold true. The system aids in developing solutions to mitigate climatic and environmental negative effects, thereby making sustainable urban planning more achievable (See Figures 8, 9, 10).

Figure 8

Calculating relationships between data using Python

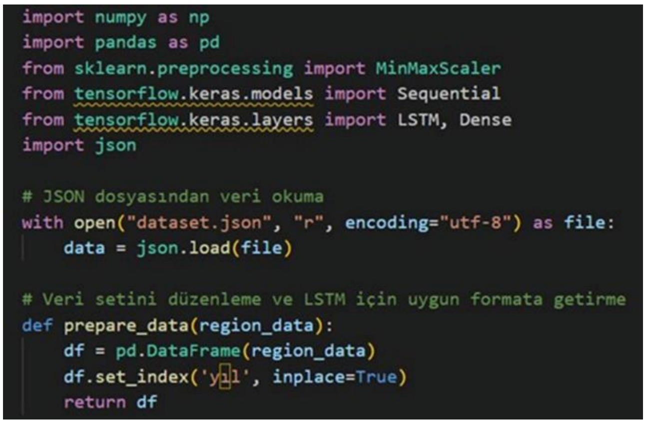


```python
# Gerekli kütüphaneleri yükleme
import numpy as np
import pandas as pd
from sklearn.preprocessing import MinMaxScaler
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import LSTM, Dense
import json

# JSON dosyasından veri okuma
with open("dataset.json", "r", encoding="utf-8") as file:
    data = json.load(file)

# Veri setini düzenleme ve LSTM için uygun formata getirme
def prepare_data(region_data):
    df = pd.DataFrame(region_data)
    df.set_index('yıl', inplace=True)
    return df

```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 61ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 65ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 44ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 45ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 46ms/step
Bağlıca Bölgesi için tahminler tamamlandı.
Tüm tahminler Excel dosyasına kaydedildi.
PS C:\Users\ASUS\Desktop\Green Area Prediction>
```

Figure 9

Calculating relationships between data using Python (source: author)



```
import numpy as np
import pandas as pd
from sklearn.preprocessing import MinMaxScaler
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import LSTM, Dense
import json

# JSON dosyasından veri okuma
with open("dataset.json", "r", encoding="utf-8") as file:
    data = json.load(file)

# Veri setini düzenleme ve LSTM için uygun formata getirme
def prepare_data(region_data):
    df = pd.DataFrame(region_data)
    df.set_index('yıl', inplace=True)
    return df
```

Figure 10

Calculating relationships between data using Python (source: author)

```
{
    "yıl": 2012,
    "yeşil_alan": 476288.56,
    "nüfus": 14024,
    "ortalama_sıcaklık": -0.8,
    "yağış": 53,
    "nem": 74
}
```

The purpose of this algorithm is to provide a starting point for traditional planning systems by incorporating various data, allowing the creation of master plans and implementation plans within this framework. By identifying the relationship between climatic risks and rapid urbanization, it aims to provide an interactive scenario tool for resilient and smart urban planning in the future. Sustainable urban planning policies, once implemented, can reduce cities' vulnerability to climate risks over the coming decades. This algorithm guides experts in integrating climate change into urban planning practices and highlights the parameters that planners need to consider when developing projects. It supports cities in combining nature-based solutions and other mechanisms to reduce climate vulnerabilities, ensuring livable and equitable urban development.

The scenario modeling and urban design methodology system based on specific structural features will have the following characteristics:

1. It is web-based, making it accessible to a wide user community in addition to developers.
2. It is user-friendly and simple to use.
3. It can model different scenarios relatively quickly and effectively with a range of input values.
4. It is evidence-based and transparent, allowing the identification, examination, and replacement of evidence sources as needed.
5. It is developed through an open-source process.

Today, most computer-based modeling systems are not open source, making it challenging or impossible to track the calculation process. The relationship with the research underlying the calculations is often not clearly defined (Gourlay & Crooks, 2018). Furthermore, even with open-source systems, adding new features requires access to the original source code and substantial programming expertise (Smith & Tarrant, 2016).

Finally, modeling systems typically require extremely complex calculations that can produce irregular and unreliable results, being highly sensitive to initial conditions (Finkel & Jansen, 2017). This software avoids these risks.

Software Functionality

The software assists in evaluating various urban design scenarios and predicting future urban heat and humidity resulting from increased population and construction. It enables the identification and implementation of effective alternatives to reduce temperature and humidity. Designed for use by architects, planning offices, urban planners, and other relevant stakeholders, the software leverages detailed data collection methodologies and analyses the relationships between data variables.

Technical Details

The "Smart Planning System" is built using Python and incorporates analytics and machine learning libraries, including Pandas, Numpy, and Scikit-learn. The software relies on comprehensive descriptions of data collection methods and relationships between collected data to provide accurate predictions and insights.

Below are the detailed explanations of the methodology of the study under the following headings

Urban Construction

Acquiring Data from Identified Neighborhoods:

1. I identified the outskirts of Ankara, the capital of Türkiye, with the most rapid increase in construction. Initially, I obtained population growth data. To verify this information, I acquired project permit numbers from the neighborhood municipalities. These initial data provided the basis for identifying the study areas. The results, which were already visibly observable, led me to four neighborhoods experiencing Ankara's westward expansion.
2. In these four neighborhoods, I began collecting data on the increase in construction, changes in the quantity of green space (both increases and decreases), population growth, and variations in ahbourhoodverage summer temperature and humidity for the years 2012–2021.
3. First, I determined the amount of construction increase. To do this, starting from 2012, I identified newly constructed buildings each year by examining month-by-month aerial photographs on Google Earth. I then verified the Google Earth data by reviewing aerial photographs from the municipalities' GIS systems chronologically. In the second stage, I used the zoning plan of parcels available on the municipalities' websites to identify the net construction increase in square meters. In the third stage, I reviewed the construction area specified in building permit documents from the municipalities for these structures. This triple-system approach enabled me to accurately determine the annual construction increase in each neighborhood.

Building Height (BH)

At this stage, I considered data such as the Floor Area Ratio (FAR), total construction rights, building height (or number of floors), and parcel setback distances provided in the zoning plans for buildings constructed in the four neighborhoods between 2012 and 2021. I identified the parcels in the zoning plans where structures were built each year and obtained information about the maximum floor heights or the maximum number of floors designated for these areas.

Green Space and Undeveloped Areas

I identified undeveloped areas and green spaces by employing a similar approach to the one used for determining construction area increases. In this category, I considered not only green spaces such as parks but also undeveloped areas with soil and vegetation—areas that are zoned but lack construction, thus comprising the total land area. Between 2012 and 2021, I analyzed aerial photographs and images from the GIS systems of neighborhood municipalities chronologically to identify green areas and parks using both Google Earth and the municipalities' GIS systems.

To calculate changes in undeveloped areas and green spaces over the years, I added the floor area ratio (FAR) in square meters of developed areas to the green areas in the zoning plans. I confirmed the area from both land registry records and FAR values in the zoning plans, ensuring a two-step verification process.

Air Temperature and Humidity Levels

In conventional planning, urban construction is generally concerned primarily with building density. Building Density (BD), Building Height (BH), and Floor Area Ratio (FAR) are specified in the plans, and construction proceeds accordingly. However, the potential increase in temperature resulting from this construction is not typically calculated.

To identify the increase in construction area, I reviewed data from the Metropolitan Municipality, District Municipality, and Ministry, as well as the master zoning plan and implementation plan obtained from these institutions. Aerial photographs were examined for verification. All this data led me to four neighborhoods in the Etimesgut District of Ankara, which showed the highest increase in construction area. Additionally, I obtained data on temperature, precipitation, and humidity changes for these neighborhoods, covering different months and years, from the Ministry of Environment, Urbanization, and Climate Change and the district municipality. For climate change projections, I utilized the database created by the Eurasia Institute of Earth Sciences at Istanbul Technical University. This database provided point estimates for temperature and humidity for the sample area using interpolation methods. I considered factors such as the density and representation of point data, geographical conditions, and similar factors in the spatial maps obtained through these interpolation methods. Based on this data, I determined the potential changes in temperature and humidity for Ankara between 2011 and 2050 using the database prepared by the Eurasia Institute of Earth Sciences at Istanbul Technical University, the A2 scenario, the ECHAM5 global model, and the RegCM3 regional model. To identify the relationship between the increase in construction area, changes in humidity and green space, and summer temperatures in the neighborhoods I identified, I used SPSS software. Based on this relationship, I developed a software called the "Smart Planning System." This software demonstrated that the values in the master zoning plan and implementation plan have a third dimension and that urban planning should not be conducted in just two dimensions and solely on paper, independent of urban data.

FINDINGS

This study aims to predict future trends by analyzing the connections between construction area increases, changes in humidity and green space, and extreme summer temperatures.

In the first phase, data on construction area increase, humidity, and green space changes, along with extreme summer temperatures, were collected and analyzed from four neighborhoods in the Etimesgut district of Ankara, Türkiye, which experienced the highest construction area increase between 2012 and 2021. The relationships among these variables were identified. In the second phase of the study, a Python-based software tool, named the "smart planning system," was developed based on these identified relationships. This smart planning system relies on these relationships to make future predictions. According to the system, if no precautions are taken, these future predictions will hold true. The smart planning system facilitates the development of solutions to prevent climatic and environmental negative effects, making sustainable cities more attainable.

The software aids in evaluating various urban design scenarios and predicting future urban heat and humidity due to increased population and construction. This allows for the identification and implementation of suitable alternatives to reduce temperature and humidity. The software is suitable for use by architects, planning offices, urban planners, and other relevant stakeholders.

According to the data obtained, there was an increase in construction area in the neighborhoods studied as follows: 30,304 m² in Seker neighborhood, 120,902 m² in Sehit Osman Avcı neighborhood, and 109,874.4 m² in Baglıca neighborhood, all occurring in 2015. The highest increase in Göksu neighborhood was recorded in 2013, reaching 197,345.2 m². In the years with the highest increase in construction area in these four neighborhoods, summer temperature, summer precipitation, and humidity also increased more compared to other years.

The software provides predictions for the years 2025-2031 based on the relationship between green area, construction area, temperature, precipitation, and humidity from 2012 to 2021. I presented these prediction results for the four neighborhoods in separate tables (See Tables 1, 2, 3, 4).

Table 1

Based on the software results, the future prediction for Sehit Osman Avcı neighborhood (source: author)

	green_area	**population**	**average_temperature (sommer)**	**Precipitation (sommer-mm)**	**Humidity (sommer-%)**
2025	96435,7031	27525,51758	31,79552746	37,79734039	72,03839111
2026	94054,1641	28529,31445	31,79568965	37,86324463	72,05337524
2027	92457,1328	29542,36328	31,79576176	38,73406219	72,06436157
2028	91389,1875	30557,94922	31,81615556	38,80910645	72,07241058
2029	90676,3984	31567,76367	31,89635484	38,98778229	72,07832336
2030	90201,25	32562,30273	32,35695484	38,99977855	73,08265686
2031	89884,7891	33531,39844	32,79745484	39,65404129	73,08583069

Table 2

Based on the software results, the future prediction for Seker neighborhood (source: author)

	green_area	**population**	**average_temperature (sommer)**	**Precipitation (sommer-mm)**	**Humidity (sommer-%)**
2025	476888,9063	10534,19531	31,363289833	49,91720581	78,47746031
2026	476374,4688	10635,62891	31,364825306	50,21553925	78,47753143
2027	477629,25	10723,32617	32,375146961	50,94123459	79,37759329
2028	476193,5313	10799,32129	32,380090828	50,94300079	79,57760538
2029	476026,2188	10865,30566	32,382455711	51,14355011	79,77763329
2030	475182,4375	10922,69434	33,38858427	51,54372177	80,47765135
2031	475168,5313	10972,67773	33,392466216	51,94377518	80,87778453

Table 3

Based on the software results, the future prediction for Göksu neighborhood (source: author)

	green_area	**population**	**average_temperature (sommer)**	**Precipitation (sommer-mm)**	**Humidity (sommer-%)**
2025	842972,125	54174,95703	33,96447325	47,92079544	71,16513824
2026	839359,1875	64786,97656	33,96870923	47,92082596	71,16726685
2027	836826,125	76865,39844	33,96988964	48,76082596	71,16762543
2028	835054,375	88862,35938	33,97021866	48,92082596	72,16768646
2029	833817,5	98994,17188	34,01031116	49,01082596	72,16770172
2030	832954,9375	106317,3125	34,22033644	49,43082596	72,26770172
2031	832354,0625	110994,3516	34,97034311	50,12082596	72,26970172

Table 4

Based on the software results, the future prediction for Baglıca neighborhood (source: author)

	green_area	**population**	**average_temperature (sommer)**	**Precipitation (sommer-mm)**	**Humidity (sommer-%)**
2025	1685362,625	22399,47266	33,303549767	41,42856598	79,06104706
2026	1678483,625	22787,03516	33,297549725	41,4486084	79,07151031
2027	1673571,75	23121,59961	33,29598093	41,4564476	79,08813049
2028	1670076,75	23410,74023	33,295570374	41,45951462	79,09693268
2029	1667596,5	23660,86328	33,295463085	42,46071625	79,09750543
2030	1665839,5	23877,4082	33,295434475	42,46118546	79,09816047
2031	1664596,375	24065,00391	33,295427322	42,46136856	79,0998147

The analysis of future projections for the Sehit Osman Avcı, Seker, Göksu, and Baglıca neighborhoods reveals notable trends in green space, population growth, summer temperatures, precipitation, and humidity from 2025 to 2031.

Sehit Osman Avcı Neighborhood:

- Green Space: A gradual decrease in green space is observed, declining from 96,435.7 m² in 2025 to 89,884.8 m² in 2031.
- Population: The population is projected to increase significantly, rising from 27,525.5 to 33,531 individuals.
- Summer Temperature: Average summer temperatures are expected to increase from 31.8°C to 32.8°C.
- Precipitation: Summer precipitation is projected to increase from 37.8 mm in 2025 to 39.7 mm in 2031.
- Humidity: Summer humidity is forecasted to rise, from 72.0% to 73.1%.

Seker Neighborhood:

- Green Space: Green space remains largely stable, decreasing slightly from 476,888.9

m² to 475,168.5 m².

- Population: A modest increase in population is expected, from 10,534.2 to 10,972.7 individuals.
- Summer Temperature: Average summer temperatures are anticipated to increase from 31.4°C to 33.4°C.
- Precipitation: Summer precipitation from 49.9 mm to 51.9 mm.
- Humidity: Summer humidity is forecasted to rise, from 78.5% to 80.9%.

Göksu Neighborhood:

- Green Space: A decrease in green space is projected, declining from 842,972.1 m² to 832,354.1 m².
- Population: The population is expected to nearly double, increasing from 54,175 to 110,994 individuals.
- Summer Temperature: Significant increases in summer temperatures are forecasted, rising from 34.0°C to 35.0°C.
- Precipitation: Summer precipitation is projected to increase, from 47.9 mm to 50.1 mm.
- Humidity: Humidity is expected to rise slightly, from 71.2% to 72.3%.

Baglıca Neighborhood:

- Green Space: A slight decrease in green space is anticipated, from 1,685,362.6 m² to 1,664,596.4 m².
- Population: The population is projected to grow moderately, from 22,399.5 to 24,065 individuals.
- Summer Temperature: Summer temperatures are expected to remain relatively stable, ranging from 33.3°C to 33.6°C.
- Precipitation: There will be a small increase in summer precipitation, from 41.4 mm to 42.5 mm.
- Humidity: Humidity is projected to rise slightly, from 79.1% to 79.1%.

The data indicates that, across all neighborhoods, there is a general trend of decreasing green space coupled with increasing populations, which is associated with rising summer temperatures and humidity. The Seker neighborhood shows relatively stable green space and humidity levels, while Göksu experiences substantial population growth and temperature increases. The findings underscore the impact of urban expansion on environmental parameters and highlight the need for strategic planning to manage these changes effectively. Addressing these trends through adaptive measures and improved urban planning can mitigate adverse environmental effects and support the development of sustainable urban environments.

DISCUSSIONS

Urban construction is a significant contributor to urban heat and humidity effects. However, these negative impacts on the urban climate can be mitigated through thoughtful design and planning. The findings suggest that adopting building models with sparse, low, and widely spread structures can help reduce temperature and humidity levels in cities. This aligns with previous research indicating that urban morphology plays a crucial role in shaping microclimates (Oke, 1982; Santamouris, 2014).

Nevertheless, managing building density and height in rapidly expanding cities, especially in developing countries, presents challenges. Lower development intensity may inadvertently lead to urban sprawl or inadequate housing, as pointed out by Angel et al. (2011).

In many developing cities experiencing rapid growth and rising populations, optimizing the spatial arrangement of buildings could serve as a viable strategy to reduce the overall heat and humidity effects. However, spatial arrangement is often overlooked as a planning metric. As such, introducing relevant indicators to assess the relationship between population growth, construction area expansion, urban temperature, and humidity is vital. This could support the achievement of Sustainable Development Goals (SDGs), particularly those related to sustainable cities and communities (United Nations, 2015).

The study's findings also offer practical strategies for urban managers to address urban heat, humidity, and summer rainfall. For instance, construction areas driven by increasing urban populations often face elevated artificial heat, a phenomenon well-documented in urban heat island studies (Santamouris, 2015). One approach to mitigate this is by using surface materials that reflect more light and absorb less heat, a strategy supported by Akbari et al. (2001). Vertical greening, as suggested by Liu et al. (2022), is another effective alternative that not only reduces heat absorption but also enhances indoor cooling, thereby reducing reliance on air conditioning.

Despite the proven effectiveness of these strategies in combating urban heat, humidity, and summer rainfall, many cities remain reluctant to adopt them. This reluctance could be attributed to various factors, including cost, lack of awareness, or insufficient policy frameworks. Therefore, integrating these strategies into urban planning practices and policies is essential for fostering resilient and sustainable cities.

CONCLUSIONS

This study aimed to address a critical gap in traditional urban planning by introducing a "smart planning system" that leverages data-driven approaches to predict future trends in urban environments. By analyzing the relationships between construction area expansion, humidity, green space changes, and extreme summer temperatures, the study sought to develop a tool that can forecast future urban conditions and support sustainable planning.

The findings reveal significant insights into the impacts of urban growth on environmental parameters. The data indicate that increasing construction areas and rising populations are closely linked to higher summer temperatures and humidity levels. Specifically, the projections for the Sehit Osman Avcı, Seker, Göksu, and Baglıca neighborhoods illustrate a trend of increasing temperatures and humidity, with variations depending on the specific characteristics and growth rates of each area.

The "smart planning system" developed in this study provides a novel approach to urban planning by integrating detailed data from aerial images, municipal records, and other sources. This system predicts future environmental conditions and supports urban planners, decision-makers, and stakeholders in making informed decisions. It highlights the importance of incorporating advanced analytics and forecasting into urban planning to mitigate potential negative effects of rapid urban development.

The results suggest that without intervention, the negative impacts of urban expansion on temperature and humidity are likely to intensify. The study underscores the need for proactive measures to manage these effects, such as optimizing green spaces and adopting climate-resilient construction practices. By providing a framework for assessing future scenarios and their implications, the "smart planning system" facilitates the development of strategies to promote sustainable urban growth and enhance environmental resilience.

In conclusion, this study demonstrates that integrating data-driven approaches into urban planning can significantly improve the ability to anticipate and manage the environmental impacts of construction and population growth. Future research should focus on refining predictive models, expanding the dataset, and exploring additional variables to further enhance the accuracy and applicability of the "smart planning system." Ultimately, such efforts will contribute to creating more resilient and sustainable urban environments, capable of adapting to the challenges posed by rapid urbanization and climate change.

Ethical Statement

The article has not been derived from any master's or doctoral thesis. It is an original work.

Ethics Committee Approval

This article does not require ethical committee approval.

Author Contributions

Research Design (CRediT 1) M.A. (%100)

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Sustainable Development Goals (SDG)

13 Climate Action

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