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Impact of Built Area on Increasing Surface Temperatures in Makassar City

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ABSTRACT

Makassar City, the fourth largest city in Indonesia and the main hub in Eastern Indonesia, covering an area of 175.8 km², has undergone significant changes due to the rapid rate of land conversion. This process has led to a decline in densely vegetated areas, which has impacted the rise in air temperature in built-up areas. This study aims to analyze the impact of built-up areas on the increase in air temperature in Makassar City. The data used were derived from MODIS imagery to measure air temperature changes, and analyzed using spatial analysis methods based on a spatial approach utilizing geographical data related to location. The results of the study indicate that air temperature levels in Makassar City in 2023 tended to be very high, although some areas were classified as having high and low-temperature levels. Based on these findings, strategic measures are recommended to control the rate of surface temperature increase, particularly through the development of green areas and the protection of water bodies as part of urban planning efforts.

Kata Kunci: Built-up Area, Surface Temperature, Makassar City

ABTRACT

Kota Makassar, sebagai kota terbesar keempat di Indonesia dan pusat utama di Kawasan Timur Indonesia dengan luas 175,8 km², mengalami perubahan signifikan akibat laju konversi lahan. Proses ini menyebabkan penurunan kawasan bervegetasi padat, yang berdampak pada peningkatan suhu udara di kawasan terbangun. Penelitian ini bertujuan untuk menganalisis dampak kawasan terbangun terhadap peningkatan suhu udara di Kota Makassar. Data yang digunakan berasal dari citra MODIS untuk mengukur perubahan suhu udara, dengan metode analisis spasial berbasis pendekatan keruangan, menggunakan data geografis terkait lokasi. Hasil penelitian menunjukkan bahwa tingkat suhu udara di Kota Makassar pada tahun 2023 cenderung sangat tinggi, meskipun terdapat beberapa wilayah dengan kategori suhu tinggi dan rendah. Berdasarkan hasil ini, direkomendasikan langkah strategis untuk mengendalikan laju peningkatan suhu permukaan, terutama melalui pengembangan kawasan hijau dan perlindungan area perairan dalam perencanaan pembangunan kota.

Keywords: Kawasan Terbangun, Suhu Permukaan, Kota Makassar

1. INTRODUCTION

Cities are the center of various economic and social activities, where various community activities occur intensively and sustainably, thus making cities the epicenter of growth and change in many aspects of human life. City development does not only involve physical aspects, such as the development of infrastructure and public facilities, but also includes complex non-physical dimensions, such as changes in social, economic and cultural structures that occur along with increasing population and increasing activity. economics (Castells, 2010 & Hall, 2014). In this context, city development is often characterized by an increase in built-up areas—areas designated for buildings and infrastructure, such as housing, offices, roads and other public facilities. This increase in built-up area is largely due to the intensification of community activities and increasingly massive development, which often triggers various changes in land use in big cities (Seto, 2012; Maru et al, 2024; Maru et al, 2018).

These changes in land use, which often occur quickly and without careful planning, can have a direct impact on the environmental conditions of cities. One of the most significant environmental impacts is an increase in air temperature in urban areas, known as the Urban Heat Island (UHI) phenomenon, where the temperature in the

city center becomes higher compared to the surrounding areas which are greener and less dense (Arfandi et al, 2024; Utami et al, 2024). This condition is caused by various factors, including a decrease in the amount of vegetation, an increase in hard surfaces that absorb and store heat, as well as heat emissions from motorized vehicles, industry, and buildings (Nur et al, 2024; Nuryadin et al, 2024).

Makassar, as one of the main metropolitan cities in Indonesia, cannot be separated from the dynamics of this development. Geographically, the Makassar area and Selayar Island are located between 5 to 7 degrees South Latitude and 119 degrees 20 minutes to 120 degrees 30 minutes East Longitude, which makes it located in the tropical zone with a warm and humid climate throughout the year. The city of Makassar, which has a long history as a center of trade and culture in eastern Indonesia, is now facing the challenge of increasing urbanization. This rapid urbanization process is driving an increasing demand for housing, which in this context takes the form of new housing to accommodate rapid population growth (Amdah, 2024; Nasrul et al, 2024; Saputro et al, 2017).

The demographic and geographical characteristics of the people of Makassar also influence the city's development patterns. Most of the people live in fertile volcanic mountainous areas with many flowing rivers, such as around Mount Bawakaraeng and Mount Lompobatang, as well as on the coastal plains which are mostly inhabited by a mixed population of Bugis and Makassar ethnicities. Both groups have strong maritime and agricultural traditions, which further enrich the social and cultural fabric of the city. However, uncontrolled urbanization and the ever-increasing expansion of built-up areas have also worsened urban environmental conditions, especially related to air quality problems and significant temperature increases.

One of the most pronounced negative impacts of urban development and rapid industrialization in Makassar is the decline in environmental quality. The increase in urban temperatures or Urban Heat Island (UHI) does not only occur due to natural factors such as weather and climate changes, but is mostly caused by human activities, such as intensive use of fossil fuels, reduction in green open space, and greenhouse gas emissions. from various sectors, including transportation, industry and housing (Rusdi et al, 2024). These activities make a major contribution to increasing global temperatures, which in turn affects the balance of urban ecosystems and increases health risks for residents, especially those who are vulnerable to extreme temperature changes (Maru and Ahmad, 2015. Therefore, there is a need for more planning better and more sustainable in city development so that these negative impacts can be minimized and the quality of life of urban communities can continue to be improved (Maru et al, 2015).

Built-up areas are land that has undergone development or paving including buildings, roads, industry, public facilities and other infrastructure (Maru and Ahmad, 2014). The increase in population causes the area of built-up areas to increase, which can affect environmental conditions and surface temperatures. Waterproof materials used in built areas can absorb solar radiation, high thermal conductivity, and emit heat energy to the surrounding environment. Rising temperatures are also caused by the rate of land conversion, which causes a reduction in densely vegetated areas. Over time, significant temperature increases can lead to urban heat islands, changing societal microclimate patterns, resource consumption, and lifestyles.

This research aims to understand how increasing land use changes can affect air temperature in built-up areas and measure the extent to which urban warming affects air temperature. Rising air temperatures can cause changes in weather patterns, including an increase in extreme weather events such as heat waves, storms, floods, and droughts. This can disrupt agriculture, infrastructure, and people's daily lives. Increasing air temperatures in urban areas, known as urban warming, can create hotter micro conditions and increase the risk of extreme heat for urban residents. This can lead to increased energy demand for cooling, increasing energy consumption, and greenhouse gas emissions.

2. METHODS

This research was conducted in Makassar City, South Sulawesi, which was chosen as a study location to explore the phenomenon of increasing air temperature in urban areas. Makassar is one of the largest metropolitan cities in Indonesia with a high level of urbanization, making it a relevant place to study temperature changes due to the influence of development and human activities. In this research, the data used is MODIS (Moderate Resolution Imaging Spectroradiometer) imagery, which is remote sensing data with moderate resolution and is often used to monitor environmental conditions globally. MODIS imagery functions to describe the image or appearance of the earth's surface visually and analytically, providing detailed information regarding surface temperature conditions and their variations over time. This data is considered very appropriate for detecting and monitoring the phenomenon of increasing temperature because of its ability to provide data with a high observation frequency and a wide coverage area.

This research uses spatial analysis methods to understand and identify patterns of increasing air temperature in Makassar City (Maru et al, 2016). Spatial analysis is an approach that focuses on spatial dimensions, which includes various techniques such as geospatial statistics, image processing, and spatial analysis to explore relationships and phenomena that occur in geographic space. In this context, geographic data from MODIS

imagery is processed using ArcGIS Desktop 10.8 software, which allows researchers to interpolate temperature data with high precision. This interpolation process helps fill in data gaps by estimating temperature values at points that are not directly detected by satellites, thereby producing a more complete and accurate temperature distribution map. With this approach, this research aims to provide a comprehensive picture of the temperature distribution pattern in Makassar City and understand the factors that influence its increase, so that it can be used as a basis for city planning that is more sustainable and adaptive to climate change.

3. RESULTS AND DISCUSSION

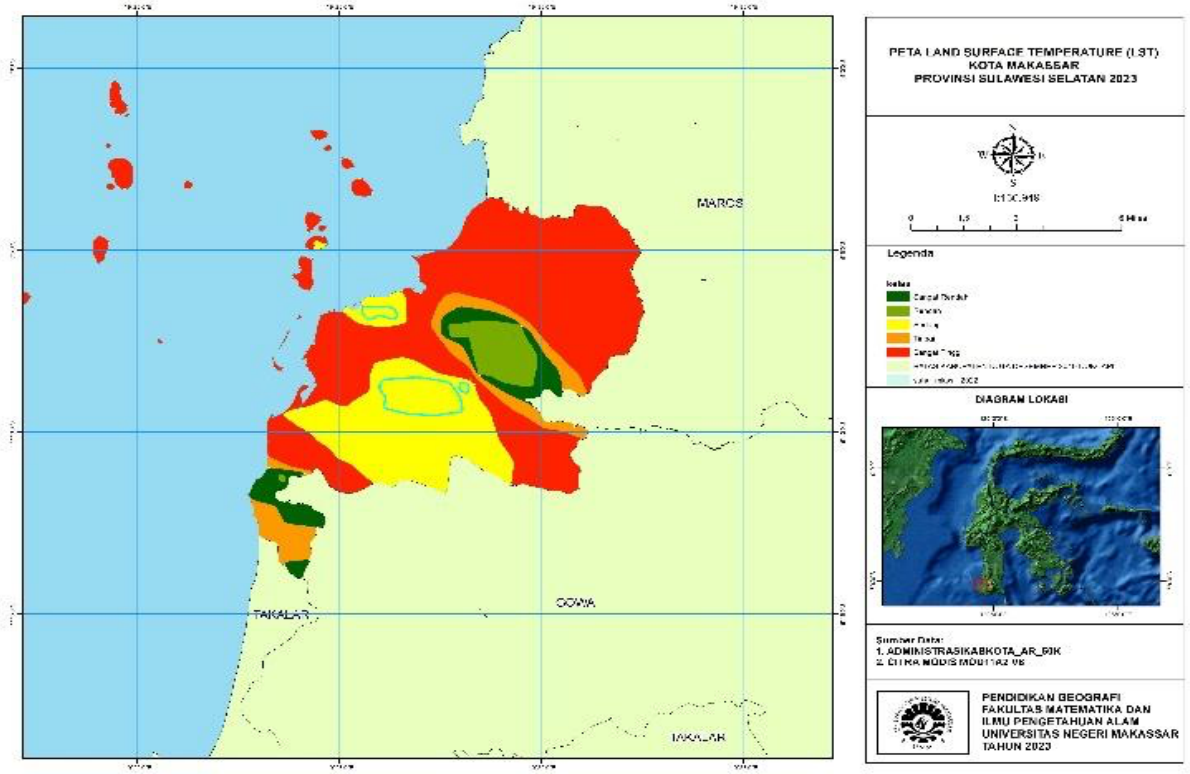

Figure 2. Built-up Area of Makassar City

The image above shows a map of air temperature distribution in Makassar, analyzed using MODIS imagery. The map reveals that most built-up areas in Makassar have very high air temperatures, estimated to cover around 75% of the total built-up area. These very high temperatures typically occur in areas with a dense concentration of buildings, such as the city center and industrial zones. This pattern reflects the impact of rapid urbanization, where the conversion of green land into built-up areas has reduced the environment's ability to absorb heat, thus creating an urban heat island effect.

In addition, about 25% of the built-up areas in Makassar show high air temperatures, but not at the very high level. These areas are generally located around regions with less building density or better availability of green spaces compared to the city center. On the other hand, moderate temperatures are found in around 50% of the built-up areas, indicating variations in temperature distribution that may be influenced by a combination of factors such as proximity to green areas, land use types, and building structures. These areas highlight the importance of maintaining a balance between development and the presence of environmental elements like vegetation and water bodies.

Areas with low air temperatures are found in certain locations, estimated to cover around 15% of the built-up areas. Very low temperatures account for only about 10% of the total area of Makassar City and are generally located around green spaces or bodies of water, which contribute significantly to reducing local temperatures. These findings underline the need for more prudent spatial planning policies, including the management of green spaces and the protection of water bodies. This strategy is essential not only to mitigate the effects of urbanization on air temperature but also to improve environmental quality and ensure sustainable urban development in the future.

Table 1. Land Surface Temperature of Makassar City

No	Temperature (°C)	Criteria	Color	Areas
1	28	Very Low		514096,414355
2	30	Low		11365703,838717
3	31	currently		14245029,205307
4	32	Hight		42911436,860026
5	35	Very Hight		6903553,441944

Based on the data in the table above, it can be seen that built-up areas in the city of Makassar have very high air temperatures caused by urbanization. The development of high built-up areas can hurt the urban environment where changes in land cover, especially built-up areas, can increase surface temperatures. Furthermore, built-up areas such as residential areas, industries, and roads have a fairly strong correlation with high surface temperatures. This is because built-up areas have less green open space so surface temperatures increase.

Makassar City, as one of the metropolitan cities in Indonesia, is experiencing a fairly high rate of urbanization which has increased the need for housing, in this case, housing. Since the last 10 years, Makassar City has experienced a fairly high rate of increase in the number of built-up areas, between 5-6%. Identifying trends in changes in built areas in urban areas, especially Makassar City, is very important as a consideration in evaluating and monitoring compliance with the granting of building permits based on area designation by the Makassar City Regional Spatial Planning Plan (RTRW). Detection of built-up area trends must be carried out using a spatial-temporal approach so that it can provide information on the distribution of built-up areas and trends in changes in built-up areas as a whole and comprehensively from time to time so that strategies can be designed to suppress the rate of development that is not based on its intended use.

Due to the increasing demand for affordable housing, many developers prefer suburban areas as housing development locations, which also include cheap and affordable land. The rapid development of housing development has led to significant growth in urban areas. Highly developed urban areas can hurt the urban environment due to changes in land cover which can increase surface temperatures, especially in cities.

Urban areas such as residential areas, industrial areas, and highways show a very strong correlation with high surface temperatures. This is caused by a lack of green open space in urban areas and an increase in surface temperatures. The development of built-up areas also has an impact on the loss of fertile agricultural land. This can reduce local food production and increase dependence on food imports. The development of built-up areas is often accompanied by an increase in motor vehicle and industrial activity, which can increase exhaust emissions and air pollution, causing health problems such as respiratory diseases and other health problems. The development of built-up areas often displaces green open spaces such as parks, forests or agricultural land. This loss of green open space can reduce the environment's ability to absorb carbon dioxide, provide habitat for wildlife, and provide recreational and health benefits for residents.

Therefore, considering that there is a significant relationship between urban areas and surface temperature, it is necessary to control the proportion of surface temperature caused by urban areas and strengthen the issuance of building permits, especially in green areas and water bodies. Urban water and green spaces are known to help mitigation increase in surface temperature in urban areas.

4. CONCLUSION

This rapid development of built-up areas can have negative impacts on the urban environment, such as increasing surface temperatures. Built-up areas that have little green open space tend to have higher surface temperatures. Therefore, it is important to control surface temperature rates by regulating building permits, especially in green areas and waters. Detection of built-up area trends is carried out using a spatial-temporal approach to provide information about the distribution of built-up areas and trends in change. Thus, this research contributes to understanding changes in built areas in Makassar City and the importance of management that is in accordance with urban spatial planning.

Built-up areas are land that has undergone development or paving including buildings, roads, industry, public facilities and other infrastructure. The increase in population causes the area of built-up areas to increase, which can affect environmental conditions and surface temperatures. Waterproof materials used in built areas have the ability to absorb solar radiation, high thermal conductivity, and emit heat energy to the surrounding environment. Changes in the distribution of built-up areas, especially impervious land cover, are indicators of

urban growth. Therefore, monitoring and identifying changes in built areas is important for planning sustainable urban areas.

Built-up areas will absorb and reflect more solar heat, causing an increase in the UHI phenomenon in urban areas, showing a positive relationship between surface temperature and building density. The denser the city, the higher the surface temperature. Urban areas tend to absorb and radiate more heat than non-urban areas. This can cause the formation of urban heat islands, where the temperature in the area is higher than the surrounding undeveloped areas. The development of urban areas often involves the removal of vegetation such as trees and parks that provide protection from heat and lower temperatures through evaporation. Tall buildings and structures can change airflow patterns, which can affect surrounding air circulation and heat distribution.

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