Journal of Computation Physics and Earth Science
ISSN: 2776-2521 (online)
Volume 5, Number 1, April 2025, Page 107 - 112
https://journal.physan.org/index.php/jocpes/index

Impact of Urban Heat Island on Shifting Weather Patterns in Sidoarjo and Malang: BMKG Daily Data-Based Analysis

Assajdah Abdullah[1], Muhammad Zaki Albukhori[2], Krisna Dewi[3], Wyra Steven Hutagalung[4], Muhammad Yazid Ilmany[5], Syahrajad Al Syarqiyah[6], Zulfitrah Mokoginta[7]

[1,2,6]Undergraduate Program in Applied Meteorology (STMKG)
[3]Undergraduate Program in Applied Climatology (STMKG)
[4]Undergraduate Program in Applied Geophysics (STMKG)
[5,7]Undergraduate Program in Applied of Instrumentation Meteorology, Climatology, and Geophysics (STMKG)

Article Info

Article history:

Received March 16, 2025
Revised March 21, 2025
Accepted March 22, 2025

Keywords:

Urban Heat Island
Temperature
Weather
Sustainable urban

A B S T R A C T

The Urban Heat Island (UHI) phenomenon is an increase in surface temperature in urban areas compared to the surrounding, more rural areas. This phenomenon can affect shifts in weather patterns, including an increase in average temperature, changes in rainfall patterns, and an increase in extreme weather events. This study aims to analyse the impact of UHI on shifting weather patterns in Indonesia using BMKG daily climate data. The method used includes a quantitative approach withtime series analysis to understand the trend of changes in air temperature and rainfall in Sidoarjo and Malang. The results showed a correlation between UHI intensity and changes in weather patterns,where areas with high UHI intensity experienced a significant increase in temperature and changes in rainfall patterns. This research is expected to provide insights for more sustainable urban planning in the face of UHI impacts in Indonesia.

Corresponden Author:

Muhammad Zaki Albukhori,
Undergraduate Program in Applied of Instrumentation Meteorology, Climatology Geophysics (STMKG)
Tangerang City, Banten, Indonesia
Email: zakialbukhor56@gmail.com

1. INTRODUCTION

Urban Heat Island (UHI) is a phenomenon that occurs due to urbanisation that causes an increase in surface temperature in urban areas compared to surrounding areas. In general, UHI refers to an increase in air temperature, but UHI can also refer to the relative heat of a surface or material above it. UHI inadvertently increases local climate change due to atmospheric and surface modifications in urbanised areas. However, UHI has no direct effect on global warming because the occupation of a city constitutes only a small fraction of the Earth's entire surface. UHI has important implications for human health and comfort, air pollution, energy balance, and urban planning [1]. UHI is a phenomenon or occurrence of increased air temperature that occurs in urban areas compared to rural areas that reach temperatures of 3-10°C [2] .

Urban heat islands (UHIs) exacerbate the risk of heat-related mortality associated with global climate change. The intensity of UHIs varies with population size and mean annual precipitation, but a unifying explanation for this variation is lacking, and there are no geographically targeted guidelines for heat mitigation. The urban heat island (UHI) effect is defined as the temperature difference between an urban centre and the outlying regions. It has some additional characteristics: for instance, considerable research has indicated that the UHI effect appears more frequently under calm and weak wind conditions with a cloudless sky at night, and that its intensity is affected by daytime and nocturnal circulations [3].

The causes of UHI include land cover change, the use of materials with high heat absorption, and anthropogenic activities that generate additional heat. The impact of this phenomenon not only affects the

microenvironment, but can also cause regional changes in weather patterns. Sidoarjo City is located at 112°43′00″ east longitude and 7°27′00″ south latitude. Sidoarjo City is one of the sub-districts in Sidoarjo Regency, East Java. The city has an area of about 56 km² with a total population of approximately 210,507 people in 2013. Sidoarjo city is located about 22 km south of Surabaya city. Topographically, Sidoarjo City has a relatively flat topography with an average altitude of about 3-5 metres above sea level. The region is a part of the north coast of East Java which is characterised by flat and fertile Land.

Malang City is located at 112°37′12″ East Longitude (East) and 7°58′48″ South Latitude (South). Malang City is at an altitude between 440-667 metres above sea level. The city is surrounded by mountains, such as Mount Arjuno to the north, Mount Semeru to the east, Mount Kawi and Panderman to the west, and Mount Kelud to the south. With an area of approximately 145.28 km², Malang City has a population of around 820,243 people (based on 2014 data), to the highest recorded 932,127 people in mid-September 2021, showing an increase of around 10% compared to the previous year of 844,933 people. This indicates an increase in the phenomenon of urbanisation involving land transformation from open areas to urban areas, exacerbating the UHI effect.

In Indonesia, population increase and urban expansion have accelerated the occurrence of UHI. Temperature changes due to UHI can affect rainfall patterns, humidity, and increase the frequency of extreme weather events. Therefore, this study aims to analyse the UHI phenomenon in Indonesia and its influence on shifting weather patterns by utilising BMKG daily climate data based on time series analysis, which is periodic data collected over time, to describe the development of a region. Periodic data analysis allows us to know the development of one or several events and their relationship/influence on other events [4]. The pattern of data movement or variable values can be followed or recognised by the presence of periodic data, so periodic data can be used as a basis for:

1. Analyse rainfall and average temperature.
2. Combating UHI by conducting sustainable urban planning.

2. RESEARCH METHOD

This study uses a quantitative approach with a time series analysis method to understand the trend of changes in air temperature and rainfall in Sidoarjo City and Malang City. The data used are secondary data from Meteorology, Climatology and Geophysics Agency (BMKG), namely Juanda Meteorological Station for Sidoarjo City and Malang Geophysical Station for Malang City. The data analysed includes daily average air temperature (in °C) and daily rainfall (in mm) for the period 2015 to 2024.

The analysis was conducted by calculating the average air temperature and average rainfall in January in 2015 and 2024 in each study area. The average results of each parameter in both years were then compared to obtain the difference in temperature and rainfall changes. This difference is used as the basis for analysing the microclimate changes allegedly caused by the Urban Heat Island (UHI) phenomenon in the study area.

In addition, this study also includes observations of literature studies to see the research patterns that have developed regarding urban heat islands. Literature studies start from journals that have existed for the past 10 years or more due to the limitations of existing papers.

3. RESULT AND DISCUSSION

This research began with processing BMKG daily climate data through the website dataonline.bmkg.go.id which obtained several results that became the basis for analysing UHI. Based on BMKG daily climate data, Juanda Meteorological Station in 2015 the average monthly temperature at Juanda Meteorological Station was 27.55 ° C. In 2024, the average increased to 28.40 ° C. with an increase in average temperature in 9 years of about 0.85 ° C. Then the daily climate data of BMKG, Malang Geophysical Station shows the average monthly temperature in 2015 was 26.06°C and in 2024 the average temperature increased to 28.10°C with an average temperature increase of about 2.04°C in the last 9 years. Image 1 and 2 below show graphs of temperature changes in Sidoarjo and Malang over a period of 9 years.

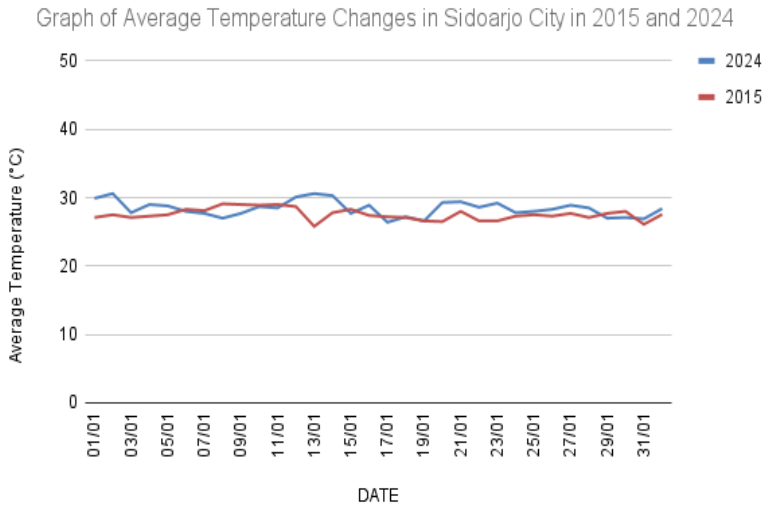

Fig. 1. Graph of Average Temperature Change in Sidoarjo City in 2015 and 2024

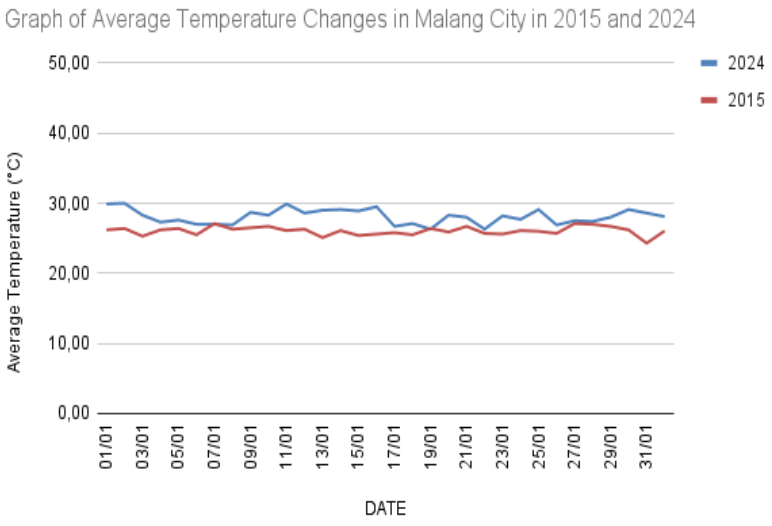

Fig. 2. Graph of Average Temperature Change in Malang City in 2015 and 2024.

After observing the average temperature of each region, the results are obtained as follows,
1. Temperature increases at both sites indicate a localised warming trend.
2. the temperature increase in Malang was greater than Juanda.

The increase in temperature in both locations, with the elevation of Malang city at 285 masl which usually has a lower temperature than lowland areas such as Sidoarjo Juanda which is at an elevation of three masl, with a significant increase in temperature in Malang compared to Juanda could be due to the rapidly

increasing urbanisation in Malang, as the 2021 census data increased by about 10% from the previous year, so can be concluded. While Juanda (Sidoarjo) has been a metropolitan area with a more mature infrastructure for a long time, the change in average temperature at Juanda is not significant in Malang but is still affected by the effects of the UHI.

After observation through an increase in average temperature, observation of daily rainfall parameters as a method of understanding the trend of changes in air temperature and rainfall in Sidoarjo City and Malang can be done with time series analysis from BMKG stations by processing average rainfall data in 2015 and 2024. Figure 3 and Figure 4 below show a diagram of changes in average rainfall in Sidoarjo City and Malang in the period 2015-2024.

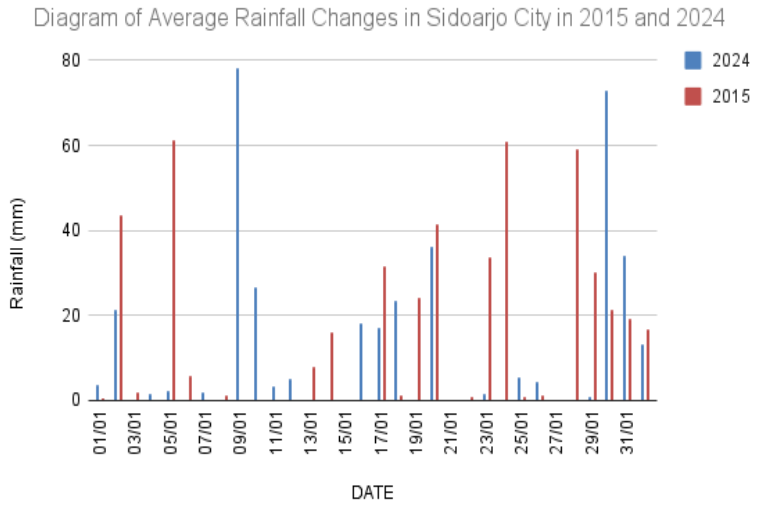

Fig. 3. Diagram of Changes in Average Rainfall in Sidoarjo City in 2015 and 2024

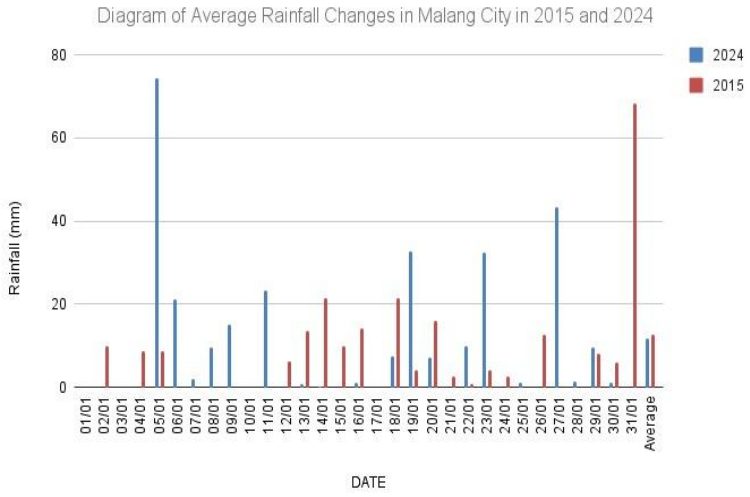

Fig. 4. Diagram of Changes in Average Rainfall of Malang City in 2015 and 2024

From the Diagram of Changes in Average Rainfall in Sidoarjo City and Malang in 2015 and 2024, it can be seen that in the observation data of Juanda meteorological station, in 2015 the average monthly rainfall was 16.60 mm and experienced a decrease in rainfall to 13.28 mm, with a decrease in a period of 9 years

decreased by 3.32 mm. At the Malang geophysical station the average rainfall observation in 2015 was 12.59 mm, also in 2024 there was a decrease in rainfall by 0.83 mm to 11.76 mm.
From the analysis of observations of changes in average rainfall in Sidoarjo and Malang, it was found that,

1. There was a decrease in rainfall at both observation sites.
2. Juanda has a more significant decrease in rainfall than Malang.

The occurrence of decreased rainfall in both locations can be attributed to the UHI effect which causes the land surface to become warmer, so that water evaporates faster and local precipitation patterns change, as temperature increases, the evaporation process increases, but relative humidity decreases, which can reduce rainfall potential. Then a more significant decrease in rainfall at Juanda compared to Malang, this can occur because Juanda which has a lower elevation, namely, 3 masl compared to Malang which is at 285 masl, which makes Juanda more vulnerable to the effects of global warming and weather changes. Temperature changes in Sidoarjo and Malang may also be influenced by regional factors such as global climate change. However, the local effect of UHI appears to be more dominant in Malang, which can be seen from the rapidly growing urbanisation factor in Malang city.

Provide a statement that what is expected, as stated in the 'Introduction' chapter can ultimately produce the 'Results and Discussion' chapter, so that there is congruence. In addition, it can also be added to the prospect of developing research results and the application of prospects for further studies (based on the results and discussion).

4. CONCLUSION

The UHI phenomenon is a challenge for governments, with rapid urbanisation exacerbating the phenomenon through increased population density, the use of heat absorbing infrastructure and the conversion of green spaces. By structuring infrastructure development and open land management to suppress the effects of UHI, which are reflected in increased temperatures and changes in rainfall patterns, the government can carry out mitigation strategies in the form of increasing green space to increase evapotranspiration and reduce ambient temperature, then the use of building materials that can reflect heat, such as the use of light coloured house paint that has a high albedo to reduce heat absorption, the application of stricter regulations in industrialisation is needed for industrial emissions that contribute to increasing city temperatures.

With a multidisciplinary approach that includes aspects of urban planning, technology, and environmental policy. This implementation can create a more comfortable and sustainable urban environment and can reduce the effects of UHI affecting cities.

ACKNOWLEDGMENT

The authors wish to thank the State College of Meteorology, Climatology, and Geophysics and also the Indonesia State College of Meteorology, Climatology, and Geophysics and the Indonesian Agency for Meteorological, Climatological, and Geophysics for suggestions on this project.

REFERENCE

[1] Hermawan, E. (2015). The Urban Heat Island (UHI) Phenomenon in Several Big Cities in Indonesia as One of the Impacts of Global Environmental Change.
[2] Naf, M. Z. T., et al. (2018). Study of Urban Heat Island Phenomenon in Big Cities in Indonesia. Journal of Meteorology and Climatology.
[3] Y.-H. Kim and J.-J. Baik. Daily maximum urban heat island intensity in large cities of Korea, Theoretical and Applied Climatology, vol. 79, pp. 151–164, 2004.
[4] Supranto, J. (1987). Statistical Analysis: For Decision Making. Jakarta: Erlangga.
[5] Badan Meteorologi, Klimatologi, dan Geofisika. (2024, January). BMKG daily average rainfall and temperature data - Sidoarjo. Retrieved 21 March, 2025, from https://dataonline.bmkg.go.id/data-harian
[6] Badan Meteorologi, Klimatologi, dan Geofisika. (2015, January). BMKG daily average rainfall and temperature data - Sidoarjo. Retrieved 21 March, 2025, from https://dataonline.bmkg.go.id/data-harian
[7] Badan Meteorologi, Klimatologi, dan Geofisika. (2024, January). Daily average rainfall and temperature data BMKG - Malang. Retrieved 21 March, 2025, from https://dataonline.bmkg.go.id/data-harian
[8] Badan Meteorologi, Klimatologi, dan Geofisika. (2015, January). Daily average rainfall and temperature data BMKG - Malang. Retrieved 21 March, 2025, from https://dataonline.bmkg.go.id/data-harian
[9] Patrick E. Phelan,et al. (2015). Urban Heat Island: Mechanisms, Implications, and Possible Remedies
[10] Abdul Munaf Mohamed Irfeey, et al. (2023). Sustainable Mitigation Strategies for Urban Heat Island Effects in Urban Areas
[11] Yingsheng Zheng, et al. (2023). Investigating the Impact of Weather Conditions on Urban Heat Island Development in the Subtropical City of Hong Kong
[12] Irvan Lasaiba (2022). UrbanAreas in the Perspective of Poverty, Slums, and Urban Heat Island (A Literature

Review).
[13] Ervan Ferdiansyah, et al. (2022).Identification of Urban Heat Island and Influencing Factors Using Google Earth Engine.
[14] Hermawan, E. (2022). Urban Heat Island: Impacts and Solutions. Journal of Urban and Environment.
[15] Gabriele Manoli, et al. (2019). Magnitude of Urban Heat Islands is Largely Explained by Climate and Population.
[16] Li-Wei Lai, et al. (2009). Air quality influenced by urban heat island coupled with synoptic weather pattern.
[17] Darmawan, S., & Taufan, I. (2020). ELECTROMICS: Journal of Electrical Energy Engineering,Telecommunication Engineering, & Electronics Engineering.
[18] Ervan, F., & Penggalih, W. R. (2022). Identification of Urban Heat Island and its Influencing Factors Using Google Earth Engine. The Climate of Tropical Indonesia Maritime Continent Journal.