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Impact of Land Use on Urban Heat Island Phenomenon: A Spatial Analysis of Pare-pare City, South Sulawesi

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ABSTRACT

Urban Heat Island is a phenomenon where surface temperatures are higher in urban areas than in rural areas. One of the cities that experienced this phenomenon was the city of Pare-pare, which was caused by the conversion of vegetation land into settlements due to rapid population growth. This study aims to determine the influence of land use on the Urban Heat Island phenomenon in Pare-pare City. The methods used include spatial analysis and descriptive analysis, secondary data collection in the study was obtained from the Indonesian Geospatial portal and Google Earth Engine and using ArcGis 10.8 software in conducting spatial analysis. The results of the analysis show that there are relationships such as Soreang, Ujung, West Bacukiki and also the north of Bacukiki District which experiences the Urban Heat Island phenomenon due to dense settlements and many road networks. Areas with land cover in the form of settlements and roads have higher surface temperatures than areas with high land cover in the form of vegetation such as the southeastern part of Bakkiki District. The impact of Urban Heat Island is that it causes a decrease in air quality and excessive energy use. The recommended mitigation is the implementation of environmentally friendly infrastructure such as greening around buildings, green roofs, and small parks. The results of this study can be used as useful information for the government in making sustainable spatial planning policies and to evaluate development to reduce the impact of Urban Heat Island.

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1. INTRODUCTION

The ongoing climate change phenomenon, accompanied by an increase in the earth's surface temperature, has become one of the most prominent and pressing environmental issues today, especially in urban areas throughout the world (Samsu, 2019; Nur et al, 2024; Utami et al, 2024; Maru and Ahmad, 2014; Maru et al, 2024; Nasrul et al, 2024). This increase in surface temperature did not occur suddenly, but is the result of a series of interrelated factors and is increasingly exacerbated by human activities. Several main factors that play a major role in driving temperature increases include increased human activity in land conversion, green and natural areas being converted into housing and infrastructure to support the needs of urban residents (Angkasa et al., 2023; Rusdi et al, 2023; Maru et al. , 2015).One real manifestation of this phenomenon is the striking temperature difference between the city center, which is dense with human activity, and the outskirts which are more open and green, a phenomenon known as an Urban Heat Island or UHI (Darlina et al., 2018; Akbari and Kolokotsa, 2016). This Urban Heat Island not only affects

physical environmental conditions in urban areas but also has a significant impact on human health, increasing the risk of health problems associated with high temperatures, as well as influencing energy use patterns, such as higher air conditioning requirements, especially in cities. Cities like Pare-pare have felt the impact of this phenomenon (Angkasa et al., 2023)

Pare-pare City, known as one of the smallest cities in South Sulawesi Province, has recorded significant demographic developments and land use changes in the last few decades. Based on data compiled by the Central Statistics Agency in 2021, Pare-pare City has a population of 152,922 people, with a fairly high population density, reaching 160,309 people per square kilometer, over an area of around 99.3 km². Along with the rapid increase in population and the inevitable process of urbanization, Pare-pare City has experienced a significant decline in the area of vegetation, which is increasingly being converted into settlement areas to accommodate residential and urban infrastructure needs.

Research conducted by Ahmad (2021) revealed a trend of decreasing vegetation area that occurred consistently from year to year, wherein 1990, the vegetation area was still recorded at 7,706.25 hectares, but then shrank to 7,301.19 hectares in 2000, reduced again to 7,070.78 hectares in 2010, and continued to decline until only 6,945.25 hectares remained in 2019. This decrease in vegetation area has had a significant impact on changes in land cover in Pare-pare City, where the area was previously dominated by forest Forest areas have been converted into agricultural land, and even existing agricultural land has not been spared from being converted into settlement areas, as explained by Indrawati Dewi (2020). This phenomenon reflects how rapidly environmental changes are occurring in this city, triggered by the pressure of urbanization and ever-increasing population growth.

The decrease in vegetation that occurs in an area not only results in the loss of green space but also contributes directly to an increase in surface temperature, which then affects the microclimate of the area (Angkasa et al., 2023; Arfandi et al., 2024). A similar thing was revealed in Hernawati's (2018) research, the decrease in the amount of vegetation had a significant effect on changes in surface temperature in Pare-pare City. The increase in temperature which occurs along with the reduction in vegetation area has triggered the Urban Heat Island (UHI) phenomenon in various points in Parepare City. Vegetation is one of the elements that influences the air around it, the more vegetation on a land, the lower the surface temperature around the land and the less vegetation there is on a land, due to factors changing the function of land to housing or other purposes, the higher the surface temperature on that land (Hernawati, R., & Darmawan, S. 2018). Based on these problems, researchers feel it is very important to carry out scientific evidence through analysis of the development of the Urban Heat Island (UHI) using spatial analysis methods which aim to see the increase in surface temperature in Pare Pare City during the period 2013 to 2019.

Referring to the description above, it is very important to carry out research aimed at understanding in depth how land use in Pare-pare City influences the urban heat island phenomenon. The comparative parameters that influence the urban heat island are land use in the form of settlements, vegetation and roads in 2019. Each parameter has a different albedo value or heat absorption value, thus influencing the surrounding surface temperature (Almeida et al., 2021). This research provides clearer insight into the relationship between land use and temperature rise in cities, and information for the development of sustainable spatial planning policies for evaluating regional development in order to reduce temperature rise (Hidayah, 2018).

2. METHOD

Data collection in this research was carried out in a location geographically located in Pare-pare City, a city in South Sulawesi Province. The city of Pare-pare is located at geographic coordinates between 3° 57' 39" to 4° 04' 49" South Latitude and 119° 36' 24" to 119° 43' 40" East Longitude, which shows its strategic position on the map of the region. This city has an area of around 99.33 km², which is divided administratively into four sub- districts, namely Bacukiki, West Bacukiki, Ujung, and Soreang. Each of these sub-districts has different geographic, demographic, and land use characteristics, which provide important variations in the context of this research.

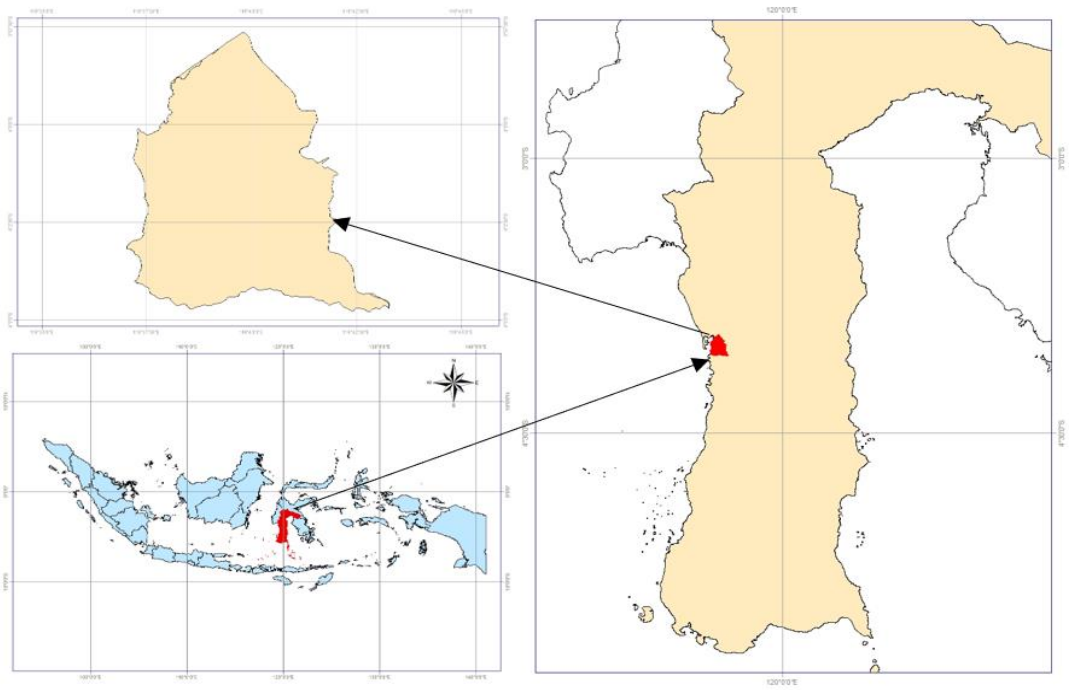

Figure 1. Administration Map of Pare-pare City.

This research utilizes a combination of spasial analysis methods and descriptive analysis in the data processing and analysis process to achieve research objectives. The spasial analysis method is used to integrate various data using ArcGIS 10.8 software (Darmawan, 2017), where this process involves combining or overlapping two or more different parameters, such as land use maps, administrative boundaries, and land surface temperature maps. (land surface temperature). This process allows mapping the relationships and interactions between these parameters visually and spatially. In addition, descriptive analysis methods were applied to analyze and assess maps, land use patterns, and the development of the Urban Heat Island (UHI) phenomenon that occurred in the area studied (Hikmah, 2022). To support this analysis, this study uses Modis11A2 Satellite Image Acquisition data. V6.1 Terra Land Surface Temperature and Emissivity 8-Day Global 1km to obtain land surface temperature information via the Google Earth platform Engine , as well as data from the City of Pare-pare to obtain land surface temperature information via the Google Earth platform. Engine . information about administrative limitation And land use in the That city. With Through this approach, it is hoped that a deeper understanding can be obtained about the dynamics of surface temperature and its impact on land use patterns in Pare-pare City.

Table 1. Research Data

Data	Year	Data Types	Map Source
Settlement Distribution Map	2019	Secondary	Indonesia Geospatial Portal
Vegetation Distribution Map	2019	Secondary	Indonesia Geospatial Portal
Road Network Map	2019	Secondary	Indonesia Geospatial Portal
Land Use Map	2019	Secondary	Indonesia Geospatial Portal
Surface Map Temperature	2013 & 2019	Secondary	Fashion Image11A2 V6.1 (Google Earth Engine).

In this research, there are three main types of variables used, namely settlement, vegetation, and road network, each of which is presented in mapping form to simplify analysis. These variables are integrated in the map to provide a comprehensive picture of the various aspects studied. For further information regarding the variables used and how each variable was identified and mapped, see Table 2 below.

Table 2. Research Variabel

No	Variabel	Albedo
1.	Settlement	8-18%
2.	Vegetation	10-30%
3.	Road network	5-10%

Source: Miswanto, 2022

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Analysis of Pare-pare City Land Use

In Figure 2 above, it can be observed that the settlements distribution pattern in Pare- pare City shows a clear concentration in three main sub-districts, namely Soreang District, West Bacukiki District, and Ujung District, with most of the settlements focused in the western part of the city. In contrast, in Bacukiki District, the distribution of settlements does not show a concentrated concentration at one point, but is spread more evenly throughout the sub-district area. This illustrates the differences in settlement patterns between one sub-district and another in the city.

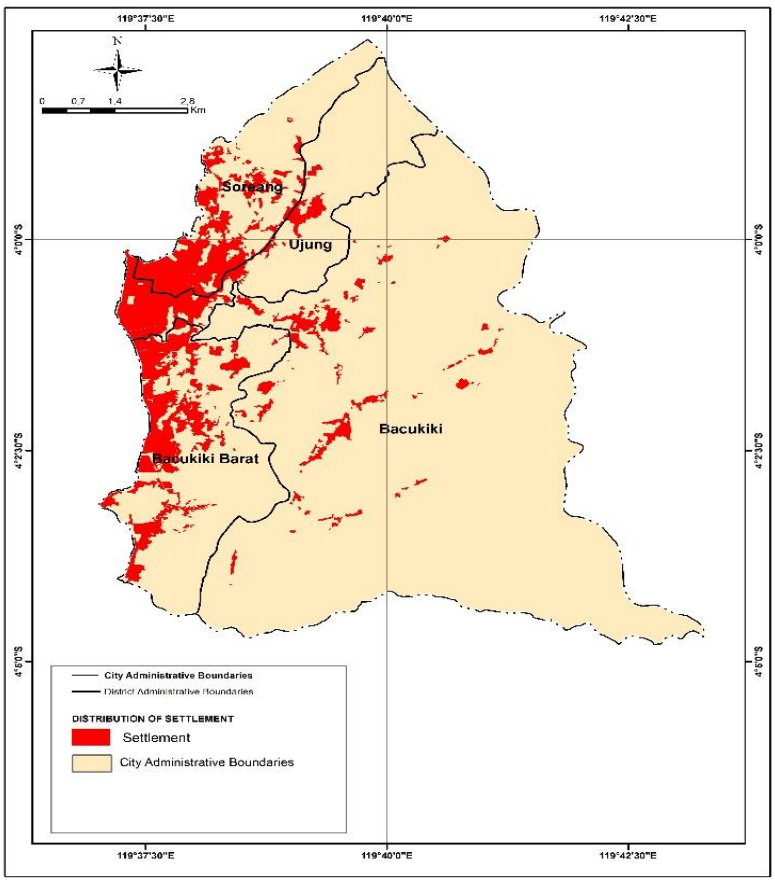

Figure 2. Map of the distribution of Pare-pare city settlements in 2019

In Figure 2 above, it can be observed that the settlements distribution pattern in Pare- pare City shows a clear concentration in three main sub-districts, namely Soreang District, West Bacukiki District, and Ujung District, with most of the settlements focused in the western part of the city. In contrast, in Bacukiki District, the distribution of settlements does not show a concentrated concentration at one point, but is spread more evenly throughout the sub-district area. This illustrates the differences in settlement patterns between one sub-district and another in the city.

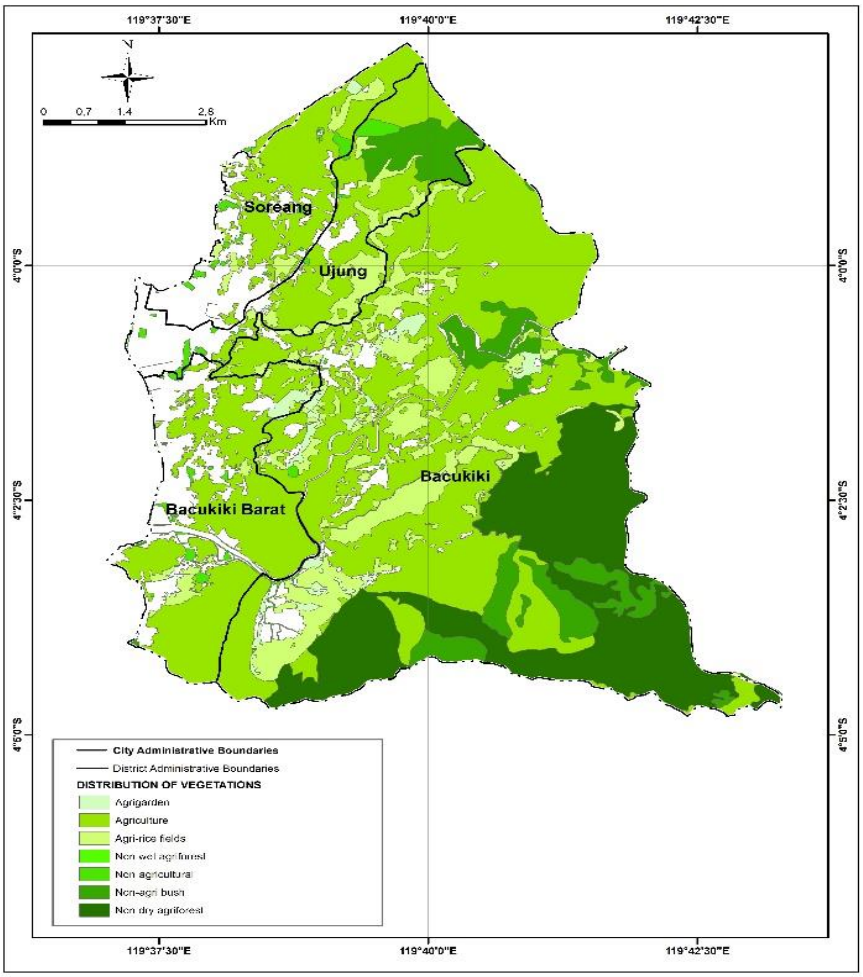

Figure 3. Pare-pare City Vegetation Distribution Map in 2019

In the image show above it can be seen that the distribution of vegetation in Pare- pare City shows significant changes, where land that was previously vegetation has been converted into settlement land in settlement areas. This can be seen clearly on the map, where areas that are not marked on the map indicate areas that have changed their function to become settlement areas. Meanwhile, in the southern part of Pare-pare City, the map shows that there are no settlements at all, and the entire area in the southern part of the city is still dominated by vegetation. In other words, the map shows that land use in the south of Pare-pare City consists mainly of vegetation, while settlement areas are concentrated in other parts of the city

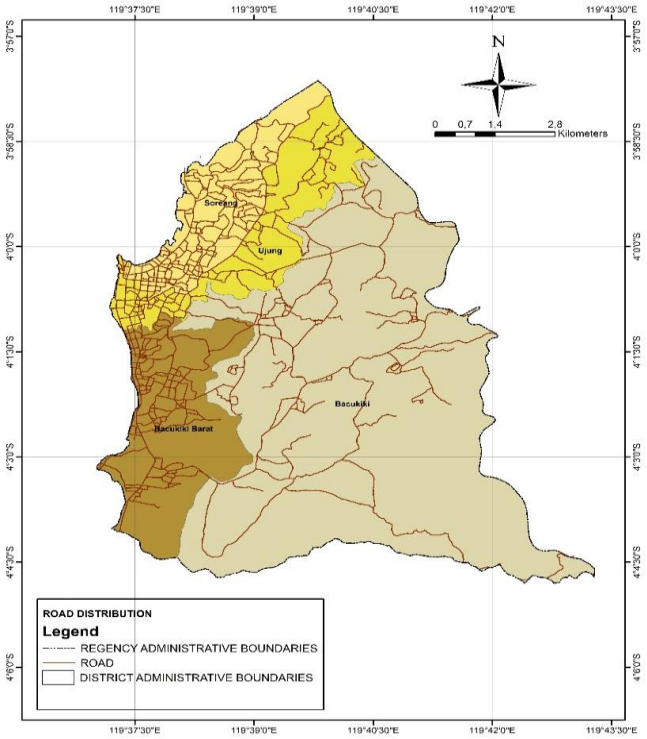

Figure 4. Pare-pare City Road Network Map in 2019

In the image shown above, it can be observed that the road network in Pare-pare City is centered in several main sub-districts, namely Soreang District, West Bacukiki, and Ujung District, all of which are located in the western part of the city. The distribution pattern of the road network shows that the road infrastructure in Pare-pare City is designed in such a way that it connects various areas effectively. The existing road network not only connects the sub-districts mentioned, but also ensures that the four sub-districts in Pare-pare City—including those not specifically mentioned—have an integrated road network system. This underlines the existence of comprehensive planning in the development of road infrastructure, which aims to facilitate access and connectivity between areas throughout the city.

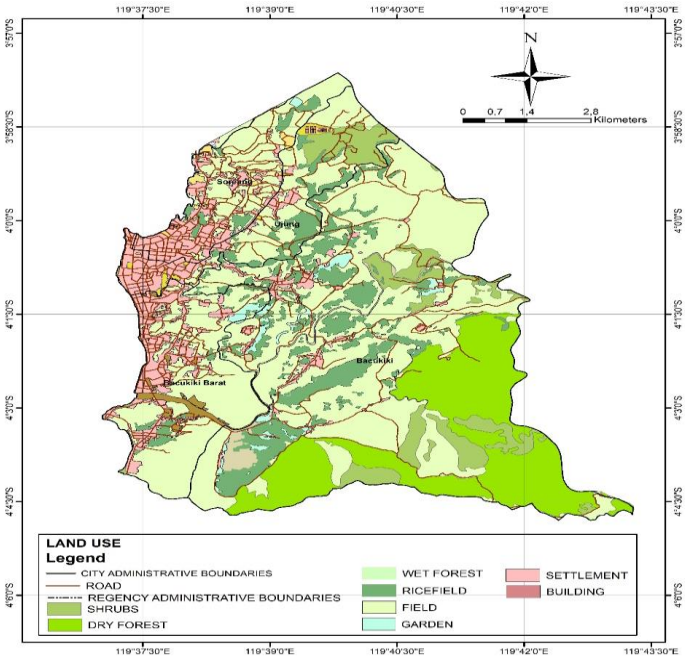

Figure 5. Pare-pare City Land Use Map

The image above is a map of landuse in Pare-pare City in 2019 obtained from the Indonesia Geospatial Portal. Land use is a research variable to measure the spread of urban heat islands with land use as an indicator. Different land uses in an area have different influences as well as their ability to reflect sunlight (Miswanto, 2022). These differences in land use certainly have a big influence on the process of forming and accelerating the urban heat island phenomenon (Rumengan S.H et al., 2019).

Settlement land the city of Pare-pare is centered on Soreang District and West Bacukiki District, then Ujung District which has some land uses in the form of settlements and others in the form of vegetation. Meanwhile, in Bacukiki District, in the map above, the majority of land use is vegetation, settlements in this district tend to be fewer and not only concentrated in one point but spread out. These differences in land use certainly have a big influence on the process of forming and accelerating the urban heat island phenomenon (Rumengan S.H et al., 2019). For example, vegetation, land use in the form of vegetation has benefits in improving the microclimate in urban areas so that land use in the form of vegetation helps in keeping the temperature in an area low (Rawung FC, 2015). On the other hand, settlement areas actually cause land surface temperatures to increase. This is a factor why urban heat islands often occur in densely populated urban areas (Satryo IF, 2021). So that the surface temperature and air temperature in an area are greatly influenced by the type of land cover in that area (Wicaksono et al., 2021).

3.1.2. Analysis of UHI development using land surface temperature (LST) Maps.

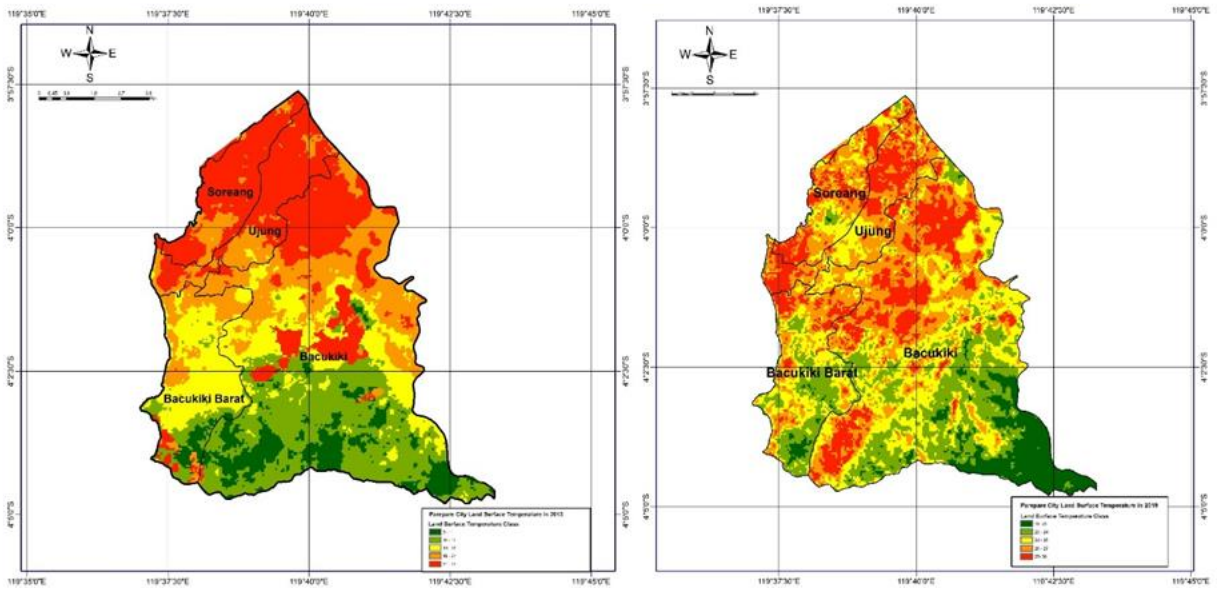

Figure 6. Land Surface Temperature Map of Pare-pare City in 2013 (a) and 2019 (b).

The city of Pare-pare is a city with high and dense activity, so it experiences the urban heat island phenomenon or urban hot temperatures that are higher than the surrounding area (Chairil A, 2023). The population growth rate of Pare-pare city from 2012 to 2021 is 15.8%. In 2013 the population of the city of Pare-pare was 132,048 people, while in 2021 it was 152,922 people. Based on data from the Central Statistics Agency for 2021, this figure is divided into 4 sub-districts, namely Soreang sub-district with the largest population of 46,903 people, followed by West Bacukiki sub-district with 45,197 people, then Ujung sub- district with 33,843 people and Bacukiki sub-district with 25,511 people.

The impact that occurs in densely populated areas will affect the use of land that was previously vegetation to become settlement, thus affecting surface temperatures in the area (Pramitha AF et al., 2023). The land surface temperature comparison map above shows changes in the temperature

distribution in Pare-pare City in 2013 and 2019. In 2013, the highest temperature in Pare-pare City was in the north precisely in Soreng District, Ujung and also part of the north of Bakukiki District. Meanwhile, in the south, precisely in Bacukiki District, the surface temperature is relatively low, which is symbolized by the green symbology. While, on the land surface temperature map in 2019, the temperature distribution of heat is wider than in 2013. The relatively low temperature in 2013 also decreased in 2019. Therefore, it can be concluded that there is an increase in the distribution of high temperatures in Pare-pare City and the southern area namely in Bacukiki District. Pare-pare City which in 2013 had the highest temperature of 21-27 °C, in 2019 the low temperature area decreased drastically, especially in the south of Bacukiki District which is symbolized by yellow, orange to red and low temperatures which are symbolized by green are starting to decrease. In addition, there has also been an increase which initially in 2013 the highest temperature was only in the range of 21-27°C to 27-30°C in 2019. The temperature distribution in the range of 27-30°C is evenly distributed in every sub-district except for Bacukiki District in the southeast which is still symbolized in green.

Measuring the level of urban heat island development is carried out by identifying the LST map above. Land surface temperature (LST) is the temperature recorded by satellite imagery as a result of the temperature radiation of objects on the earth's surface (Astuti Sola, 2021).

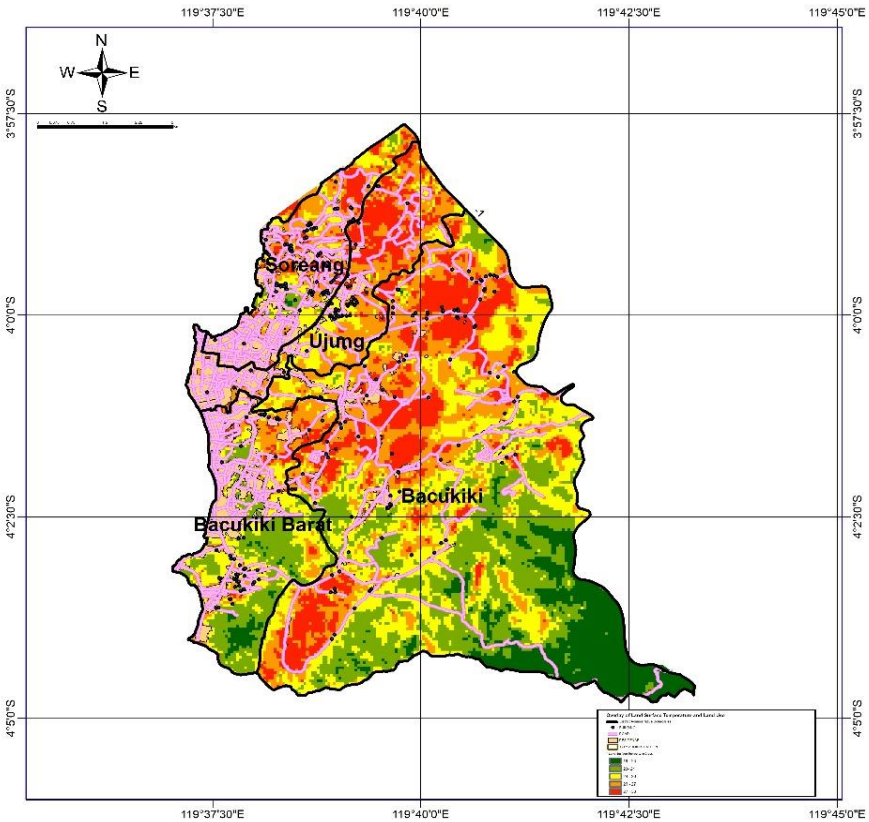

Figure 7. Surface temperature map added with shapefile of road network distribution and land use in the form of settlements

The results of the surface temperature map added with the shapefile of the distribution of the road network and settlements above can be seen that densely populated areas and there are also many asphalt roads have an influence on the surface temperature in the city of Pare-pare which is symbolized by yellow, orange, and red. In the west, north and also in the central part of Pare-pare City, it can be seen that the surface temperature distribution is 27-30°C. Meanwhile, in the southeast of Pare-pare City, which has minimal asphalt roads and there are also no densely populated areas, there is a tendency for temperatures to be lower than other areas. The temperature in the area ranges from 23-24°C and 19-23°C

3.2. Discussion

Changes in land use in a city are inevitable, this is due to the increasing needs of the community. As a result, it causes a decrease in environmental quality such as reduced vegetation (Dewi & Rudiarto, 2014). Pare-pare City is an example of this, Pare-pare City is one of the smallest cities in South Sulawesi province. Based on data from the Central Statistics Agency, the population of Pare-pare reaches 1,540 people/km2, has an area of 99.3 km2, and has a population of 152,992 million people in 2021, while in 2023 the population will increase to 160,309 million people.

This of course has an impact on the reduction of vegetation land, causing surface temperatures in cities to increase due to the change of vegetation land to settlement and road network (Zahrotunisa, et al., 2020). Lower vegetation areas in an area can cause an increase in surface temperature (Astuti Sola, 2021). This is because in areas that have vegetation that is still maintained and spacious, it can make the surface temperature more stable so that it can prevent urban heat islands (Putra Muhammad, 2018). In addition, another factor that can also cause surface temperatures to increase is the addition of urban facilities such as buildings, roads, and settlements. Facilities in this area allow an increase in temperature so that microclimatic conditions are created, especially in the area (Nugraha & Atmaja, 2020). The conversion of land from the initial vegetation to settlement areas and roads can affect the albedo value (Ferdiansyah E, 2022). The albedo value at the surface determines the urban heat island phenomenon in the city. The albedo value for settlement land use ranges from 8-18%, vegetation 10-30%, and road networks in the form of asphalt 5-10% (Miswanto E, 2022).

This series of events is the process of a phenomenon called Urban Heat Island (UHI). The Urban Heat Island phenomenon is a difference in temperature in urban areas compared to surrounding areas and even rural areas (Kontryana Afrilyani, 2021). Urban Heat Island will have a higher value in an urban area if the urban area has a high building density and also a low vegetation density (Mubarok Rizal et al., 2021). The quality of life of the community will decrease in the areas affected by Urban Heat Island (Mubarok Rizal et al., 2021). The decline in people's quality of life can be in the form of pollutant concentration, human health, and global warming (Pratiwi & Jaelani, 2020).

The increase in land cover in the form of settlement areas affects the density of urban vegetation, resulting in land conversion, and the reduction of green open space, creating a regional spatial pattern that will significantly affect the increase in urban temperature, thereby triggering the occurrence of urban heat islands (Akbari & Kolotsa, 2016). In addition, land cover in the form of asphalt also greatly affects surface temperature, because asphalt absorbs more than other light-colored surfaces (Voogt, 2014 in Astuti Sola, 2021). This is in line with Samsuddin's (2017) statement that the darker the color on a surface, the more heat is trapped.

4. CONCLUSIONS

Based on the results of the research and analysis that has been carried out, it can be concluded that there is a strong relationship between the distribution of urban hot islands and land use. A high population will require facilities and infrastructure so it is necessary to change land from vegetation land to settlement land. This shift in land use will increase surface temperatures. Converted settlement land such as buildings and roads have a higher surface temperature than areas with land cover in the form of vegetation.

This is evidenced based on the results of the analysis of surface temperature maps and land use maps that there is a relationship between the land use settlement and the emergence of urban heat island, for example in settlement areas to the west of the city of Pare-pare which include Soreang, Ujung and West Bacukiki Districts and the northern part of Bacukiki District which experiences the phenomenon of urban heat island as evidenced by the symbolization of red (27-30°C) and orange (26-27°C). Meanwhile, in the southeastern part of Pare-pare City, Bacukiki District, which has a good vegetation density, the soil surface temperature map shows a symbol of green (19-23°C) and yellow (23-24°C) which is a different temperature from that in densely populated areas and road networks in the west because it is influenced by vegetation factors.

Reduced vegetation due to land conversion affects the increase in urban temperature significantly, thereby triggering the occurrence of urban heat islands. In addition, land cover in the

form of asphalt and settlements also greatly affects surface temperature, because the land cover has a low albedo value compared to vegetation. The difference in albedo values emphasizes the importance of the existence of vegetation in urban areas in order to reduce the impact of the urban heat island phenomenon.

Based on the research conducted, it is recommended for further research so that it is necessary to conduct more in-depth research related to the causes of the urban heat island phenomenon such as the influence of climate or other factors. In addition, it is also recommended to use cloud-free satellite imagery because it can affect the analysis results on the surface temperature map.

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