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Research of urban heat island and greenhouse effect-Taking Tel Aviv’s rising temperature as an example

Ruxi Zhang

Shanghai Pinghe School, Shanghai, China,200000

jocelynzrx@163.com

Abstract. It appears that the environment must be sacrificed at this stage of fast urbanization and economic development, and balancing economic development and environmental conservation becomes a struggle. The greenhouse effect is a perpetual wake-up call for humanity from a macro perspective, while the urban heat island effect within cities continues to influence human life from a micro one. The paper aims to study the presentation of the urban heat island effect and some of the anthropogenic causes, as well as the presentation of global warming and the greenhouse effect on surface temperature change and the anthropogenic factors behind it by taking Tel Aviv, Israel as an example. This research suggests that Tel Aviv's average yearly temperature has risen over the last 51 years, which could be related to human-caused global warming. Besides, there is a strong association between UHI and building density, and the loss of green space in urban areas adds to the establishment of UHI. The study helps policymakers decide and develop effective mitigation technologies for the greenhouse effect and UHI for future city expansion to be sustainable.

Keywords: Environment, urban heat island effect, global warming, greenhouse effect.

1. Introduction

The purpose of this article is to analyze the greenhouse effect as it presents itself in the temperature of Tel Aviv, as well as the relationship between the greenhouse effect and human activity using Tel Aviv as an example. In addition, the study will take a more microscopic approach, looking into the urban heat island impact in Tel Aviv.

The greenhouse effect happens naturally when certain gases in the Earth's atmosphere capture heat from the sun, keeping the planet warm enough to support life. Human activities like the use of fossil fuels, deforestation, and industrial operations, on the other hand, have increased the concentration of these gases, resulting in an amplified greenhouse effect and global warming. Israel, including Tel Aviv, has been affected by the greenhouse effect, and the country has set targets to reduce its carbon emissions.

The urban heat island effect describes the phenomena in which urban regions have greater temperatures than surrounding rural areas as a result of human activities such as transportation, industry, and building materials. Tel Aviv is a Mediterranean metropolis with an urban heat island effect. Multiple approaches have been used to investigate the effect of urban spatial patterns on heat exposure in Tel Aviv. Satellite data was also used to examine the impact of local land use on Tel Aviv's urban heat island effect. Urban green areas are thought to be an effective strategy to mitigate urban heat island effects while also providing comfort to local residents.

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Investigating the greenhouse effect and urban heat island (UHI) is critical for understanding the environmental effects of human activities and planning for the future. Human activities have increased greenhouse gas concentrations, leading to global warming. Moreover, because of human activities such as transportation, manufacturing, and building materials, urban regions encounter higher temperatures than neighboring rural areas. UHI has the potential to have both direct and indirect effects on human health and the environment. UHI is predicted to intensify in the future due to ongoing warming, and urbanization is expected to increase, making it critical to address the relationship between UHI and climate change.

2. Temperature Change in Tel Aviv

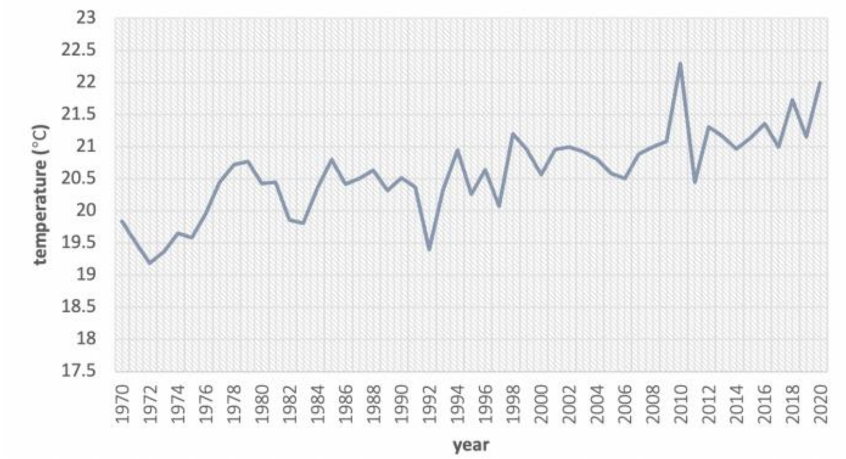

Figure 1. Annual average land surface temperature.

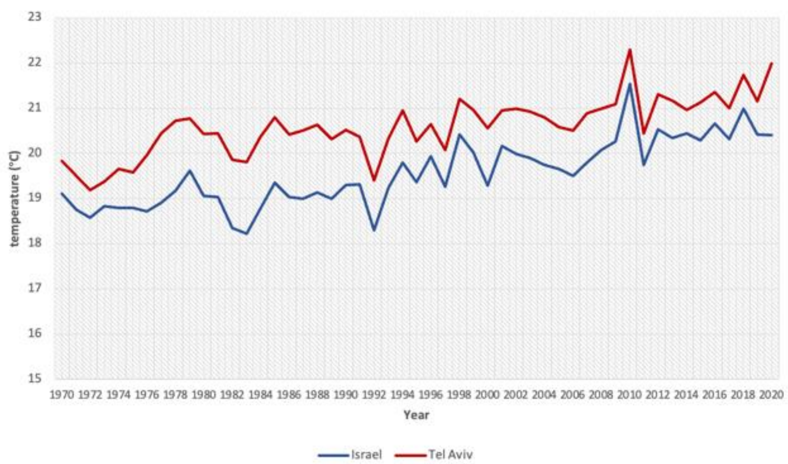

Figure 2. Compares the average annual temperature of Tel Aviv and Israel from 1970-2020

Between 1970 and 2020, the average temperature across Tel Aviv increased from 19.84°C to 21.99°C, an increase of 2.15°C. Although there are fluctuations in the average annual temperature data, Tel Aviv's average annual temperature indicates an overall rising trend. Fluctuations in the average yearly temperature, the climate variability, is mainly produced by natural forces and cannot be distinguished from anthropogenic (human activity) influences on temperature using simple data analysis, hence they will be ignored in this report for the time being.

The rise in Tel Aviv's annual average temperature could be a result of global warming. Human activity is a major contributor to global warming. Manufacturing, transportation, and other human activities are examples of human activity. The combustion of fossil fuels (coal, oil, and natural gas) produces substantial volumes of carbon dioxide and other greenhouse gases, all of which contribute to the greenhouse effect, which causes temperatures to rise. Furthermore, the greenhouse effect contributes to global warming.

Tel Aviv as the second largest city in Israel shows a higher average annual temperature than the whole country. According to Figure 2, the temperature trend in Tel Aviv follows the trend of the country, but the temperature is about 0.53 to 1.59 degrees Celsius higher.

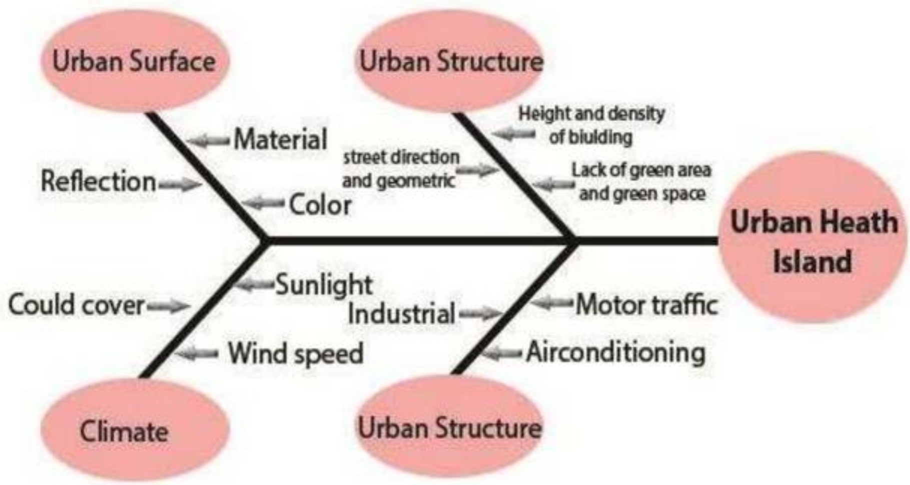

Figure 3. The cause of UHI [1].

When switching the view from large scale to small scale, an extremely severe urban heat island effect can be found within the city of Tel Aviv.

One research showed that during midday the city is ~3.6 °C warmer than the surrounding rural area. Land Surface Temperature in the southern part of the city was hotter by ~7–9 °C compared to the northern part due to a lack of urban vegetation [2]. Figure 3 shows several factors that lead to UHI.

3. Methodology

The data for this report were obtained from publicly available databases on the web, with annual average surface temperatures from 1970 to 2020 obtained from the website Physical Science Laboratory, and other data from the websites Statista and Our World in Data. The data were processed and analyzed using Excel, and linear plots were created to show not only how the temperature varied over the months and seasons of the year, but also how the average annual temperature in Tel Aviv varied over a 51-year period, and to draw conclusions about the patterns. The rest of the images related to the analysis of the spatial structure of the city of Tel Aviv and the analysis of the thermal of the city are cited. Comparing the spatial structure of the city and the thermal of the corresponding areas, the connection and pattern between the two can be visualized.

4. Results

4.1. Greenhouse gas emission

According to the data, Israel's annual CO_2 emissions increased gradually from 1970 (16.56 Mt), reaching a peak in 2012 (74.78 Mt), and have been decreasing since then. Israel's total CO_2 emissions in 2020 were 55.01 Mt, an increase of 38.45 Mt compared to 1970 (Figure 4). The increasing CO_2 emissions increase the CO_2 concentration in the air and lead to the greenhouse effect.

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In Israel, GHG emission is mainly caused by power generation (including thermal power and electricity), transportation, and industry. All three of these factors require the burning of large amounts of fossil fuels and therefore produce large amounts of GHG.

When comparing Figures 4 and Figure5, it is evident that power generation accounts for the majority of GHG emissions and has nearly doubled in 29 years, as have transportation and industry. The cause for this rise could be that Israel's urbanization and economic expansion require more power, industry, and transportation. Furthermore, the population growth in Israel has increased the demand for power and heat, led to the expansion of the city, and increased the number of vehicles.

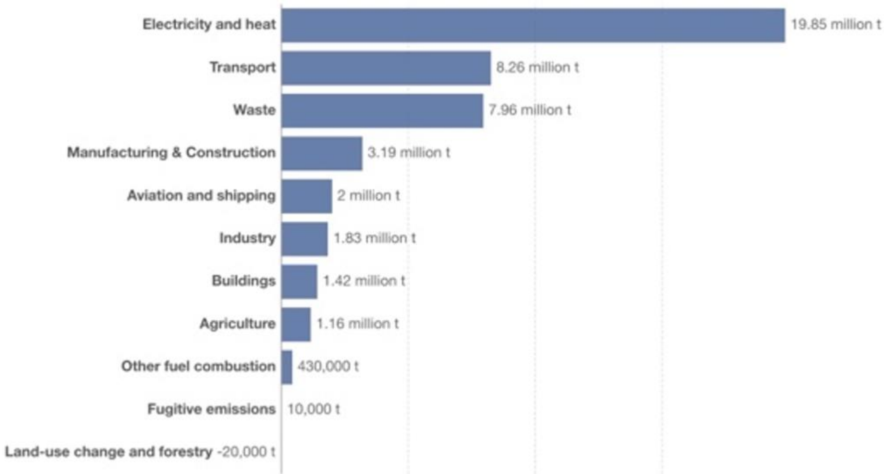

Figure 4. Greenhouse gas emmissions by sector, Israel, 1990[3].

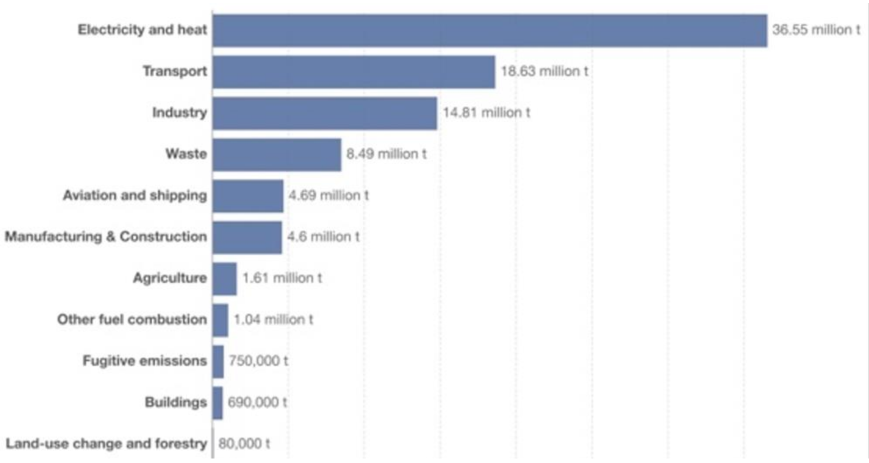

Figure 5. Greenhouse gas emmissions by sector, Israel, 2019[3].

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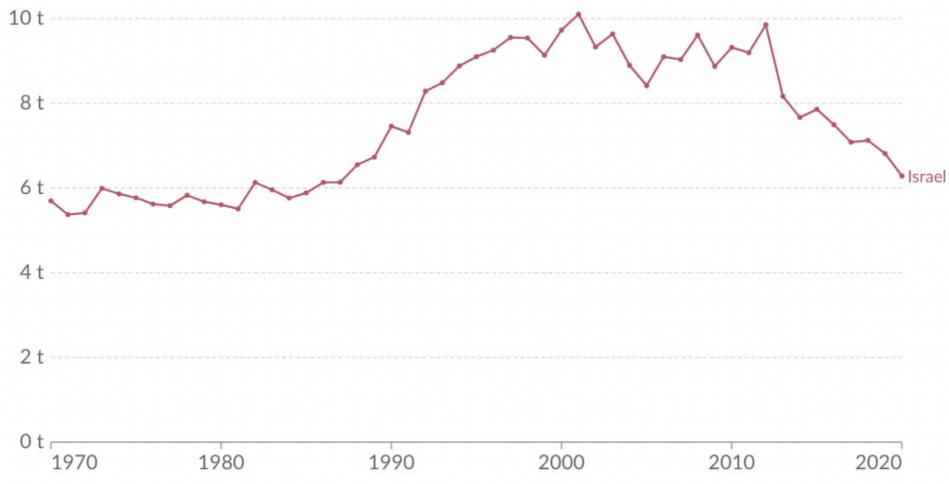

Figure 6. Annual carbon dioxide emissions [3].

4.2. Urban Heat Island

4.2.1. Buildings and Roads. The rising number of buildings and roadways is one of the distinguishing elements of urbanization. The planning and organization of urban buildings are critical since it is strongly tied to the urban heat island effect.

The UHI and Building density relationship test results show a high coefficient of determination, so this shows that the relationship between UHI and building density has a very high relationship [4]. According to previous research, the residential neighborhoods that have a higher building density and height of Tel Aviv are the most heat-vulnerable areas in Tel Aviv [2]. As the map in Figure 7 shows, It is clear that those areas with a higher density of buildings have a higher temperature. The material that is used to build up these buildings is normally concrete, which has the ability to directly absorb heat from sunlight and retain the heat.

With thermal imaging, we can see those temperatures close to the surface, i.e., the ground, the road, and vehicles are all much hotter than the building. Road development is critical for Tel Aviv's high-density metropolis since it facilitates transit. Roads are often asphalted; nonetheless, asphalt roadways and other dark surfaces in metropolitan areas are the dominant factors of UHI [5]. Because asphalt is very dark in color and hence has a very low albedo of only 0.04, when solar radiation finds its way to its surface, it absorbs the majority of it and reflects nearly nothing, causing heat to be retained at the surface and thereby causing UHI.

4.2.2. Green Space. The reduction in the amount of green space in urban areas is usually due to human activities such as urbanization, deforestation, and land-use changes. Vegetation is significant in that it helps reduce urban heat island effects by deflecting the radiation from the sun since it has a high albedo and deforestation greatly contributes to the formation of the UHI.

According to Figure 8, by comparing Tel Aviv is separated into different parts based on the difference in land use, including green residential, residential, public park, and industrial, and the land surface temperature, what is clearly shown is that the Park areas have a significantly lower land surface temperature.

From 1970 to 2020, the process of urbanization will inevitably lead to deforestation in order to maximize the use of land and to the construction of high-rise buildings in areas previously covered by vegetation. Because the situation of UHI is getting more serious, the Tel Aviv government has adopted some mitigations to mitigate UHI, such as the green roof and green residential[6].

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However, because the maximum cooling distance of urban green space is rather small [7], and the greenspace is not dispersed enough, it does not really neutralize elevated air temperatures caused by the UHI effect.

4.3. The effects of rising temperature and possible mitigations

Because temperatures in Tel Aviv are on an upward trend, this certainly increases the risk of extreme weather for the city. Comparing the data from 1970 and 2020, as shown in Figure 8, in 2020, while the average monthly temperature increased, the summer of 2020 became longer, i.e., the high temperatures lasted longer. Tel Aviv is a coastal city, and sea level rise due to rising temperatures can be devastating to coastal areas. Therefore, the government must adopt mitigations to address the rising temperatures.

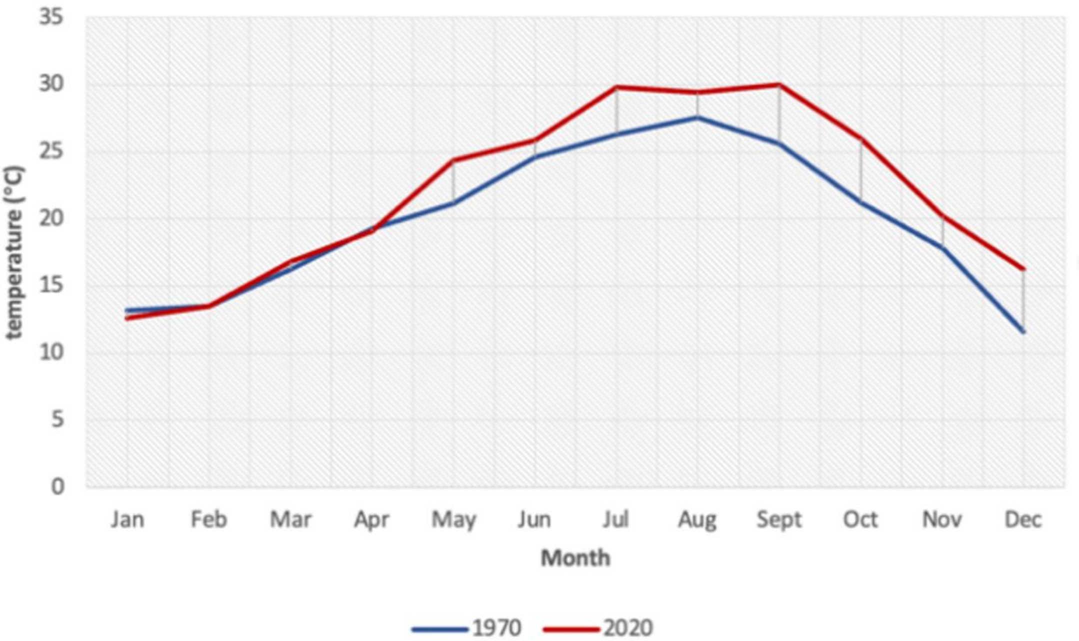

Figure 7. Compares the land surface temperature in 1970 and 2020[6].

There are several ways to slow down the rising temperatures: Increase the green areas of the city and rationalize them so that their cooling effect is maximized; Replacing asphalt roads with materials with higher albedo; Setting up policies to reduce the emission of CO2 and GHG from industrial production; Utilizing new energy sources, including solar energy, wind energy, and so on; Promoting the use of public transportation by urban residents, including the development of public transportation to make it more convenient and the adoption of no-traffic policies

5. Conclusion

Finally, the study looked at the consequences of the greenhouse effect and the urban heat island in Tel Aviv. The study's findings indicate that the average annual temperature in Tel Aviv has risen over the last 51 years, which could be attributed to human-caused global warming. The rise in temperature is also driven by the urban heat island effect, which is generated by human activities such as transportation, industry, and building materials. The study found that the UHI is directly related to building density and that the loss of green space in urban areas has aggravated the UHI. The study also emphasizes the significance of urban green spaces in reducing UHI and providing comfort to local populations.

However, there are some limitations in this study. Because the study was limited to Tel Aviv, the findings may not be applicable to other cities. Furthermore, the study only used secondary data, whereas future studies could benefit from gathering primary data.

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Future research on this subject will prioritize the development of effective mitigation methods for the greenhouse effect and the consequences of UHI. Policymakers should prioritize the reduction of greenhouse gas emissions and the promotion of urban green spaces. Green roofs and green residential communities could be effective UHI mitigation strategies. Furthermore, future studies may concentrate on the effects of UHI on human health and the environment in order to create effective mitigation measures.

In conclusion, the greenhouse effect and UHI are serious environmental issues that must be addressed right away. The findings of this study highlight the importance of policymakers prioritizing the reduction of greenhouse gas emissions and the promotion of green spaces in urban areas. Effective mitigation technologies for the greenhouse effect and UHI are required for future city expansion to be sustainable.

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