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Risk Burden of Heat-Related Morbidity Due to Urban Heat Island Effect in Tamalanrea District, Makassar

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ABSTRACT
One of the problems in the urban environment is the rise in land surface temperature and heat buildup (Urban Heat Island) around built-up areas. People living in UHI areas will experience an increased risk of health burdens. Therefore, early identification for disaster mitigation is needed to achieve a sustainable city. This study aims to provide an overview of the risk of the spread of heat-related diseases based on the relative risk value in Tamalanrea District. This study considers the relationship between Land Surface Temperature (LST) values in 2019, 2020, and 2021 with the incidence of heat-related diseases obtained from the Integrated Health Center Recording and Reporting System (IHCRRS) in Tamalanrea District, Makassar City in 2019, 2020 and 2021. Data analysis used Pearson correlation test and Standardized Morbidity Ratio (SMR) epidemiological approach. The results showed a significant relationship between LST values and the incidence of hypertension, heart disease, and asthma in 2019 and the incidence of headache and hypertension in 2021. Bira and Kapasa sub-districts were at the highest risk for the spread of heat-related diseases than other sub-districts with a risk score > 4.00 (very high). These findings can be used to help guide public health interventions and preventive urban planning efforts.

INTRODUCTION

One of the problems in urban environments is the increase in surface temperature around built-up areas. Urban materials such as building facades, roads, and other paved areas will absorb and store more heat and cause changes in thermal comfort conditions.[1] Changes in land cover will change the reflectance process of solar radiation on the earth's surface and cause global warming.[2] Global warming can accelerate and bring a series of disasters to urban communities.[3] The impact of global warming combined with the Urban Heat Island (UHI) effect adversely affects the health and well-being of urban residents.[4] UHI is a condition where the area has a warmer temperature than the surrounding area, due to the concentration of built-up land in certain locations.[5] People living in areas affected by UHI effects are at increased risk to health. UHI can contribute to thermal discomfort and various forms of morbidity and mortality.[1]

In 2019, high temperature was first listed as a risk factor by the Global Burden of Disease.[6] This happens because increasing temperatures can affect human physiological conditions and make the body more vulnerable to heat exposure.[5] The symptoms of heat-related diseases correlate with surface temperature patterns in urban environments.[7] Indicating that the value of LST or ground surface temperature can be an indicator of heat risk events.

Based on the results of Liong (2021), there was an increase in the average LST value in Makassar City by 0.39°C in the temperature range between 30-32°C.[8] In addition, the level of comfort in Makassar City has decreased due to high temperatures. This is evidenced by the recording data by the climatology station the temperature of Makassar City in 2019 was recorded at 38,2°C the highest temperature during the BMKG observation year.[9] When heat exposure becomes more frequent, it will adversely affect the comfort and health of urban residents of Makassar City and risk becoming a burden of morbidity. Compared to mortality, morbidity is considered to cover a wide range of health events and is more suitable for assessing the effects of temperature exposure on health.[10]

The relationship between temperature and mortality has been studied extensively in many studies, but its effect on morbidity has received less attention.[12]

Law No. 16/2016 on the Ratification of the Paris Agreement to the United Nations Framework Convention on Climate Change stipulates to hold the global average temperature rise below 2°C above pre-industrialization levels and to continue efforts to reduce the temperature rise to 1.5°C above pre-industrialization levels. This is a wake-up call about the risks that heat poses to urban communities.[11]

Indirectly, climate change and heat can exacerbate all causes and morbidity of certain diseases through reduced physical health. Heat will lead to heat stress and death in the most severe cases.[12]

One location that has the potential for Urban Heat Island effects is Tamalanrea Sub-district. This is due to the location of Tamalanrea Sub-district is an area of concentration and development of various educational activities equipped with other supporting activities. As an education center area, this sub-district experiences impacts due to changes in land cover and function. UHI is one of the urban planning issues that require monitoring as well as specific strategies to reduce its impact.[5]

Therefore, it is important to understand how the UHI phenomenon risks health impacts in Makassar City. This is done as a mitigation effort of the UHI phenomenon, identifying the morbidity risk burden of the UHI phenomenon can reduce the vulnerability of urban communities to rising urban temperatures.

This study aims to analyze the degree of surface temperature change in urban space and the relationship to heat-related diseases and map the areas at risk of morbidity burden due to UHI effects.

MATERIAL AND METHOD

This research is a type of descriptive research through a quantitative approach. The research location was administratively carried out in Tamalanrea District, Makassar City, by taking surface temperature data and morbidity data at the Integrated Recording and Reporting System of Puskesmas (SP2TP) which were scattered based on research criteria. The data collected in this study are LANDSAT 8 OLI/TIRS image data

for 2019, 2020, and 2021. One important parameter in urban climate is Land Surface Temperature (LST), which directly controls the UHI effect.[12] Land surface temperature is a variable that describes thermal conditions that can be retrieved from satellite records.[13]

This study used LANDSAT 8 OLI/TIRS satellite data obtained from Google Earth Engine to obtain LST data in 2019, 2020, and 2021 and morbidity data obtained from the Integrated Health Center Recording and Reporting System (IHCRRS) distributed based on research criteria. Table 1, shows the time of land surface temperature data collection used and Table 2, shows the service area of the Tamalanrea sub-district health center.

Furthermore, a correlation analysis was using SPSS 27 conducted to test whether LST is closely associated with the incidence of morbidity in Tamalanrea Sub-district, Makassar City. The morbidity rate has a more important role than the mortality rate because if the morbidity rate is high, it will trigger death, which automatically causes a high mortality rate. Thus, morbidity can be used to describe the general condition of health.[14]

First, we collected morbidity rates in 2019, 2020, and 2021 at each health center in Tamalanrea sub-district. Then a relative risk epidemiological approach was conducted using the Standardized Morbidity/Mortality Ratio (SMR) method. This approach shows the risk burden of the area affected by the disease. Excess Risk is one of the SMR-based approach models available in the GeoDA tool. Through this tool, a spatial assessment of relative risk value was conducted to measure the morbidity burden caused by the impact of temperature change in Tamalanrea Sub-district, Makassar City. Excess risk/relative risk is a form of standardized morbidity or mortality (SMR) often used in public health approaches that are estimated as the ratio of the sum of all disease events across locations to the total population at risk.[15] The conceptual framework in this study is depicted in the structure in Figure 2.

Table 1. Landsat Data Used

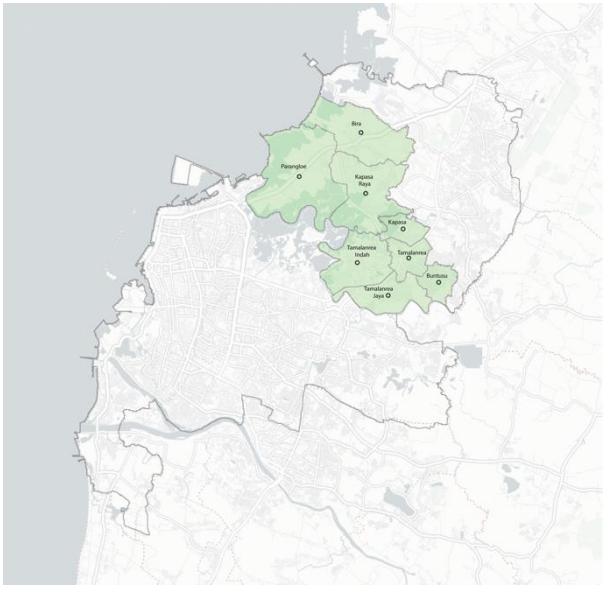
Location	Time	Season
Tamalanrea District	April – October, 2019	Dry Season
	November – December, 2019	Rainy Season
	April – June, 2020	Dry Season
	July – December, 2020	Rainy Season
	June – August, 2021	Dry Season
	September – December, 2021	Rainy Season

Source: Secondary Data of BNPB, 2022

Table 2. Description of Tamalanrea District Health Center Area

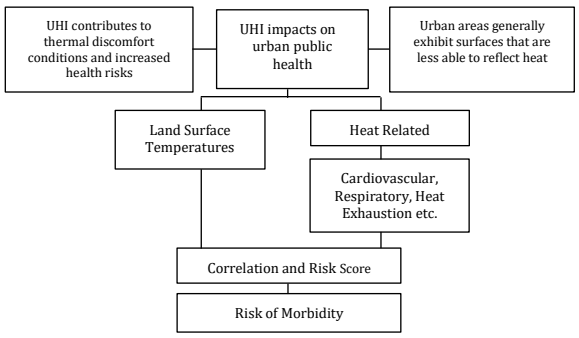
Location	Sub District	Health Center
Tamalanrea District	Tamalanrea Indah	Antara
	Tamalanrea Jaya	Tamalanrea Jaya
	Parangloe and Bira	Bira
	Tamalanrea Kapasa	Tamalanrea Kapasa

Source: Secondary Data of Makassar Health Department, 2021



Source: Primary Data, 2022

Figure 1. Research Sites



Source: Primary Data, 2022

Figure 2. Conceptual Framework

RESULTS

Based on the results of the analysis of land surface temperature measurements in 2019, 2020, and 2021 in the dry season period in Tamalanrea District can be seen in Table 3. The data shows that 2019 is the year with the highest average temperature in the dry season period which is in the temperature range of 28 - 31°C. The highest average temperature is in Parangloe and Tamalanrea sub-districts, which is 31°C for 2019. In 2020, the highest average temperatures were in Buntusu and Tamalanrea sub-districts, which were 25°C. As for 2021, the highest average temperature is in Tamalanrea sub-district, which is 27°C.

The following mapping results of land surface temperature for the dry season period in Tamalanrea Sub-district are shown in figure 3. In general, it shows that Tamalanrea Sub-district has a variety of surface temperatures in each neighborhood. In 2019 there was an increase in the average land surface temperature compared to 2020 and 2021. In 2020 there was a decrease in average temperature, then the temperature increased again in 2021, this can be seen from the color gradation shown on the map.

The results of land surface temperature measurements in 2019, 2020 and 2021 in the rainy season period in Tamalanrea District can be seen in Table 4. 2019 is the year with the highest average temperature in the rainy season period which is in the temperature range of 26 - 30°C and the highest average temperature is in Buntusu, Kapasa and Tamalanrea Sub-district, which is 30°C. In 2020 the land surface temperature decreased which was in the temperature range of 24-27°C and the highest average temperature was in Kapasa and Tamalanrea Sub-district.

Then in 2021 the land surface temperature again experienced a decrease which was in the temperature range of 23-25°C and was in Tamalanrea Indah, Tamalanrea Jaya and Kapasa Sub-district, namely 25°C. The following are the results of mapping the surface temperature of the Rainy season period in Tamalanrea District.

The following results of the mapping of the ground surface temperature of the rainy season period in Tamalanrea Sub-district are shown in figure 4. In general, there was an increase in the average land surface temperature in 2019 compared to 2020 and 2021 which experienced a decrease in temperature each year, this can be seen from the color gradation shown on the map.

Table 3. Minimum, Maximum, and Average Values of LST in Tamalanrea District during the Dry Season

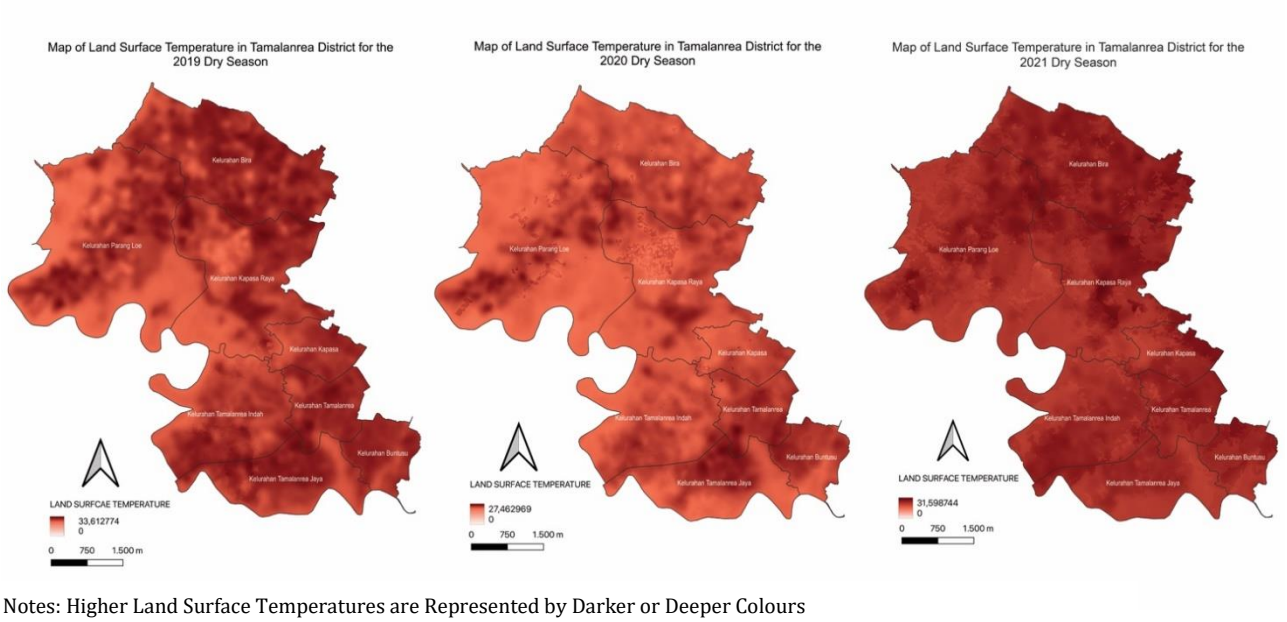
Sub-District	2019			2020			2021		
	Min (°C)	Max (°C)	Mean (°C)	Min (°C)	Max (°C)	Mean (°C)	Min (°C)	Max (°C)	Mean (°C)
Bira	26	32	29	22	27	23	22	29	26
Parangloe	25	33	31	21	26	22	21	32	24
Buntusu	28	32	30	22	27	25	23	29	26
Kapasa	27	32	29	23	28	24	24	28	26
Kapasa Raya	25	30	28	22	24	23	22	26	24
Tamalanrea	27	34	31	23	28	25	22	29	27
Tamalanrea Indah	25	33	30	21	28	24	22	29	26
Tamalanrea Jaya	26	34	30	21	28	24	22	29	25

Source: Primary Data, 2022

Table 4. Minimum, Maximum and Average Values of LST in Tamalanrea District during the Rainy Season

Sub-District	2019			2020			2021		
	Min (°C)	Max (°C)	Mean (°C)	Min (°C)	Max (°C)	Mean (°C)	Min (°C)	Max (°C)	Mean (°C)
Bira	25	31	28	23	24	25	23	24	24
Parangloe	23	32	28	24	30	24	22	28	23
Buntusu	26	36	30	24	29	28	22	29	24
Kapasa	26	31	30	24	27	27	23	27	25
Kapasa Raya	24	28	26	23	26	24	22	25	23
Tamalanrea	26	33	30	23	27	27	21	28	23
Tamalanrea Indah	25	32	29	22	26	26	21	28	25
Tamalanrea Jaya	24	33	29	22	27	25	19	27	25

Source: Primary Data, 2022



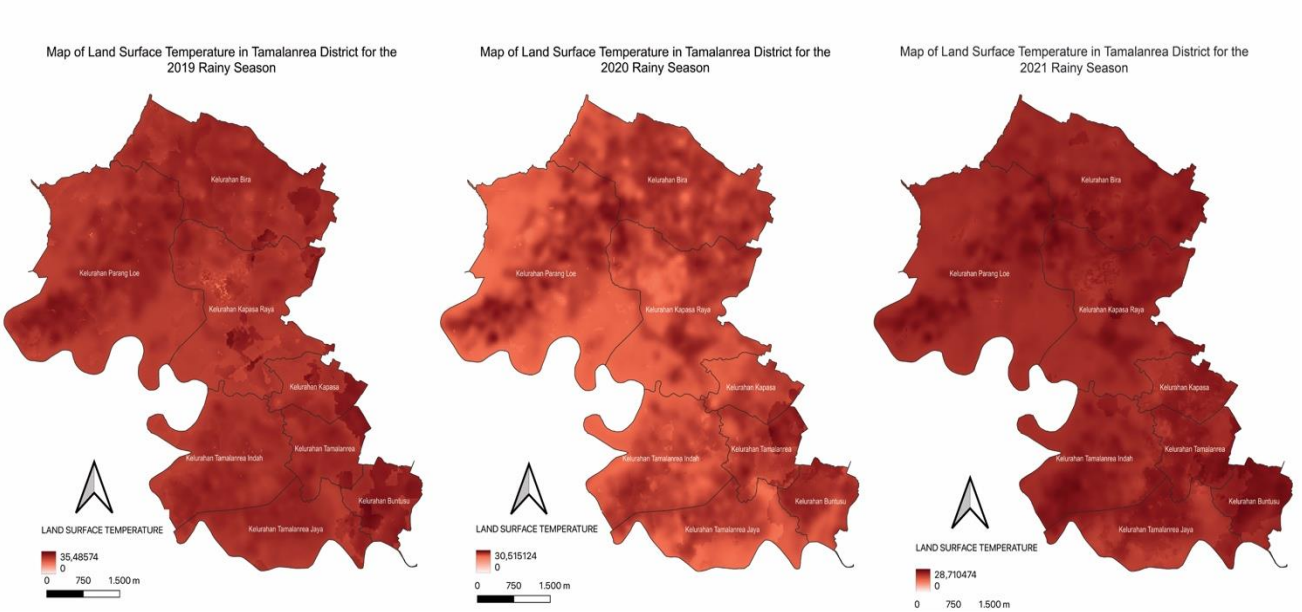
Notes: Higher Land Surface Temperatures are Represented by Darker or Deeper Colours

Source: Primary Data, 2022

Figure 3. Map of the Land Surface Temperature of the Tamalanrea District in 2019, 2020, and 2021 during the Dry Season

Based on SP2TP data for 2019, 2020 and 2021, six heat-related symptoms were identified in Tamalanrea sub-district as signs or symptoms considered to be affected by urban heat islands. Urban heat island-related diseases identified in Tamalanrea sub-district in 2019 included hypertension, headache, myalgia, ARI, heart disease and asthma, but the distribution of these diseases did not occur evenly across health services.

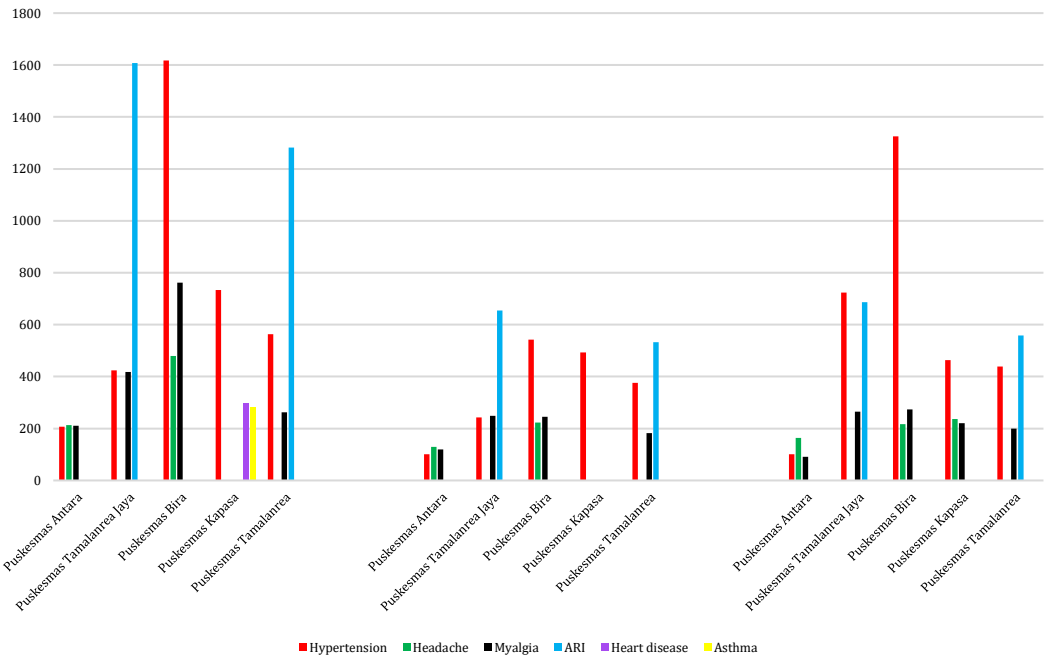
Hypertension disease was identified to occur in all health centers in Tamalanrea Sub-district. Heart disease and asthma only occur in Kapasa Health Center. The figure 5, shows that many heat-related diseases that occurred in 2019 were hypertension and ARI. In 2020, the types of heat-related illnesses are different from the previous year. Where from six types of heat-related diseases identified in 2019, there were four types of diseases in 2020. This also happened in 2021 when ARI was the most common disease in 2020. Meanwhile, in 2021, hypertension was the disease with the highest incidence rate. Significant positive correlation results were only shown in three health centers out of five health centers spread across Tamalanrea Sub-district namely Antara, Tamalanrea Jaya, and Kapasa Health Centers Table 5. While the other two health centers did not show positive correlation results on disease incidence and land surface temperature.



Notes: Higher Land Surface Temperatures are Represented by Darker or Deeper Colours

Source: Primary Data, 2022

Figure 4. Map of the Land Surface Temperature of the Tamalanrea District in 2019, 2020, and 2021 during the Rainy Season



Source: Primary Data, 2022

Figure 5. Frequency of Heat-Related Diseases in Tamalanrea District in 2019, 2020 and 2021

Tamalanrea Jaya Health Center shows significant positive correlation results with a perfect level of relationship in hypertension in 2019, Puskesmas Antara in hypertension in 2021, and Puskesmas Kapasa has a positive and significant correlation in heart disease and asthma in 2019, and headache in 2021. This shows that rising land surface temperatures can affect ambient temperatures and disrupt the activities of urban communities. Land surface temperature is positively correlated with the incidence of hypertension, headache, heart disease and asthma from patients or people accessing health facilities in Tamalanrea sub-district. It can be assumed that patients who are exposed to heat and get indirect effects will require action or treatment to prevent disease.

An epidemiologic approach is used to estimate the risk of heat-related morbidity with excess temperature due to UHI effects. Excess risk mapping is a form of Standardized Morbidity or Mortality Rate (SMR) that is often used. The relative risk value of the spread of heat-related diseases in Tamalanrea sub-district is needed to see which sub-districts have a high risk of disease because of UHI and provide special behavior in these areas so that more rapid, planned, and sustainable treatment can be carried out immediately to prevent the effects of UHI attacking urban communities.

In disease mapping, the SMR approach is useful for identifying high-risk areas. The risk scores in Figure 6, show that Bira and Kapasa Sub-Districts are at the highest risk compared to other sub-districts with risk scores >4.00. This risk score can be seen in the incidence of hypertension in the sub-district of Bira, and asthma and heart disease in the sub-district of Kapasa in 2019.

In addition, in 2021, Bira and Kapasa Sub-Districts are also at the highest risk with a risk score of 2.00-4.00 for the incidence of hypertension and headache. These findings suggest that heat-related diseases that are positively correlated to surface temperature pose a health threat to urban populations in Tamalanrea District in 2019 and 2021.

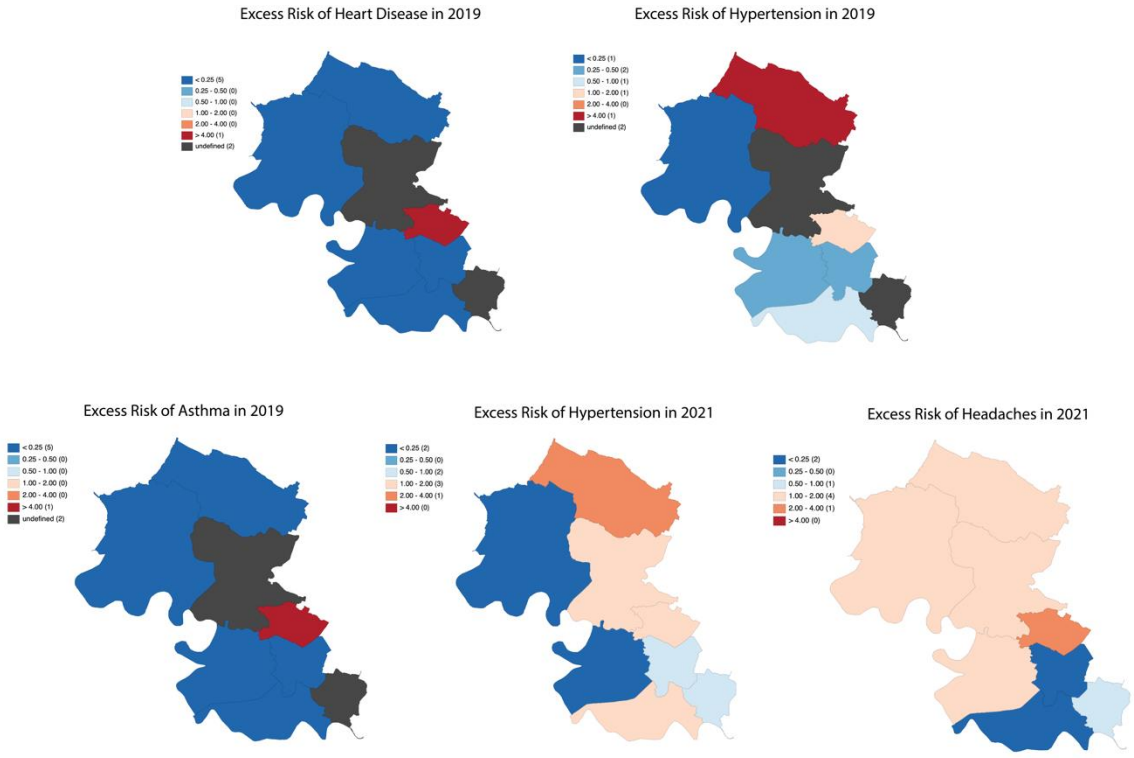
Table 5. Correlation between Heat-Related Diseases and LST

Disease	LST 2019		LST 2020		LST 2021	
	R	***p-value***	**R**	***p-value***	**R**	***p-value***
Antara Health Center						
Headache	0.416205	0.178374	0.056044	0.862655	0.223782	0.484441
Hypertension	0.566078	0.055029	0.427179	0.166034	0.759284**	0.004179*
Myalgia	-0.098275	0.761239	0.112088	0.728726	0.394405	0.204545
Tamalanrea Jaya Health Center						
ARI	-0.098102	0.761648	0.306622	0.332361	-0.223782	0.484441
Hypertension	0.835336**	0.000718*	0.391618	0.208051	0.083624	0.796113
Myalgia	-0.443018	0.149197	0.195465	0.542650	0.449946	0.142190
Bira Health Center						
Headache	-0.369835	0.236705	-0.083624	0.796113	-0.393004	0.206303
Hypertension	-0.563101	0.056606	-0.250873	0.431579	-0.055847	0.863133
Myalgia	0.171379	0.594334	0.224177	0.483649	-0.056044	0.862655
Kapasa Health Center						
Headache					0.706824**	0.010163*
Hypertension	0.220730	0.490573	0.195123	0.543370	0.419591	0.174507
Myalgia					0.224177	0.483649
Heart Diseases	0.589649**	0.043605*				
Asthma	0.835336**	0.000718*				
Tamalanrea Health Center						
ARI	0.416205	0.178374	0.418121	0.176179	0.279236	0.379430
Hypertension	0.098102	0.761648	0.196502	0.540468	0.394405	0.204545
Myalgia	0.172897	0.591021	0.307700	0.330577	0.257248	0.419565

Source: Primary Data, 2022

* is mean the value is significant

** is mean the value has a level of correlation relationship



Source: Primary Data, 2022

Figure 6. Excess Risk Map

DISCUSSION

The land surface temperature values obtained in this study may differ from those obtained in Liong, 2021 studies due to differences in the time and scale of the study area. In addition, LST values show differences between one environment and another. The land surface temperature in Tamalanrea Sub-district is in the range of 19-36°C and rises by 1°C when experiencing seasonal changes. This has a detrimental effect on the morbidity of the urban population.

The health impacts of increased LST are categorized as psychological impacts such as anxiety and aggressive behavior when exposed to excessive heat. In addition, excessive heat exposure may exacerbate the underlying disease and will be the main cause of the disease. The incidence of heat-related diseases will increase as the ambient temperature also increases due to current climate change.[16]

To understand the relationship between LST and heat-related illnesses, a correlation model was used. The frequency of identified heat-related illness symptoms correlated with LST results. This is in line with the findings that heat-related illness symptoms correlate with surface temperature patterns in urban environments.[7] Although, the correlation between LST and heat-related illness does not imply a direct cause of heat-related illness, it can be one of the risk indicators of the morbidity burden. UHI directly affects human health by generating heat waves, heat stress, and the spread of vector-borne diseases and can also lead to increased and chronic exposure to air pollutants and decreased physical health.[16] Increased temperature will disrupt daily activities. Although not as severe as other countries, Makassar City has moderate to tropical climate conditions. Therefore, early anticipation of the impact of urban heat is necessary.

Urban heat poses a risk to the health of urban residents, but it is also important to remember that there are many other risk factors that influence and harm. Air pollution, traffic noise, poor water quality, poor housing, and over-crowding can also be risk factors.[17] Air pollution is also the cause of various respiratory diseases such as COPD and asthma.[19]

The findings of this study, the risk score of Tamalanrea sub-district is in the range of 0.25 -

4.00. The resulting risk score estimation is based on the SMR model approach. The high-risk score indicates that the neighborhood has a higher risk level of incidence compared to other areas. Furthermore, a low-risk score indicates that the area is less likely to be affected by the disease. The low-risk rate is due to the low number of sufferers. Assessing the health risks of high temperature changes was thought to be feasible, to reduce the risk of heat exposure and to safeguard the health of urban residents to maintain healthy and sustainable urban spaces.

This study has limitations regarding data on individuals/patients accessing health facilities. In addition, SP2TP data collected from visits to health center limit the findings of this study. Therefore, further research on a more micro scale is needed to obtain more optimal results, and it is hoped that this study can serve as an illustration for the government to increase preventive and promotive efforts in controlling and preventing the impacts of climate change on health.

CONCLUSION AND RECOMMENDATION

The land surface temperature of Tamalanrea Sub-district is in the range of 19-36°C and rises by 1°C when experiencing seasonal changes. The increase in temperature, during the dry season will turn the centers of Tamalanrea Sub-district into undesirable hot areas in certain areas. It was found that hypertension, heart disease, asthma and headaches showed a correlation with significant values ($p<0.05$) with the land surface temperature trend. Bira and Kapasa sub-districts were at the highest risk for the spread of heat-related diseases than other sub-districts with a risk score >4.00 (very high). These findings can serve as an overview for the government to increase preventive and promotive efforts to control and prevent the effects of climate change on public health.

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AUTHOR CONTRIBUTIONS

AK writing-original draft; I and AK conceptualization; AK writing-review and editing; I, AK, and MP methodology; AK software and visualization; I and MP validation. AK = Angelia Khairunnisa; I = Ihsan; MP = Marly Patandianan.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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