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Changes in Rainfall Intensity, Rising Air Temperature, Wind Speed, and Its Relationship with Land Use in Makassar City

Didiharyono D[1*], Giarno[2], Sukriming Sapareng[3]

[1]IBK Nitro, Makassar, Indonesia
[2] State College of Meteorology Climatology and Geophysics, Tangerang, Indonesia
[3]Universitas Andi Djemma, Palopo, Indonesia

A R T I C L E I N F O

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A B S T R A K

Kota Makassar merupakan salah satu kota besar yang berkembang sangat pesat di Indonesia yang memiliki wilayah pesisir yang luas. Kota ini sangat rentan terhadap dampak perubahan variabel iklim seperti curah hujan, suhu dan kecepatan angin, terutama ketika ada indikasi perubahan penggunaan lahan secara masif. Penelitian ini bertujuan untuk mengidentifikasi perubahan tren curah hujan dengan intensitas tinggi, perubahan suhu udara, kecepatan angin, dan hubungannya dengan perubahan penggunaan lahan di Kota Makassar yang berdampak pada perubahan iklim. Data pengamatan di Stasiun Meteorologi Maritim Paotere, Makassar selama 30 tahun digunakan untuk mendeteksi perubahan variabel iklim dengan menggunakan perhitungan kemiringan pada persamaan linier, grafik garis, dan boxplot. Hasil penelitian menunjukkan bahwa suhu udara di Makassar mengalami peningkatan yang lebih rendah (0,06°C/tahun) dibandingkan wilayah Indonesia yaitu sekitar 0,3oC. Nilai kemiringan pada 07.00 WITA, 13.00 WITA, dan 18.00 WITA yang mewakili suhu pada pagi, siang, dan sore hari adalah 0,0387, 0,0476, dan 0,0417. Sedangkan kemiringan rata-rata suhu udara adalah 0,042. Namun, kenaikan suhu udara diikuti dengan penurunan akumulasi curah hujan tahunan hingga di bawah 3000 mm/tahun. Selain itu, hujan lebat yang menyebabkan banjir, peningkatan kecepatan angin maksimum juga perlu diwaspadai karena kecepatan angin merupakan salah satu penyebab bencana hidrometeorologi yang sering terjadi.

A B S T R A C T

Makassar City is one of the big cities that is growing very rapidly in Indonesia which has a large coastal area. This city is very vulnerable to the impact of changes in climate variables such as rainfall, temperature and wind speed, especially when there are indications of massive land use changes. The aim of the research is to identify changes in the trend of high-intensity rainfall, changes in air temperature, wind speed, and their relationship to changes in land use in Makassar City which have an impact on climate change. Observation data at Maritime Meteorological Station of Paotere, Makassar for 30 years is used to detect changes in climate variables by using slope calculations on linear equations, line graphs, and boxplots. The results showed that the air temperature in Makassar has a lower increasing (0.06oC/year) than Indonesian region which is around 0.3 oC. The slope values at 07.00 WITA, 13.00 WITA, and 18.00 WITA representing temperatures in the morning, afternoon, and evening are 0.0387, 0.0476, and 0.0417. While the average slope of air temperature is 0.042. However, Rising of air temperature is followed by a decrease in the accumulation of annual rainfall to below 3000 mm/year. In addition, heavy rains that cause flooding, increasing the maximum wind speed also need to be observed because wind speed is one of the causes of hydrometeorological disasters that often occur.

1. INTRODUCTION

Climate change is an event of changing weather conditions which include variables of rainfall, temperature, pressure, wind, humidity, and evaporation. In Indonesia, changes in atmospheric variables are identified as having an annual average temperature increase of about 0.3 °C, and a decrease in rainfall accumulation by 2% to 3% (Boer & Faqih, 2004). Although annual rainfall accumulation changed relatively small, changes in rain patterns have a significant impact. As an example, shifting rains at shorter times causes flooding, while at other times it can lead to drought (Sipayung et al., 2018; Sayadi et al., 2019). Meanwhile, increasing temperature changes are associated with an increase in the frequency of extreme rainfall (Allan & Soden, 2008), which causes an increased risk of flash floods and landslides. The Recent climate model simulations have projected an increase in rainfall that could lead to disasters (Chan et al., 2018; Tabari, 2020). Indonesia is a country that is prone to hydrometeorological disasters because

*Corresponding author.
E-mail addresses: muh.didih@gmail.com (Didiharyono D)

based on data from the Central Statistics Agency (BPS) the number of fatalities due to floods from 2002 to 2019 is more than 100 people every year. It was recorded that in early 2020, Jabotabek experienced two major floods, of which Bekasi and Tangerang were the worst affected área (Kendon et al., 2016). Not much different from Jabotabek's condition as the nation's capital, South Sulawesi is the fourth largest province based on the number of flood events in Indonesia. Makassar City itself as the capital city of South Sulawesi province is an area prone to natural disasters, especially floods. It was recorded that in 2019, the city of Makassar experienced the biggest flood with the death toll reaching 82 people (Hafil, 2019; Cipto, 2019). Even when the rainy season arrives, flash floods can also occur such as flash floods in Banteang and Janeponto on June 12, 2020 and Masamba which occurred on July 15, 2020 (Suryarandika, 2020).

Anthropogenic factors are thought to be the main cause of climate change (Haryanto, 2018). Rapid development in the economy and industry has a serious impact on climate change, such as the consumption of fossil energy, the number of motorized vehicles, and deforestation for land clearing (Didiharyono & Kasse, 2021). Although the phenomenon of climate change is a global phenomenon, its impact can be felt locally where climate change in Indonesia greatly affects many aspects of life including the economy, the poor, human health, and environmental conditions (Oktaviani et al., 2011). The parameters of climate change that are most felt in Indonesia are changes in rainfall, increases in air temperature, and sea level rise (Malino et al., 2021). The occurrence of extreme rainfall, prolonged drought, and changes in air temperature can potentially harm the environment and humans (Zikra et al., 2015). An increase in the amount of extreme rain will be very detrimental if it is accompanied by an increase in the frequency of landslide disasters (Barkey et al., 2019), the threat of water availability and seasonal shifts so that it can reduce agricultural productivity (Hasegawa & Matsuoka, 2015; Djalante, 2018). Rainfall variations in the Indonesian region are very dynamic, both spatially and temporally (Kuswanto et al., 2019). The non-uniformity of this rainfall patterns can affect filling in blank data through interpolation so that accuracy is required during analysis (Giarno et al., 2020). Meanwhile, the nature of the rain is categorized as above normal, normal, and below normal based on rainfall normality data in that place. The nature of normal rain is defined as the accumulation of rainfall that occurs in an area, the forecast of the season during the rainy season is around the average value for 30 years. Whereas above normal means that rainfall is higher than the upper limit of its normal value, and the nature of below normal rain means that the accumulation of rainfall during the rainy season is lower than its normal limit (Malino et al., 2021).

In addition, serious impacts of changes in climate variables include an increase in the average temperature which is closely related to the energy exchange process that takes place in the atmosphere. During the day some of the solar radiation will be absorbed by gases and particles floating in the atmosphere, causing the air temperature to increase (Wiweka, 2014). Rising temperatures for a long time can cause forest fires (Abram et al., 2021), thus threatening those that have the potential to threaten biodiversity (Malino et al., 2021). The impact of climate change that most threatens coastal cities is the threat of sea level rise which can cause permanent tidal flooding and damage to infrastructure in coastal areas (Oktaviani et al., 2011; Zikra et al., 2015; Strauss et al., 2021). Moreover, the dynamic fluctuations of these weather variables have the potential to have an impact on methods and changes in weather prediction accuracy (Didiharyono & Giarno, 2021), and stimulate the spread of disease (Giarno, 2021). Indonesia as an archipelagic country with large cities, the majority of which are located in coastal areas with a fairly wide area (Rudiarto et al., 2018). Changes in climate variables can have an impact on cities close to the coast and can have a huge impact on economic development (Christis et al., 2019). Makassar City as the capital city of South Sulawesi Province, with a high population density compared to other cities in Eastern Indonesia is very important to pay attention since this place is also prone to changes in climate variables (Thoban & Hizbaron, 2020; Andris et al., 2020). As a center of human activity and development, this city has undergone many changes in land use (Lolokada et al., 2021). Recently, two major floods occurred in the short period, 2019 and 2021 (IFRC, 2019; IFRC, 2021) so irequires a study of changes in climate variables such as changes in rainfall, air temperature, wind speed.

2. METHOD

The data was used for the three climate parameters for 24 years, starting from 1996 to 2019. The source of data was obtained from the Meteorology, Climatology, and Geophysics Agency (BMKG) of the Makassar Paotere Maritime Station. Changes in climate parameters are indicated by the rising or decreasing trend of an atmospheric variable which is usually depicted in a graph or slope value of a linear equation (Hajjarpoor et al., 2014; Hegerl et al., 2019). Then, the analysis of rainfall, air temperature, and wind speed is associated with changes in Makassar land use. Temperature is the most commonly used variable in assessing climate change, which in this study uses temperatures at 07.00, 13.00, and 18.00

local time or Central Indonesia time. Meanwhile, the intensity of extreme rainfall and strong winds is added because they have a direct impact on climate change and damage. Land-use change assessment in Makassar City uses secondary data from land change and fluctuations in climate variables associated with this land-use change (Lolokada et al., 2021). The type of research used is descriptive analysis, where an activity is described to describe the object under study by referring to references and data obtained from various data sources (IPCC, 2021). The first, each variable used will be calculated the average value. Meanwhile, the data distribution values were analyzed based on the data array from the smallest to the largest (Hu et al., 2015; Zhao et al., 2022). For example, the data that has been sorted is y_i, then the lower, middle (median) and upper quartile values are also expressed by quartile 1 (Q_1), quartile 2 (Q_2) and quartile 3 (Q_3). For the analysis of the increase also uses the trend value based on the slope of the data series with the formula.

$$z = mx + c \quad (1)$$

Where m is the slope or trend and c is a constant.

The main component in assessing the increase or decrease in climate variables is the slope which is calculated using Equation (1). Then each climate variable is presented in the form of line graphs and boxplots to clarify the presence or absence of climate change, which will then be compared and analyzed with landuse changes in the city of Makassar.

3. RESULTS AND DISCUSSION

Results

Each variable that affects climate is presented in the form of a line graph equipped with Equation (1), and in addition a boxplot graph is used to see trends in the 7-year period identified as the longest period of El-Nino. Based on this method, the presence or absence of climate change will be identified which will then be compared with changes in land use in Makassar City.

Rainfall

The results of the analysis of the amount of annual rainfall in the city of Makassar for the period 1996-2019, can be seen in Figure 1.

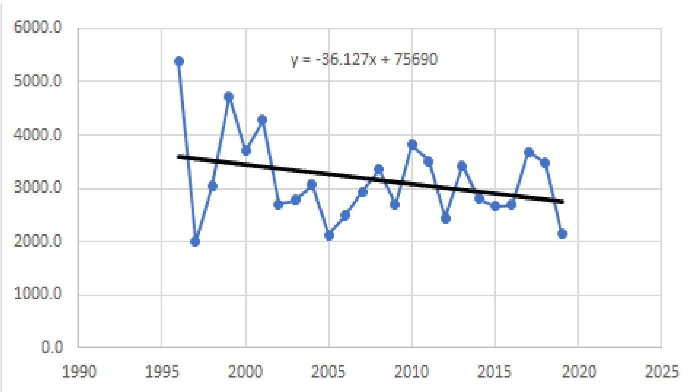


Figure 1. Average Rainfall of Makassar City 1996-2019 (years)

Based on Figure 1, it shows that the city of Makassar experienced a downward trend pattern with the accumulation of annual rainfall that occurred from 1996 to 2019. The highest rainfall occurred in 1996, namely 5389 mm and the lowest average rainfall occurred in 1996 at 1998 mm. Compared to the period before 2002, the city's annual rainfall is stable at below 4000 mm/year, although the fluctuation is very high. The trend of decreasing annual rainfall in Makassar is -36,127 mm/year. This explanation will be clearer by comparing the accumulation of monthly rainfall in this city using a boxplot as shown in Figure 2.

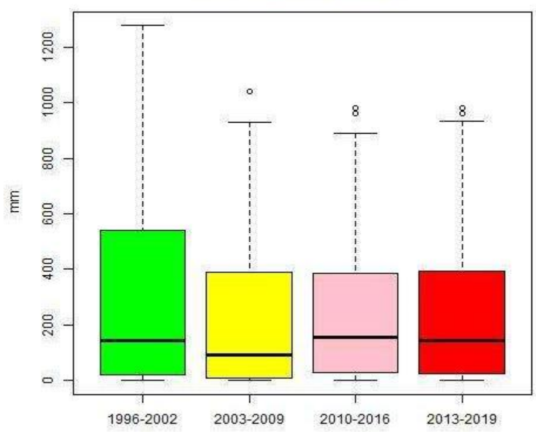


Figure 2. Boxplot of annual rainfall in Makassar City 1996-2019

Based on monthly rainfall fluctuations in Figure 2, it can be seen that the lowest median monthly rainfall was in 2003-2004. The value of the first quantile in this period is also the lowest among other periods. However, the third quantile of this period is the same as the period after it. While the period 1996-2002, has a third quantile value that is significantly higher than the others, but has the same median value as the period after 2009.

Temperature

The results of graphic analysis and annual temperature trends at 07.00, 13.00 and 18.00 Central Indonesian Time (WITA) in Makassar City from 1996-2019 are shown in Figure 3

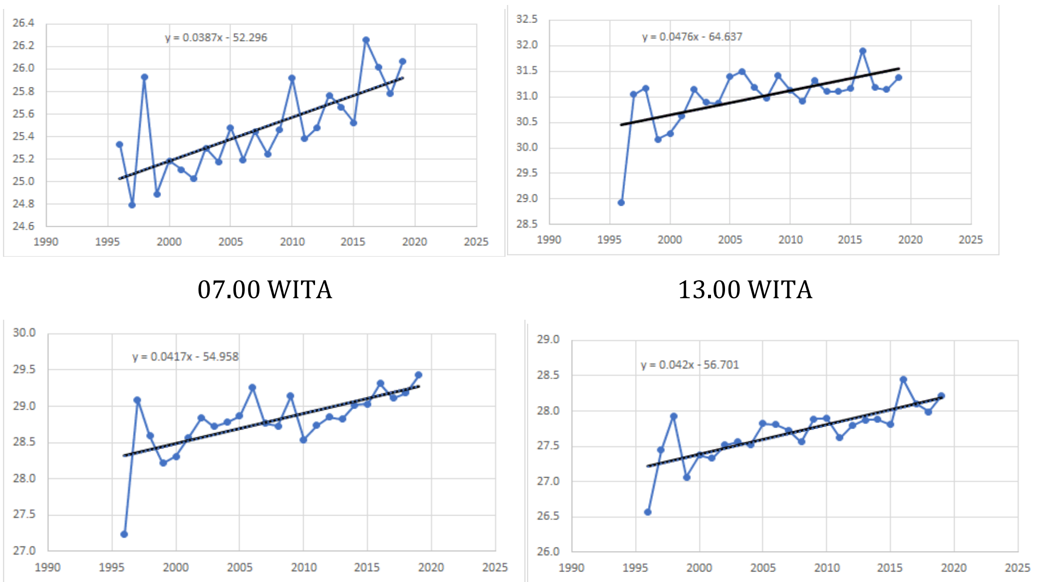
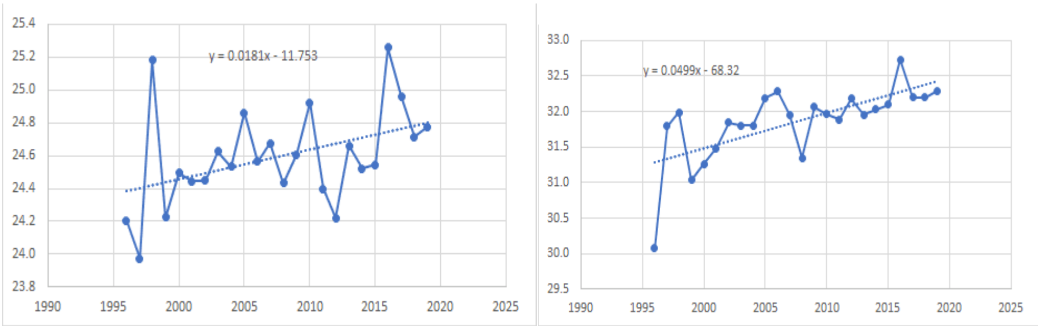


Figure 3. Makassar City Temperature from 1996-2019 at 07.00, 13.00, 18.00 and the Average

Based on Figure 3, it can be seen that there was an increase in temperature in 24 years (1996-2019) with temperatures at 07.00 WITA, 13.00 WITA, 18.00 WITA which represented morning, afternoon, and evening conditions. The graph depicts the trend pattern of the average temperature at 07.00 WITA, 13.00 WITA, and 18.00 WITA. The trend values of increasing temperature in the morning, afternoon and evening are 0.0387, 0.0476, and 0.0417. Likewise, the Makassar city's average temperature from 1996-2019 shows an increasing trend with a slope of 0.0420. The highest temperatures at 07.00 WITA and 13.00 WITA occurred in 2016 whose values were 26.3 ^{o}C and 31.9 ^{o}C, respectively. Meanwhile, the peak temperature was at 18.00 WITA and the average values for the 24 years period were 29.4 ^{o}C, and 28.2 ^{o}C which occurred in 2019. This condition is different from the minimum temperature values at 07.00 WITA, 8.00 WITA, 13.00 WITA and the average value which generally occurred at the beginning of the period, namely in 1996-1997.

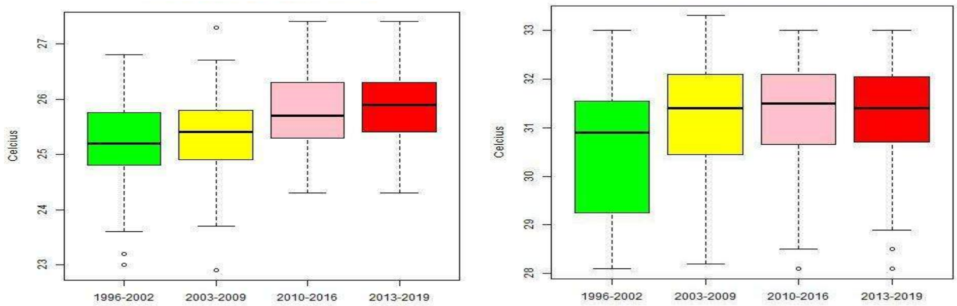
The trend of increasing the minimum temperature in this city is the lowest value compared to other trends, namely 0.0181, while for the maximum temperature the trend value is the highest as shown in Figure 4. The increase in maximum temperature which is faster than the minimum temperature results in increasing temperature disparity and variance. The impact could be that the hot and cold conditions felt by the people in Makassar City are more pronounced due to changes in heat and cold whose trend values are increasing.



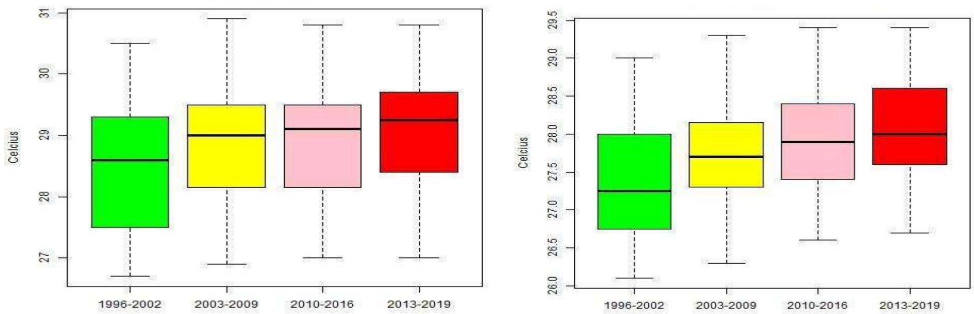
Minimum Temperatures Maximum Temperatures

Figure 4. Minimum and Maximum Temperatures in Makassar City from 1996-2019

Based on Figure 4, information is also obtained that the temperature in 2016 does not describe a relationship between temperature and rainfall, in which the rainfall is low but the temperature graph shows that the temperature has increased. One of the reasons is the weather anomaly caused by several factors, including global warming caused by the increase in greenhouse gases, especially carbon dioxide (CO2) and methane (CH4) which are dominantly caused by industrialization.



07.00 WITA 13.00 WITA



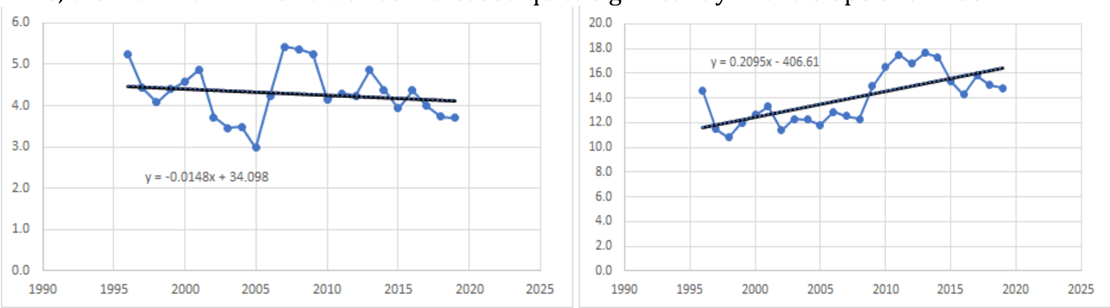
18.00 WITA Average Temperature

Figure 5. Makassar City Temperature Boxplot 1996-2019

The trend of changes in temperature at 07.00 WITA, 13.00 LT, 18.00 WITA and the average temperature is clear as shown in Figure 5 using a boxplot. The values of quantile 1, quantile 3, and the median have increased from period to period, where the most prominent increase is the average temperature and temperature at 07.00 WITA. While the median trend for temperatures at 13.00 after 2002, the increase was relatively small.

Wind Speed

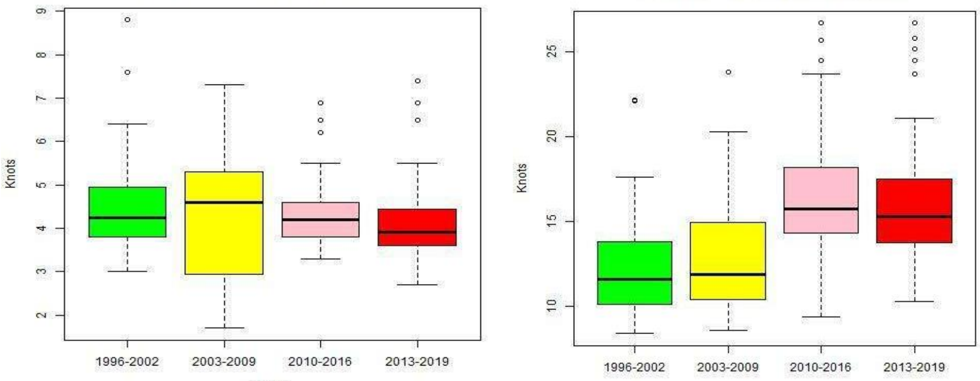
Based on the results of the analysis of the average wind speed in Makassar City from 1996-2019, it can be seen that there is a slight decrease in wind speed with a slope of -0.0148 as can be seen in Figure 6. Meanwhile, the maximum wind value has increased quite significantly with a slope of 0.2905.



Minimum Wind Speed Maximum Wind Speed

Figure 6. Minimum and Maximum Wind Speed in Makassar City 1996-2019

This speed increase condition can also be seen from the boxplot graph of wind speed in Makassar City in the period 1996-2002, 2003-2009, 2010-2016 and 2013-219 as shown in Figure 7. The average wind fluctuation increased in the period 2003-2009 where the distance between quantile 3 and quantile 1 (range) are very large, while for the period after 2009 the average wind speed almost does not experience high fluctuations. And when compared per period, the mean value is almost the same. Meanwhile, the people of this city must be aware of the increase in maximum winds, because based on the boxplot maximum winds there is an increase in the values of quantile 1, quantile 2, and quantile 3. This vigilance is important because maximum wind events are not a routine phenomenon but occur suddenly.



Average Wind Speed Maximum Wind Speed

Figure 7. Boxplot of Average and Maximum Wind Speed in Makassar City 1996-2019

Landuse Change

Landuse changes in Makassar City are very rapid where many agricultural and open lands are converted into buildings. Based on data from the Central Statistics Agency (BPS) of Makassar City, this land shift is very massive as shown in Table 1.

Tabel 1. Changes in agricultural land in Makassar City

No	Sub-Districts	Agricultural Land Area (%)	
		2006	2017
1	Mario	0	0
2	Mamajang	0	0
3	Tamalate	38	30.8
4	Rapocini	2.1	2.1
5	Makassar	0	0
6	Ujung pandang	0	0
7	Wajo	0	0
8	Bontoala	0	0
9	Ujung Tanah	0	0

No	Sub-Districts	Agricultural Land Area (%)	
		2006	2017
10	Tallo	54.5	4.2
11	Panakukkang	0.11	1.1
12	Manggala	51.2	50.2
13	Biringkanya	29.4	19.1
14	Tamalanrea	44.4	26

Based on Table 1 shows a decrease in the area of agricultural land by more than 50% from 2006 data compared to 2017. Tallo District is a sub-district whose agricultural land has decreased significantly from 54.5% to 4.2%, while Tamalanrea and Biringkanaya Sub-districts are the two sub-districts that experienced a reduction in agricultural land. highest after Tallo. These three sub-districts are located on the outskirts of Makassar City. This land conversion can be identified using irregular land changes that are very common in the eastern part of Makassar City as shown in Figure 8.

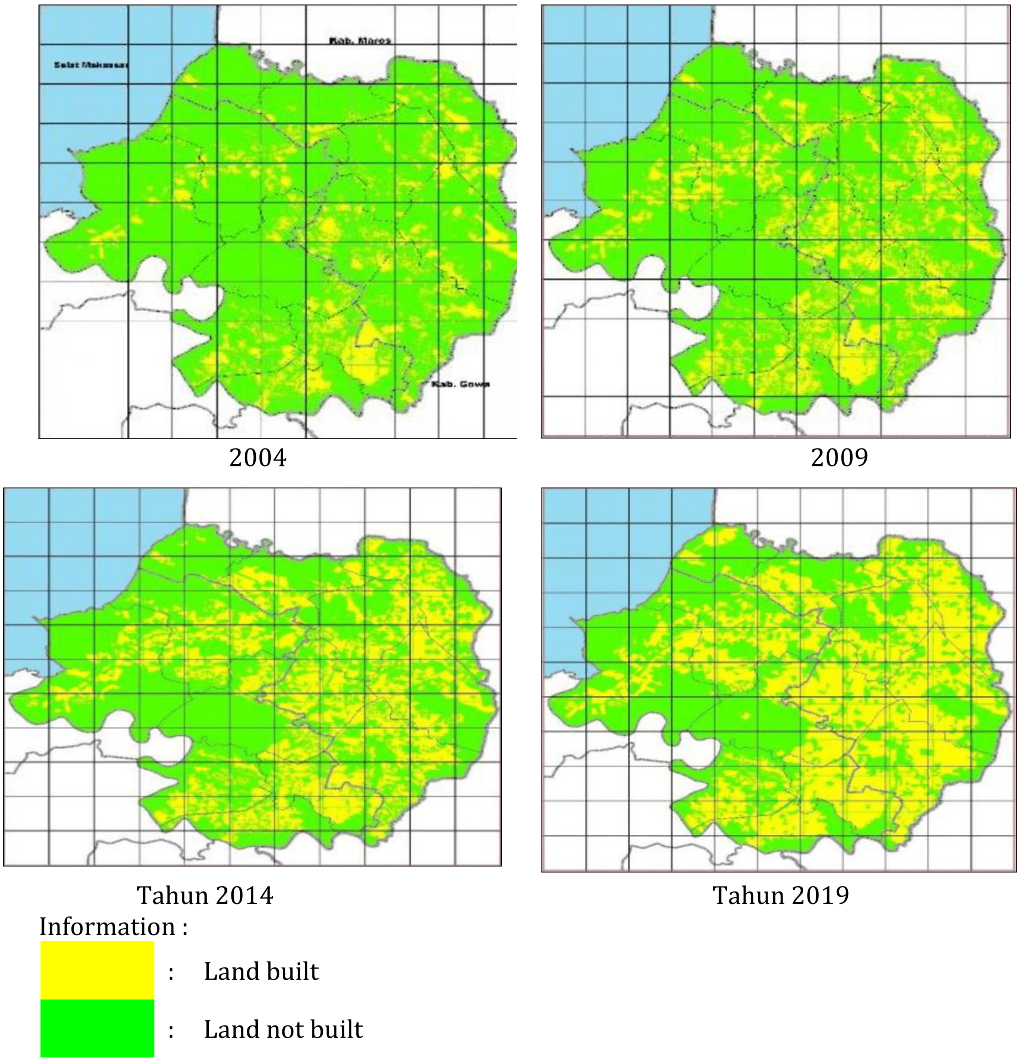


Figure 8. Landuse Change of Makassar city with Grid Map

The sub-districts of Tallo, Biringkanaya and Tamalanrea, which are located in the east of the city, were identified as changing their land from agricultural land to residential areas as shown in Figure 8. Many of the rice fields, swamps and fields in this area were purchased by developers and turned into settlements. Large-scale housing appears in these three sub-districts, such as Bukit Baruga, Bumi Tamalanrea Permai and conversion to an industrial area in Biringkanaya. As for the area close to the beach, which is the old city area, the construction is more regular. Generally renovating existing buildings so that they are less detected as sprawl areas (Lolokada et al., 2021).

Discussion

Makassar Paoetere Station as the location for research data collection is located on the coast of Makassar City which is a densely populated residential area that has existed for a long time without any agricultural land. Therefore, the data at this location is more suitable for climate change analysis due to the possibility of minimal temperature changes due to landuse changes. When compared with changes in temperature in Indonesia, which are around 0.3 °C (Boer & Faqih, 2004). Makassar city has increased with varying slopes, namely 0.0387, 0.0476, 0.0417, and 0.0420 for temperatures at 07.00 WITA, 13.00 WITA, 18.00 WITA. This value if calculated on the average in 24 years, the increase is 0.06 °C. Based on the fact that the landuse of Paoetere Makassar Station is relatively unchanged so that the increase in temperature in Makassar City is much lower than the figure of 0.03 °C.

Meanwhile, the decrease in annual rainfall accumulation in Makassar City is estimated to be more than 2%-3%, which is the average decrease in rainfall in Indonesia. In several years prior to 2002, the amount of annual rainfall was more than 3000 mm/year, whereas recently the amount has been less than this value. However, the frequent and frequent major floods that occur in the city of Makassar have changed the rain pattern in this city, where high intensity rains are more common even though the total amount of rain is lower (Suryarandika, 2020). The increase in the number of extreme rains needs to be watched out for because it causes many natural disasters (Novika et al., 2022), including landslides (Barkey et al., 2019). Not only heavy rains of high intensity, the trend of decreasing annual rainfall poses a threat to water availability so that it can reduce agricultural productivity (Hasegawa & Matsuoka, 2015; Djalante, 2018). The rapid development of Makassar City, especially in agricultural areas, requires an intensive study of its impact on the possibility of a hydrometeorological disaster. In addition to heavy rains that cause flooding, increasing the maximum wind speed also needs to be observed, because the occurrence of strong winds is a hydrometeorological disaster that often occurs.

4. CONCLUSIONS

The results showed that the temperature changes in Makassar City experienced a lower temperature increase than the Indonesian trend as a whole which was around 0.3 °C, where the Makassar City increased the increase was 0.06 °C / year and the slope of the increase was less than 0.05. This small change may be due to the location of Makassar Paotere Station, which is on the coast of the city, which is a dense residential area that has existed for a long time and has relatively not experienced agricultural land conversion. The increase in temperature in this city was followed by a decrease in the accumulation of annual rainfall in Makassar City, where before 2002, the amount of annual rainfall was more than 3000 mm, whereas recently the amount was less than this value. However, although the amount of rainfall decreases, there is an increase in the amount of extreme rain that needs to be watched out for because it can cause flooding. As for suggestions for further research, it is necessary to conduct an intensive study of its impact on the possibility of a hydrometeorological disaster in Makassar City.

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