Urban Heat Island Mitigation for CBD Areas With City Form and Ciy Function Approaches

Sartina[1], *Sulaiman* Zhiddiq[2], *Suprapta*[2], *Maddatuang*[2], *Nurfatimah* Basram[1], Rusdi[3], and *Rosmini* Maru[1*]

[1]Graduate Program of Geography Education, Universitas Negeri Makassar, 90224, Makassar, Indonesia
[2]Department of Geography, Faculty of Mathematics and Natural Science, Universitas Negeri Makassar, 90224, Makassar, Indonesia
[3]Social Science Education Study Program, Faculty of Social Science, Universitas Negeri Makassar, 90224, Makassar, Indonesia

Abstract. Urban Heat Island is part of an increase in air temperature, but UHI can also be said to be part of the relative heat of the surface or material above it. UHI has an impact on human health and comfort, air pollution, energy balance, and urban planning. However, over time, UHI can be predicted as a UHI mitigation effort in urban areas by using Landsat 8 imagery. The type of this study is qualitative descriptive research with multiple linear regression analysis. Based on the results of Landsat 8 image processing, the temperature distribution in the CBD area ranges from 22.6 – 33.6 °C. While the results of multiple linear regression analysis obtained four variables that have a strong influence on the increase in UHI on the surface in the CBD area, namely Transportation Emissions (X5) with mitigation efforts in the form of encouraging bike and ride activities, encouraging car-free days activities, and building fast public mass transportation. The Residential Land Area (X6) with mitigation efforts is in the forms of implementing the Green and Clean concept, Urban Farming based on organic plants, and High and Rise Building at IMB. The Office Area (X2) with mitigation efforts is a form of implementing the concept of Urban Farming based on organic plants, High and Rise buildings, and the development of vertical land use. The length of the road that uses asphalt (X10) with mitigation efforts is the form of adding pedestrian lanes.

1. Introduction

Global Warming is a form of imbalance of ecosystems on Earth due to the process of increasing the average temperature of the atmosphere. Global warming causes an increase in the average temperature on Earth by 1°C by 2025 [1]. Climate change is a result of global warming that is global is a climate change that is influenced by various activities carried out by humans, causing changes in the composition of the atmosphere worldwide. Another influence caused by climate change is the occurrence of observed climate patterns in addition to changes in scientific climate variability that are observed in time brackets that can be compared in the years before and after [2]. Human activities can increase global temperatures such as land use changes caused by urbanization factors.

Environmental changes caused by urbanization activities are the increase in CO_2 pollution production, physical properties of the atmosphere, chemical properties of the atmosphere, and environmental changes that can have a significant effect on weather and climate change [3]. This effect is a major problem in every developing city in the world against global warming [2]. Various aspects of human life can affect the environment and human activities in it. Environmental changes that occur result in disturbances in the form of ecosystem imbalances, causing environmental components to be reduced in function [4]. The impact of environmental changes in an ecosystem is generally not the same, but it greatly affects human life which in the end humans have to shoulder and overcome. The process of urbanization is one of the various activities carried out by humans that can cause changes in the function of the environment [5].

Land conversion can result in the reflection of sunlight that reaches the earth's surface, causing temperatures to cool and global warming. Land conversion is based on climate change such as changes in temperature, solar radiation, wind speed, and clouds [6]. Different temperatures occur in dense areas with suburban areas. generally dominated by plants, resulting in the phenomenon of Urban Heat Island [7] The UHI phenomenon is a phenomenon where the temperature that occurs in the city center is higher than the temperature that occurs on the edge of the city. The phenomenon of Urban Heat Island is caused by the clearing of built-up land and the use of materials that incorrectly cause heat to be accommodated, other human activities such as vehicles can make the reflected solar radiant heat trapped so that it causes heat somewhere [8]. This indicates that the temperature

*Corresponding author: rosmini.maru@unm.ac.id

in an area will increase along with the area of vegetation [9].

2 Research Methods

This research uses a qualitative descriptive analysis approach and then combined it with quantitative data in the form of numbers to describe the information obtained related to the urban heat island phenomenon in the CBD area of Makassar City. the free variables in this study are Electricity use (X1), Residential CO_2 emissions (X2), Trade and Services CO_2 emissions (X3), Office CO_2 emissions (X4), Road Transport CO_2 emissions (X5), RTH Percentage (X6), Residential Land Area (X7), Trade and Services Land Area (X8), Office Area (X9), Road Transportation Area (X10).

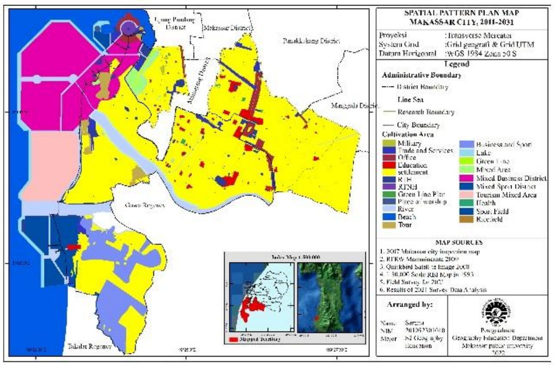

Fig. 1. Study Area**,** Primary data analysis, 2022.

3 Result and Discussion

The method used to determine the influence of the urban heat island phenomenon was carried out linear regression analysis test and to determine the surface temperature distribution using Landsat 8 TIRS OLI with image processing.

3.1 Linear Regression Analysis Test

The equations obtained from the analysis of multiple linear Regression are:

Y=30,072 + 0, 000 X5 + 0.352 X6 - 0.093 X10

Based on the results of a stepwise multiple linear regression analysis, three variables that have a significant effect with a constant temperature value of 30.072ºC were found with the influential variables being X5 (Transportation Emissions), X6 (Residential Land Area), X7 (Office Land Area), X10 (Road Length using Asphalt). Nevertheless according to [10] although from the results of data analysis produced in the ANOVA table, significant values were found, in the T-Test, no data significance was found.

3.1.1 Transportation CO_2 Emissions

According to [11] the contribution of exhaust gas, especially in large cities, reached 60-70%. With the increase in the number of vehicles, the demand for fossil fuels, both diesel and gasoline, will increase. Currently, efforts made by the government to reduce the use of taxis and city buses. Currently, the government is promoting MAMMINASATA buses to reduce air pollution due to vehicle exhaust gases, but the use of motorized vehicles and private vehicles is still very high, especially in city centers, increasing the density of the number of vehicles during working hours and commuting hours. Emissions of transportation activities are obtained from each road section in the study area, These emissions are emissions from transportation activities as a result of burning from fossils emitted by vehicles. Scattered emissions are CO_2 emissions, emissions that can generate heat from transportation activities. Transportation activities are the largest contributor to emissions in the CBD area. When viewed from Table 1 the average CO_2 emission is 35,045.72 tons/year, the minimum value is 0.00 tons/year and the maximum value is 98,798 tons/year.

Table 1. Descriptive Statistics of CO_2 Emissions of Transportation

Descriptive Statistics						
	N	**Min**	**Max**	**Mean**		**Std. Dev**
	Stat	Stat	Stat	Stat	Std. Error	Stat
X5	43	0	98798	35045.72	4683.307	30710.496
Valid N	43					

To handle CO_2 emissions can be:

- The government should promote promotion to replace cleaner fuels and environmentally friendly vehicles.
- Encourage the development of the "Bike and Ride" program in cycling.
- Determine the price of parking tickets for the CBD area.
- Progressive tax increases for people who own more than one vehicle.
- Encourage Car Free Days activities.
- Using environmentally friendly energy by replacing street lights with solar energy sources or better known as solar panels.

3.1.2 Emission CO_2 s of Settlements

The dense residential conditions in the Makassar City CBD area contribute greatly to CO_2 emissions from household activities. Emissions generated from household activities consist of the use of fossil fuels such as LPG gas and are the largest contributors to emissions in settlement activities. For emission efficiency, it can be done with the use of wood stoves in the household [8].

In addition, to reduce emissions, the concept of Urban Farming can be offered, where the concept of urban farming is to utilize sleeping land in urban areas that are converted into green productive agricultural land [12]. The area of residential land in the CBD area is the largest land use area. The blue land use conditions show that in the area there is no land use in the form of settlements of 21443.16 m^2, with a maximum value of 95943 m^2 and a minimum value is 0.00 m^2.

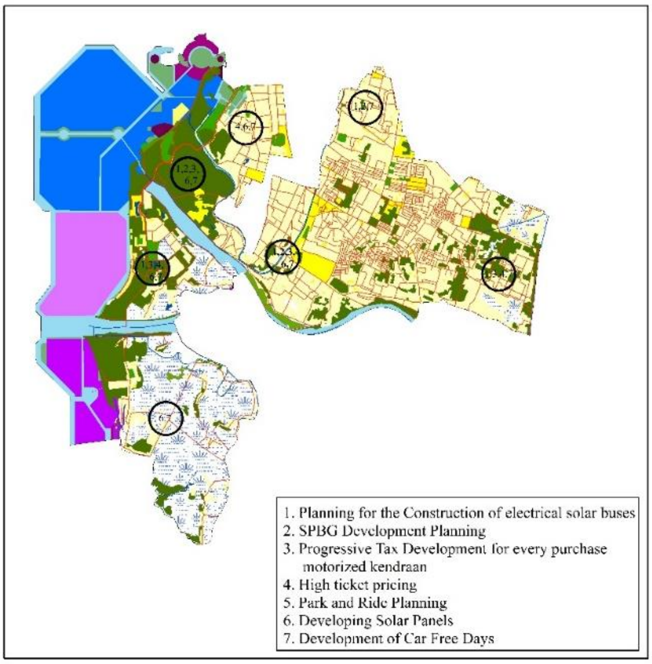

Fig. 2 Mitigation Area Plan to Reduce the Impact of Transportation CO_2 Emissions, Primary data analysis, 2022.

Table 2. Descriptive Statistics of CO_2 Emissions of Settlements

Descriptive Statistics						
	N	**Min**	**Max**	**Mean**		**Std. Dev**
X2	43	0	8166	2389.0 2	518.41 5	3399.474
Valid N	43					

In urban management related to efforts to reduce CO_2 emissions settlements can be done in the following ways:

- The government must implement Green Building in the process of issuing IMB.
- Improving the design of the building by enabling the use of LED lights.
- Applying the concept of Biopores to dense settlements.
- Application of the concept of Urban Farming to reduce heat.
- Increasing LPG usage

3.1.3 Trade and Services CO_2 emissions

Trade and services CO_2 emissions in increased surface temperatures. Land use in the form of trade and services is becoming more dominant in the CBD area. Pollutants from this activity are produced by machines or tools that produce heat that move in the food sector. Diverse industrial activities and a high concentration of population in an area will result in the UHI

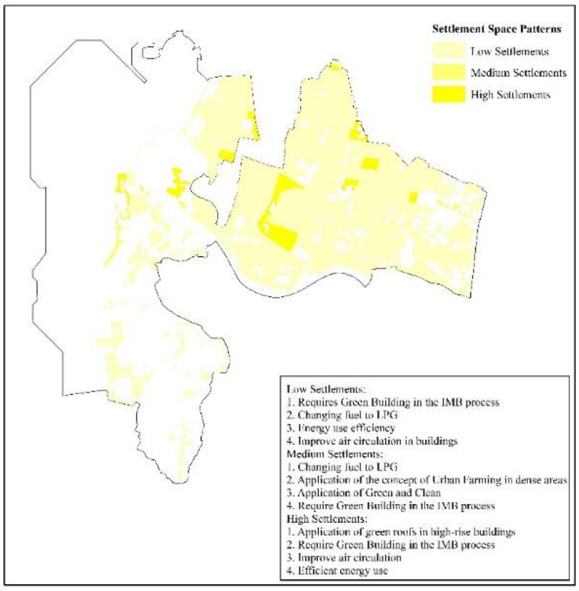

Fig. 3 Mitigation Area Plan to Reduce the Impact of Settlement CO_2 Emissions, Primary data analysis, 2022.

phenomenon. Reducing the impact resulting from industrial and trade activities can be done by applying high-rise buildings [13].

Green buildings can be applied with land use efficiency, water saving, and indoor air management. The area of trade and service land is the second largest land use area after settlements. Land use conditions in blue indicate that there is no land use in the area in the form of trade and services. The average area of trade and services in the CBD area is 722.77 m^2 with the maximum value being 18,856 m^2 and the minimum value being 0.00 m^2.

Table 3. Trade and Services CO_2 Emissions Descriptive Statistics

Descriptive Statistics					
	N	**Min**	**Max**	**Mean**	**Std. Dev**
X3	43	0	2111	76.67	359.870
Valid N	43				

In city management related to efforts to reduce CO_2 emissions trade and services can be done in the following ways:

- Application of green roofs and green walls in high-rise buildings. Vegetation plants can make buildings more comfortable because heat will be absorbed by the vegetation.
- Application of IMB regulations for environmentally friendly buildings

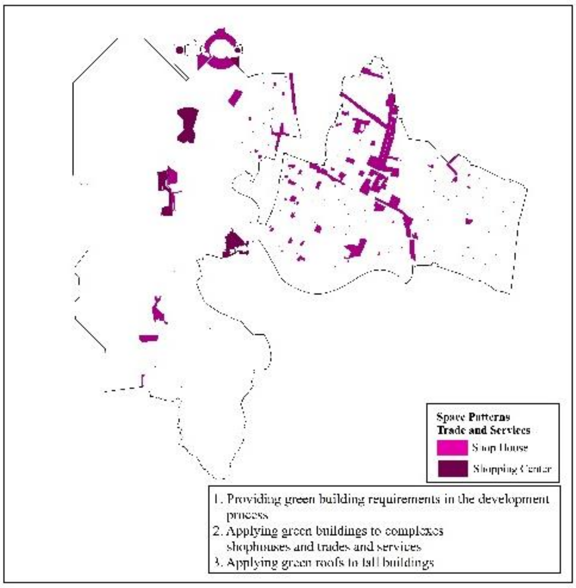

Fig.4 Mitigation Area Plan to Reduce the Impact of Trade and Services CO_2 Emissions, Primary data analysis, 2022.

Energy savings can be made by improving the efficiency of more efficient equipment as well as energy management. The things that can be done are replacing part or all of the energy equipment with more efficient energy equipment that can reduce energy consumption such as replacing old and energy-intensive equipment with more efficient ones and processing on the energy user side (Demand Side Management) which is more energy efficient.

In addition, biomass is alternative energy in reducing CO_2 emissions on the earth's surface and in the atmosphere. according to [14] about biomass, although biomass has a high carbon content, because of the zinc from trees that can reabsorb CO2, the emissions produced from the biomass will be reabsorbed so that the emissions are considered zero. Zinc is an absorber of CO_2 emissions during the growth period of 0-12 years, so to create zinc in old trees, tree cutting is carried out to create zinc. The use of low-carbon technologies as a substitute for fossil fuel PLT can reduce the release of greenhouse gases into the atmosphere

Regional regulation number 4 of 2015 concerning the Makassar City RTRW of 2015-2034, is defined as systematic and comprehensive spatial planning issued by official bodies whose planning boundaries are administrative boundaries. This instrument is used as a reference point in the development of Makassar City. The development of Makassar City is expected to be able to have a good impact on the environment with the application of AMDAL [15]. According to research conducted [8] that the RTH in Makassar City until 2017 reached 8.31%. At the end of 2018, it reached 13% while at the end of 2020, it was up to 11%. The data above shows that Makassar City has not yet reached the provisions for meeting the RTH needs of at least 20% of the total area. The government's efforts to fulfill the RTH by building city parks in the corners of the city such as the construction of Pakui Sayang Park in Rappocini district.

Fig.5 Green Building in the Fort Rotterdam area to Mitigate Surface Temperature Rise, Primary data, Primary data analysis, 2022

Fig.6 The application of green open space in the Tanjung Bunga area to improve city parks to increase carbon dioxide emission sequestration, Primary data analysis, 2022.

4 Conclusion

The highest temperature in Makassar City is found in the strategic business district of the city center and its surroundings set in a part of the coastal development area of Tamalate District, part of Mariso District, and part of Rappocini District. The highest temperature is in a densely populated area with high residential areas, as well as offices with temperatures reaching 33.6^{o}C. Meanwhile, the coldest temperatures are found in areas that have green open space, and the Jene'berang river flow. The existence of Green Open Space and river flows can reduce colder temperatures ranging from 1.05 – 2.2^{o}C.

From the results of the multiple linear regression analysis, four variables were obtained that have a strong influence on the increase in UHI on the surface in the CBD area, namely Transportation Emissions [X5] with mitigation efforts in the form of encouraging bike and ride activities, encouraging car-free days activities, and building fast public mass transportation. Residential Land Area [X6] with mitigation efforts in the form of applying the concept of Green and Clean, Urban Farming based on organic plants, High and Rise

Buildings in IMB. Office Area [X2] with mitigation efforts in the form of applying the concept of Green and Clean, Urban Farming based on organic plants, High and Rise buildings, and vertical land use development. The length of the road that uses asphalt [X10] with mitigation efforts in the form of increasing pedestrian lanes that have been provided to reduce CO_2 emissions in the CBD area of Makassar City. Socialization of urban development design to all stakeholders in formulating programs based on environmentally friendly communities

References

1. Voogt JA, Oke TR. *Thermal remote sensing of urban climates*. Remote Sensing Environmental. 2003;86(**3**):370–84.
2. Maru R, Baharuddin II, Umar R, Rasyid R, Uca, Sanusi W, et al. *Analysis of the heat island phenomenon in Makassar, South Sulawesi, Indonesia.* Sci. 2015;12(**9**):616–26.
3. Maru R. *Urban Heat Island dan Upaya Penangananya*. Prosiding Seminar Nasiobal Mikrobiology Kesehatan dan Lingkungan. 2015;2011:84–94.
4. Kurnianti R. *Ketersediaan Ruang Terbuka Hijau Dan Urban Heat Island Di Kota Makassar*. Media Penelitian dan Pengembangan. 2019;**3**(2):14.
5. Fawzi NI. *Measuring Urban Heat Island using Remote Sensing , Case of Yogyakarta City*. Vol. 19, Majalah Ilmiah Globe. 2017. 195–206 p.
6. Cao X, Onishi A, Chen J, Imura H. *Quantifying the cool island intensity of urban parks using ASTER and IKONOS data.* Landscape Urban Planning. 2010;**96**(4):224–31.
7. Nofrizal AY. *Identifikasi Urban Heat Island di Kota Solok menggunakan Algoritma Landsat-8 OLI Landsurface Temperature*. Media Komunitas Geografi. 2018;**19**(1):31.
8. Sultana S, Satyanarayana ANV. *Assessment of urbanization and urban heat island intensities using Landsat imageries during 2000 – 2018 over a sub-tropical Indian City*. Sustainable Cities Social. 2020;**52**:101846.
9. Jr RCB, Brazel SW. *Time and Space Characteristics of the Phoenix Urban Heat Island. J Arizona-Nevada Acad Sci*. 1987;21(2):75–81.
10. Stewart ID, Oke TR, Bechtel B, Foley MM, Mills G, Ching J, et al. *Generating WUDAPT's Specific Scale-dependent Urban Modeling and Activity Parameters: Collection of Level 1 and Level 2 Data*. ICUC9, Toulouse.
11. Cayan DR, Douglas A V. *Urban influences on surface temperatures in the southwestern United States during recent decades*. Vol. 23, Journal of Climate & Applied Meteorology. 1984. p. 1520–30.
12. Short CA. *Urban heat islands*. Recover Nat Environmental Architecture. 2021;140–77.
13. Peng S, Piao S, Ciais P, Friedlingstein P, Ottle C, Bréon FM, et al. *Surface urban heat island across 419 global big cities*. Environmental Science Technology. 2012;46(**2**):696–703.
14. Susilawati SA, Anwar BS. *Pengenalan Urban Heat Island Pada Peserta Didik Sebagai Upaya Mitigasi Bencana Klimatologis di Kota Surakarta*. UMS 2016.
15. Goward SN. *Thermal behavior of urban landscapes and the urban heat island*. Physical Geography. 1981;2(**1**):19–33.