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RESEARCH ARTICLE

Spatial Environmental Quality Assessment of Settlement Area in Tangerang City

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Abstract. This study aims to describe the role of changes in the characteristics of spatial patterns on the environmental quality in Tangerang City, Indonesia. It was carried out by detecting and explaining the effect of thermal comfort on the residential area using a combination of spatial and statistical analysis methods. The results showed that the changes in the characteristics of the spatial pattern, which include building density, vegetation area, accessibility, and road network connectivity significantly affected the spatial environmental quality index (IKLS) and temperature heat index (THI). Meanwhile, the changes in THI were caused by the continuous decline in vegetation area and an increase in population due to the urbanization process of Jakarta and other cities.

1. Introduction

The process of urbanization is one of the causes of changes in the landscape (Salvati et al., 2018), which affect the ecosystems and change the relationship between humans and the natural environment (Tanner & Fuhlendorf, 2018). The urban area is essentially a dynamic structure that changes with time and influences the characteristics of its environment (Whyne-Hammond, 1985). Moreover, urbanization is not only caused by variation in the landscape of urban land use but also changes in the lifestyle of the population (Madsen et al., 2018). The differences in lifestyle damage the environmental quality (Vaz et al., 2015) such as contamination of soil, water, air, and greenhouse gas emissions in urban environments (Verburg et al., 2018). When variation in land cover to non-vegetation and the process of urbanization occurs continuously, the soil surface temperature will increase and affect the residential areas (Sahana et al., 2016).

Changes in land use and cover (LULC) from vegetation to non-vegetation cause a variation in land surface temperature (LST), which is extracted using remote sensing data processing. Based on a study in Pune, India, it was discovered that within 29 years, the effect of increasing the built-up area was elevated by 43%. It increased land surface temperature (LST) by 5.8% in summer and decreased by 12.4% in winter (Gohain et al., 2021). In Beijing, China, it was reported that changes in land use and cover (LULC) due to population growth over 20 years (1997 - 2017) changed the interval of soil surface temperature from 22.06-35.85°C to 17, 00-38.29°C (Mustafa et al., 2021). Generally, an increase in surface temperature causes global warming, leading to a higher carbon dioxide (CO2) that changes the local, regional, and global climate (Marland et al., 2018). Urbanization and industrialization are one of the main factors for increasing land surface temperatures. This is supported by previous reports in India, where changes in LULC in urban, industrial, and mining areas for two years showed an increase in summer and winter surface temperatures by 0.15°C and 0.19°C per year, respectively (Das et al., 2021).

The quality of urban settlements is influenced by the physical and non-physical conditions of the area. A previous study stated that changes in physical development and land use can cause various problems in residential areas (Wesnawa, 2017). The increase in the built-up area, which is mostly used to develop urban settlements indicates a reduction in green open spaces and catchment areas (Pigawati et al., 2019). The characteristics of the urban environment affect the conditions of the quality of life of its inhabitants (Ovsiannikova & Nikolaenko, 2019). It also influences ecosystem resilience, quality of settlements, and the health of urban communities (Srivastava et al., 2016), thereby decreasing the environmental quality. This is characterized by high building density, loss of parks and open spaces, inadequate housing environment facilities, and infrastructure. Moreover, urbanization is the main cause of higher density in urban areas, which increases the area of settlements, the density of residential buildings, and changes the spatial index of the landscapes as well as their ecosystem values (Hou et al., 2019). The variations in the spatial pattern of the built-up area also affected the air quality, as indicated by the increasing number of the built-up area populations, the high proportion of the industry, coal-dominated energy structures, and increased traffic intensity (Cheng et al., 2017). The network of living environment and transportation conditions influence the quality of the urban and rural environment (Lazauskaitė, 2015). The changes in urban spatial patterns affect the variation in interaction, social adaptation, cultural patterns of local communities, and job differentiation (Surya et al., 2020) and also reduce the comfort level of the urban environment. Therefore, the quality of urban life is closely related to the policy implications of controlling the proportion of built-up areas for households and businesses with the area and distribution of green open spaces (Rosu et al., 2015).

Ecological environmental studies on human settlement categorize the important elements that need to be considered in managing residential areas, namely urban planning, land suitability, and ecological aspects (Walter, 2016). Moreover, urban settlement areas that are increasingly developing must pay more attention to the factors of human activity, climate, changes in the spatial pattern of the settlement environment, and social aspects (Clos, 2011). The main indicators for measuring the quality of the urban environment include economic, environmental conditions, safety, architecture and landscape, social environment, transportation, and recreation infrastructure (Ganebnykhl, 2019). Mayasari and Ritohardoyo (2016) stated that the quality of the settlement is influenced by the physical condition of the housing, the environment, and human activities. The quality of the housing environment is ideal when its area with an orderly layout is greater than the area of an irregular residential building layout (Fatimah, 2010). One of the causes of the decline in the quality of the residential environment is the emergence of housing that is not organized regularly (Syarmaalina, 2017) and also the extent and distribution of vegetation. The changes in the green level of residential areas are an important component that affects the variation in the quality of the urban environment (Lu et al., 2017; Yang et al., 2018). The spatial change of the buffer zone can be observed from the development of new residential areas developed in a planned (formal) or unplanned (non-formal) manner, where the increase in this area is to meet the higher housing demands (Supriyono, 2003). The increase in the number of buildings due to high population growth in the buffer zone and urbanization has indicated a serious urban problem (Purba, 2016).

The buffer zone around DKI Jakarta Province has experienced significant developments in the economic sector from different generations due to population growth. This development also increases the number of residential and urban areas, which slowly or rapidly encroach on green open spaces and agricultural land. Where the area functions as an ecological, hydrological, climate regulation, food provider, and disaster management zone. The development of the buffer zone around the province is very difficult to control due to the existing economic and social development policies. As a buffer zone in the western part of Jakarta, Tangerang City has an area of vegetation that shrinks continuously. This is shown by the increasing urban heat island phenomenon (Wibowo et al., 2013) which is influenced by converting agricultural land to housing, industry, infrastructure, and others (Rahel, 2017; Wibowo et al., 2013). In the long term, the land conversion will potentially cause negative impacts such as the emergence of slum areas, traffic jams, air and water pollution, flood disasters, and health. Meanwhile, population growth contributes the most as one of the causes of environmental damage due to urban ecological imbalance, which physically and socially reduces the quality of residential environments (Aguilar, 2008). Environmental damage in cities adversely affects ecosystem function and creates high health risks for urban residents (Landrigan, 2017; World Health Organization, 2016; Zhu et al., 2016).

In the last five years (2015 - 2019), the average building density in Tangerang City was ± 130 units/hectare, with a density of 1.5–3 meters and a population density of ± 2 6067 people/hectare, which is estimated to be 2755 people/ hectare in 2030 (Tangerang City Central Bureau of Statistics, 2020). The open green space in the city is only <5% and unevenly distributed and the slum areas are spread across 11 districts. They are located in 29 sub-districts, with the classification of light to very heavy (Integrated Plan and Medium-Term Investment Program of Tangerang City, 2019). Furthermore, the annual population growth rate for each sub-district in the last ten years (2008-2018) is significantly high, which is above 1.9% (Integrated Plan and Medium-Term Investment Program of Tangerang City, 2019; Central Bureau of Statistics, 2018). This rapid increase in population number will affect the high pressure on space use and Green Open Space's decreasing area (RTH). The ratio of green open to the built-up area in 2009 was 0.82, and the percentage of public green open space in 2011 was 34.23 hectares, or 0.18% of the total area (Tangerang City Central Bureau of Statistics, 2018). The existence of green open space is needed in urban areas to create a comfortable and healthy environment. The decline in the quality and quantity of green open space will decrease the quality of the residential environment in the city (Rahel, 2017). In 2018, the air pollution index in the city reached 95.76 points or was in the range of 50-100 on the ISPU scale, which was categorized as moderate to unhealthy quality. A previous study discovered that the sources of air pollution are transportation and industrial activities, which have increased annually (Nurwita et al., 2021). This showed that the environmental quality of residential areas in the city is experiencing pressure on the quality of the settlement such as increased pollution, an unhealthy environment, and reduced comfort. Therefore, there is a need to simultaneously control and manage all the elements that influence the environment to avoid the increasing degradation of the settlement quality that can endanger the population.

According to a previous study, the aspects of the quality of the urban environment are influenced by factors such as ground surface temperature, area and distribution of green open space, transportation and industry, as well as population density. The management of the environmental quality needs to consider the development of these factors periodically, integrated, and comprehensively to maintain and improve the residential areas. In Tangerang and other big cities in Indonesia, the population density of residential areas has implications for building density and regularity. Transportation is also spatially related to traffic density, connectivity, and accessibility of the road network. This makes it necessary to provide quantitative spatial information on housing and population density, green open space conditions, accessibility, traffic jams, air pollution, and aspects of health and the comfort of living quarters in the buffer zone. Meanwhile, the investigation to evaluate and control the development of residential areas has been carried out partially and is limited to the examination of only one and two variables. Most of the assessment indicators used depend on micro aspects and non-spatial attributes such as sanitation, building conditions, drainage, garbage disposal, cleanliness, etc. This makes the policies to manage and improve residential areas important by integrating macro and micro aspects, spatial and non-spatial aspects (Hou et al., 2019). Therefore, this study aims to analyze and map the distribution of the quality index of the settlement environment based on the spatial characteristics of buildings, vegetation, accessibility, disaster vulnerability, and socioeconomic. It also evaluates the environment's quality and formulates a settlement area development strategy based on the thermal humidity index (YHI).

This study is expected to provide comprehensive information on the quality of each environmental element and the distribution of quality for settlements in Tangerang City based on the thermal humidity index. These data are very important and needed by local governments to formulate policies related to the control and management of residential areas. In the long term, the results will be used to refine the guidelines for assessing the quality of environments, namely adding and combining the dynamics of changes in the spatial patterns of settlement areas into the current manual for assessment. Meanwhile, the spatial aspect is not considered in the guidebook as an important element and a driving factor that significantly affect the degradation of the quality of the settlement environment.

2. Methods

The study location was one of the buffer areas of DKI Jakarta, namely Tangerang City, West Java, Indonesia, and directly adjacent to Soekarno-Hatta International Airport in Cengkareng. The total area was 164.55 km^2, which included 13 sub-districts (Figure 1) and 104 urban villages with a population of 2274000 inhabitants in 2020 (Figure 2).

This study used the spatial pattern characteristics and their correlation to environmental quality, namely temperature-humidity index (THI). THI was the representation of the earth's surface temperature and humidity, which was collected by secondary data from an official agency. It also ranked the spatial environmental quality index per district in Tangerang City. Spatial pattern variables included building, population, and traffic density, regularity, vegetation, potential disaster, road accessibility, road connectivity, temperature, and humidity. The information on spatial characteristics was obtained using an algorithm calculation as shown in Table 1.

The satellite images used were Landsat and ERA5, which have grown significantly compared to the previous model ERA-15, ERA-40, or ERA-interim. This was because the depiction results of the dynamics of water evaporation are better in ERA5. These data were supported by an increase in

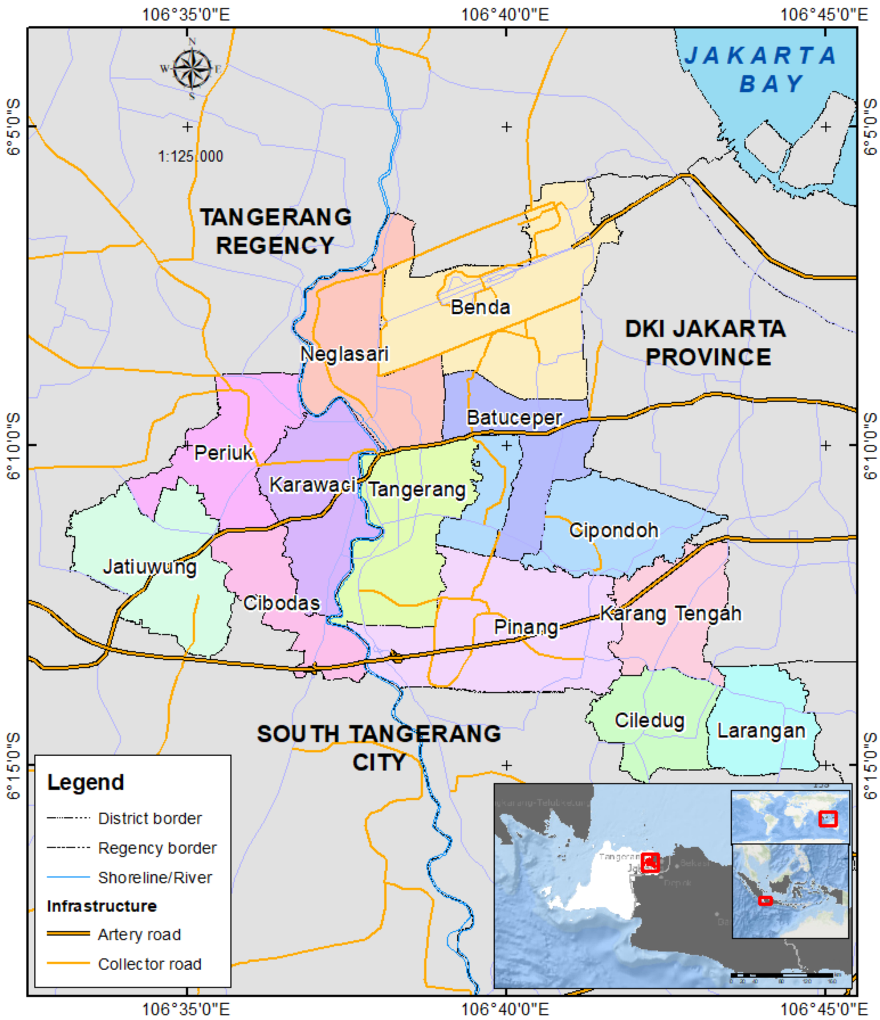

Figure 1. Boundary of Tangerang City

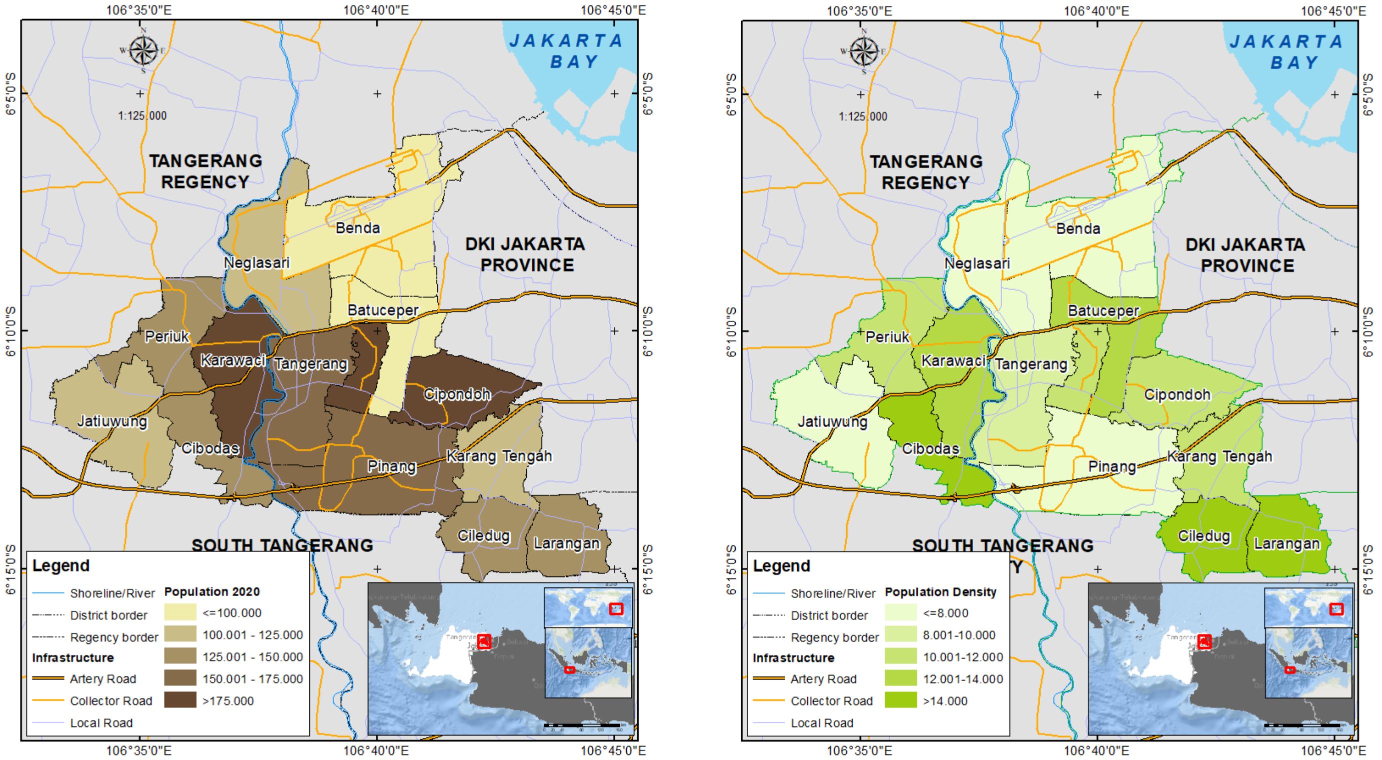

Figure 2. The spatial characteristics of the 2020 population (left) and population density (right) in each sub-district in Tangerang City

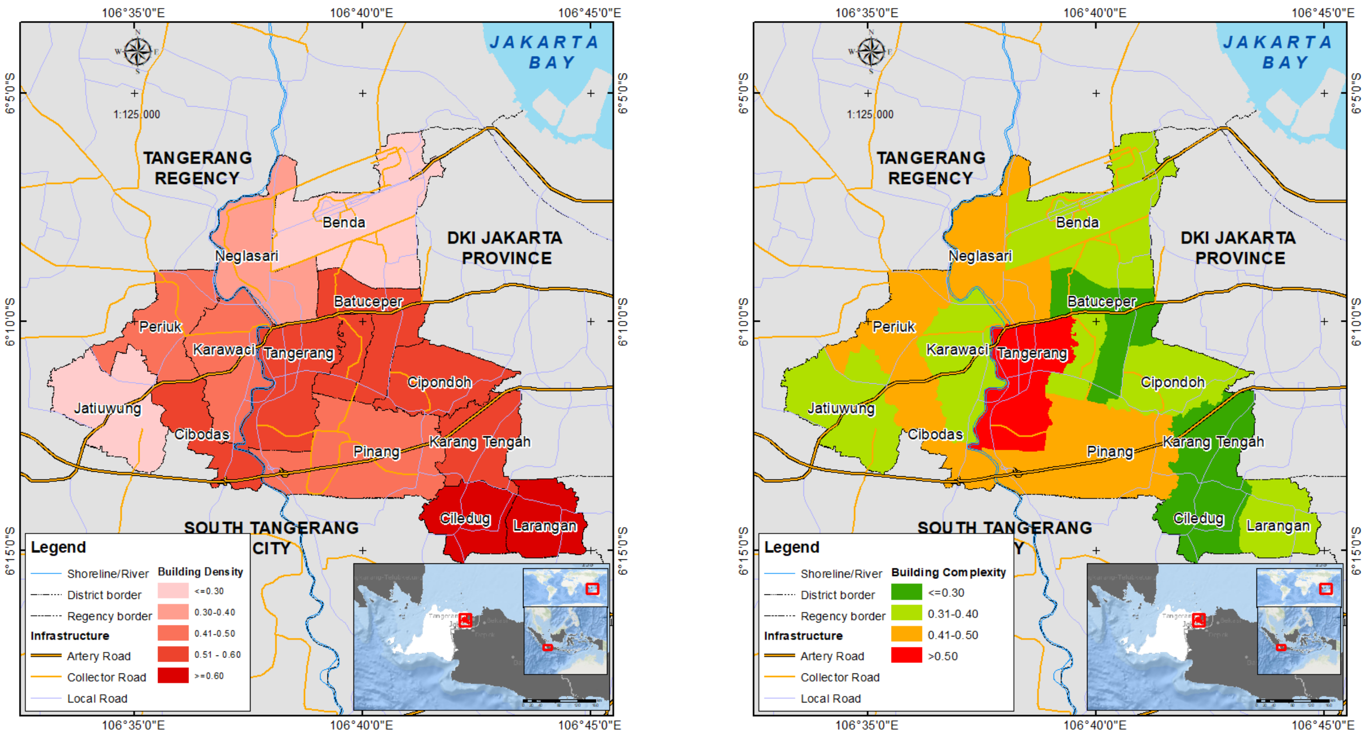

Figure 3. Characteristics of spatial patterns Building density (left) and characteristics of spatial patterns regularity of buildings (right) in each sub-district in Tangerang City

the horizontal grid spacing (from 10 Km to 30 Km), vertical levels (60 - 137), and temporal resolution (6 hours - 1 hour) (Mateus et al., 2021). The relationship between temperature, moisture content, and relative humidity (RH) was significant for meteorological forecasting. The August-Roche-Magnus approximation provided a good approximation for the equations of these three parameters (Thiis et al., 2017). This was carried out to obtain the Relative Humidity value using the August-Roche-Magnus approximation based on the temperature (T) and Dewpoint temperature (Td) values from ERA5 data.

The results of data extraction from these images were used as basic data to identify the characteristics of the spatial pattern of the study area through digital image processing and GIS techniques. It also used visual interpretation and ground checks to measure and analyze

Table 1. The formulae for calculating the spatial characteristics in Tangerang City

Spatial and environmental pattern variables	Formula	Information
Building density	P = Lp/Lk (%) P = percentage of building density Lp = Building area (km^2) Lk = area administrative area (km^2)	Comparison percentage of building area and administrative area per district in all areas of Tangerang City. The higher the percentage, the denser the houses and buildings in the area.
Order of the building	$T = 2Ju\sqrt{((\sum(rumah/Lk))}$ T = nearest neighbor index Ĵu = the closest average distance between buildings (meters) Σhouse = number of buildings in the settlement Lk = area of settlement (m^2)	The greater the T value, the more orderly the layout of buildings and houses in the area.
Vegetation	NDVI = (NIR – Red)/(NIR+Red)	NDVI is a greenness index of the distribution of green open space based on the spectral value of remote sensing data with a value ranging fr -1 to +1. The lowest value indicates the object is not chlorophyll and the highest has high chlorophyll. The more values> 0.5, the wider the plant/tree area.
accessibility	$\text{Alpha index} = \frac{m - t + s}{2t - 5} \times 100$ m = number of road links t = number of points of intersection of roads s = number of road network graphs	The alpha index reflects the level of accessibility of the movement of an area. Alpha values range from 0 to 1. The higher the Alpha value, the easier the accessibility of an area and vice versa.
connectivity	Beta Index = m/t t = number of points of intersection of roads m = number of road links	The beta index reflects the connectivity or relationship between one place and another. The higher the Beta value, the easier it is and connected from one place to another.
traffic density	The ratio of the length of the density of vehicles passing the road to the total length of the regional roads.	The length of vehicle density on the road is measured daily (morning-afternoon and evening) for a full day, based on traffic congestion data on Google traffic.
Potential disaster	Secondary data	The level of vulnerability of the area to floods and earthquakes is 0 - 1. The closer to the value of 1, the higher the level of vulnerability of the area to disasters.
Temperature	Secondary data	
Humidity	Secondary and Spatial Data	
Temperature Humidity Index (THI)	THI = 0.8T + (RH x T)/500 THI = comfort index T = Temperature (°C) RH = Relative Humidity (%)	THI reflects the comfort level of an area from the aspect of land cover temperature differences affecting the distribution of the Temperature Heat Index (THI) component in an area

the characteristics of the spatial pattern of building density, regularity, area, distribution, vegetation density, accessibility, and road connectivity. The calculation of the spatial pattern characteristic index in Tangerang City was carried out using the formula stated in Table 1.

The effect of changes in vegetation and population density on the quality of the geophysical environment in Tangerang City during the last ten years were analyzed to determine the potential environmental impacts based on multitemporal data, namely the area and distribution of vegetation in 5-year time intervals from 2010 to 2020. Meanwhile, data on temperature, humidity, and population were collected from several related institutions, which include the BMKG (Meteorology, Climatology and Geophysics Agency), the Tangerang City Government, and the National Statistics Agency. The spatial environmental quality index was calculated, ranked in 2020, and analyzed whether during the 20 years there had been a change in the environmental comfort index, as shown by the value of the THI. Meanwhile, the spatial environmental quality index per district was calculated based on the sum of each spatial characteristic variable value, including building density and regularity, vegetation, population, and traffic density, road accessibility and connectivity, as well as disaster vulnerability. Subsequently, the correlation analysis of air humidity levels and the total environmental quality index value was carried out to determine the effect of any significant spatial variables on changes in air humidity per

Table 2. Details of data sources

Spatial Characteristics	Data source
Building density	The building density map was obtained from the building distribution map in the Open Streetmap (OSM) 2020 and overlaps with the sub-district administrative boundaries from the Indonesian Earth map (RBI), which was sourced from the Geospatial Information Agency (BIG) in 2017. Calculation of density divided by area of each district.
Order of the building	The regularity map was extracted from the proximity data between buildings from the distribution map obtained from the Open Street map 2020. The results overlapped with the sub-district administrative boundaries from the Indonesian Earth Map (RBI), which was sourced from the Geospatial Information Agency in 2017.
Accessibility	Accessibility was calculated by extracting data on the number of road links, intersection points, and network graphs, which are obtained from the road network map from Open Streetmap in 2020 and overlapping with the sub-district administrative boundaries from the earth map Indonesia, from the Geospatial Information Agency in 2017.
Connectivity	Data on the number of road intersection points and the number of road links obtained from the road network map, Open Streetmap 2020 and overlapped with administrative boundaries.
Traffic congestion	Vehicle density data were extracted from google traffic data, which were the recording data from 06.00 to 19.00 WIB, dated January 3, 2021.
Flood hazard	The flood hazard map was obtained from the one released by the National Disaster Management Agency (BNPB) in 2015.
Earthquake hazard	Earthquake hazard maps were obtained from the National Disaster Management Agency in 2015.
Total Population	The population map was obtained from numerical processing of population data based on the Central Statistics Agency in 2020.
Population density	The population density map was obtained from numerical processing data from the Central Statistics Agency in 2020.
Relative humidity	Relative humidity data was based on ERA-5 2020, which was obtained from the ECMWF (European Center for Medium-Range Weather Forecasts) project.
Vegetation	The data source for NDVI analysis was obtained using Landsat imagery, with the following details: analysis for 2010 using bands 3 and 4 from Landsat 5 TM imagery, 2015 and 2020 analysis using bands 4 and 5 from Landsat 8 OLI TIRS imagery.

sub-district in the city. The sources of data based on the grouping of several spatial characteristics were stated below.

3. Result and Discussion

Description of the Spatial Characteristics in Tangerang City

The results of digital image processing and GIS from a combination of several imageries and other sources in 2020 obtained information on the characteristics of spatial patterns per sub-district in Tangerang City as shown in Figures 3 to 7 and Table 3.

The distribution of vegetation density values in Tangerang City based on NDVI analysis (Figure 7) in 2010 was between 0.011977 and 0.852539. Meanwhile, in 2015, the NDVI values ranged from 0.032645 to 0.888868 and 0.004328 to 0.827664 in 2020. Based on this analysis, it was discovered that there was no significant change in the vegetation density. The level of vegetation density based on the NDVI value can be used as the basis for classification according to the dominance of plants. According to Jaya (2014), the vegetation surface with a value range of 0.1 indicated grasslands and shrubs, 0.2-0.4 is shrubs, and 0.4-0.8 indicated trees, urban forests, or tropical rainforests. The results of NDVI analysis showed that Benda, Neglasari, Tangerang, and Pinang Sub-districts had public green open spaces in form of city forests. These annual trees were significantly dense and wide compared to other districts. In Figure 7, the color degradation from green to dark green showed an NDVI value of 1 or close to 1 until a reddish-orange or red indicates -1 or close to -1. Based on the spatial changes that occur in vegetation, the proportion of green to dark green degradation showed a decreasing trend between 2010 and 2020. Although there was a slight increase from the 2015 to 2020 interval, it was not significant. The results also showed an annual pattern of decreasing vegetation area, which indicated that the area of green open space (RTH) was shrinking.

Figures 2 to 4 and Table 3 showed that the building density of Tangerang City ranged from moderate to high. Meanwhile, very high building density (> 60%) was in Ciledug and Larangan Districts, which are most densely populated compared to other sub-districts. The general layout of the buildings was significantly regular and the areas with relatively more regular layouts are in Tangerang and Cibodas Districts. The building regularity did not correlate with building and population density. Moreover, the three regularity classes in the settlement area include regular, random, and clustered. Accessibility and road connectivity is generally evenly distributed in all areas where one place can be reached from various alternative routes. However, the level of traffic congestion in Tanggerang City is relatively dense. In the districts bordering

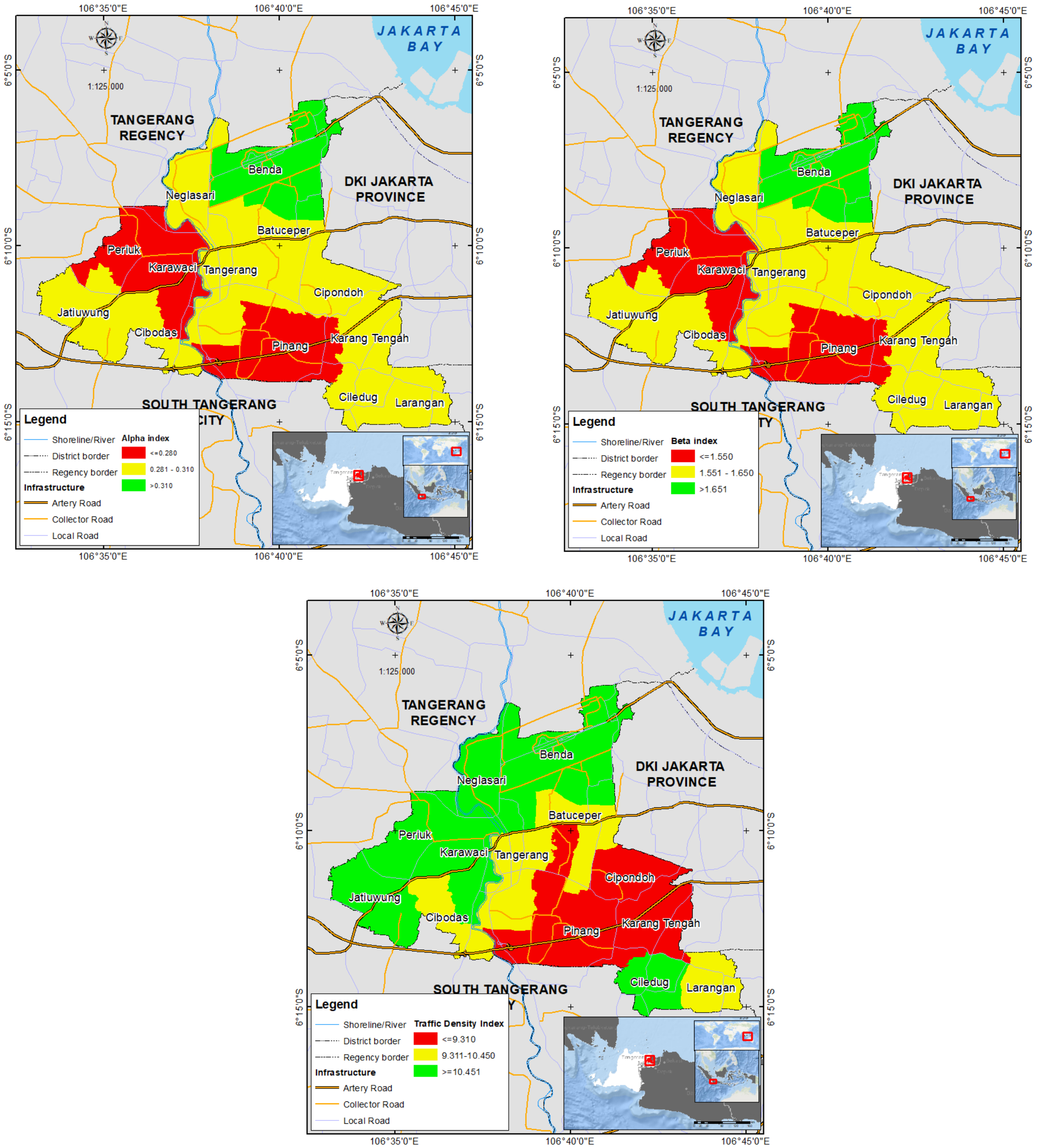

Figure 4. Characteristics of the spatial pattern of accessibility (top left), characteristics of spatial connectivity patterns (top right), characteristics of spatial patterns of traffic density (bottom) in each sub-district in Tangerang City

Soekarno-Hatta International Airport, namely Benda and Neglasari, the level of accessibility and road network connectivity is better compared to other sub-districts. Based on the calculation of the α and β indices, road accessibility and connectivity indicated that a closed circuit has been formed and connected between residential blocks at formal settlement areas but only partly in non-formal areas. The level of accessibility and high road network connectivity affected the level of traffic congestion as shown by the roads that are close to the trade and industrial areas as well as the TOL roads in Tangerang City.

The existence of vegetation, which includes public and private green open spaces, agricultural land, and shrubs, is distributed in each district with wide variations ranging from 9% to 44% of the total area. The distribution of green open space was relatively clustered, forming lines and points in residential areas (Figure 8). The value of urban greenery depicted from the NDVI index showed that the percentage of green areas in formal residential and regular buildings is smaller compared to non-formal residential areas with relatively lower building regularity.

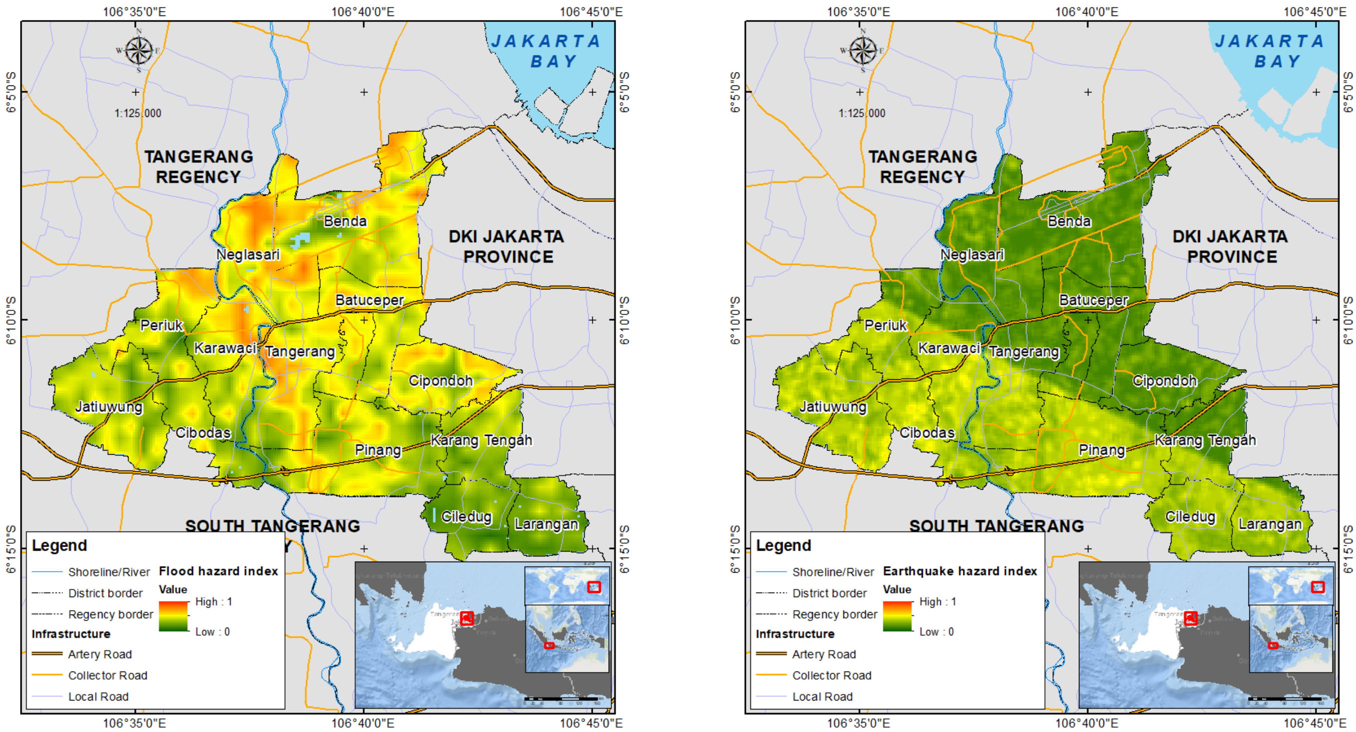

Figure 5. Characteristics of spatial patterns Potential disasters in each sub-district in Tangerang City (Left: Potential flood disaster; Right: Potential earthquake disaster)

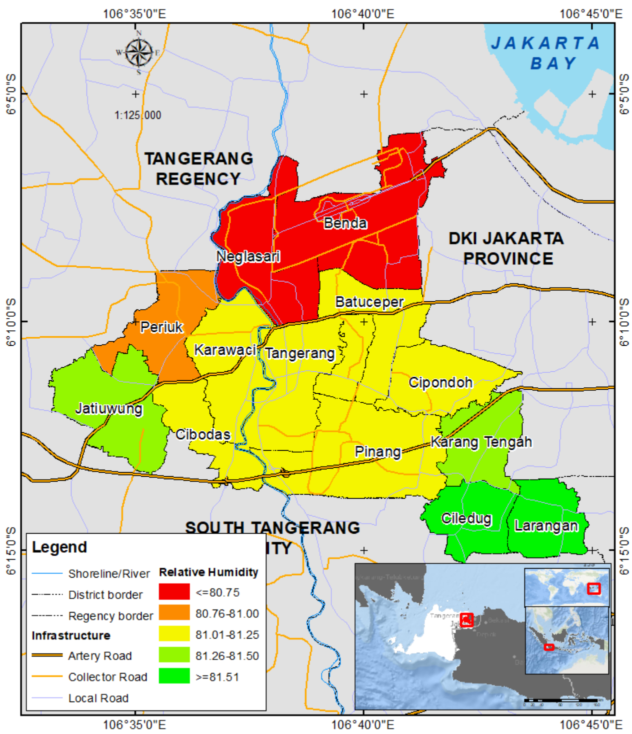

Figure 6. Characteristics of the spatial pattern of relative humidity in each sub-district in Tangerang City

The reduction rate in the percentage of vegetation from 2010 to 2020 per sub-district in Tangerang City (Figures 7-8) showed that the number of sub-districts has >30% green space is decreasing in that period. In 2010, 11 out of 13 sub-districts had a relatively good percentage of green space/ vegetation. Meanwhile, it is expected that by 2020, the number of sub-districts with green areas > 30% of the total area will be reduced to only 5, namely Benda, Neglasari, Batuceper, Periuk, and Pinang. The decrease in the percentage of vegetation due to the expansion of the built area (non-vegetation) occurred in sub-districts that developed into urban and trade centers such as Tangerang and Karawaci Districts. Generally, the cause of the reduced percentage in Tangerang City is the development of residential and trade areas.

Effect of changes in vegetation and population on the quality of the geophysical environment

Based on data from related institutions in the last 20 years as shown in Table 4, between 2000 and 2020, the ambient temperature and humidity in Tangerang City have increased. Meanwhile, the vegetation area showed a continuous decreasing pattern, while the population increased during this period (BMKG, 2021; Central Bureau of Statistics, 2021).

Statistical analysis on changes in the area and distribution of vegetation as well as the increase in population significantly affected the temperature heat index (THI) in Tangerang City. The decrease in vegetation area negatively correlated with the increase in THI (r: -0.947), while population growth positively correlated with THI (r: 0.975). Based on Table 4, it was shown that in 20 years, the physical environment conditions as described by the THI value increased, although at a slower rate. Figure 9 showed the pattern of changes in vegetation area, population, and THI of the city graphically in 5-year time intervals for 20 years. The THI value describes the comfort obtained based on human physiology related to the environmental conditions around. According to Hadi et al., (2012), THI is one of the indicators of comfort, which is reflected in the existence of green areas, indicating that cities with adequate vegetation areas are more comfortable than those with full settlements. The study by (Jing & et al, 2020)

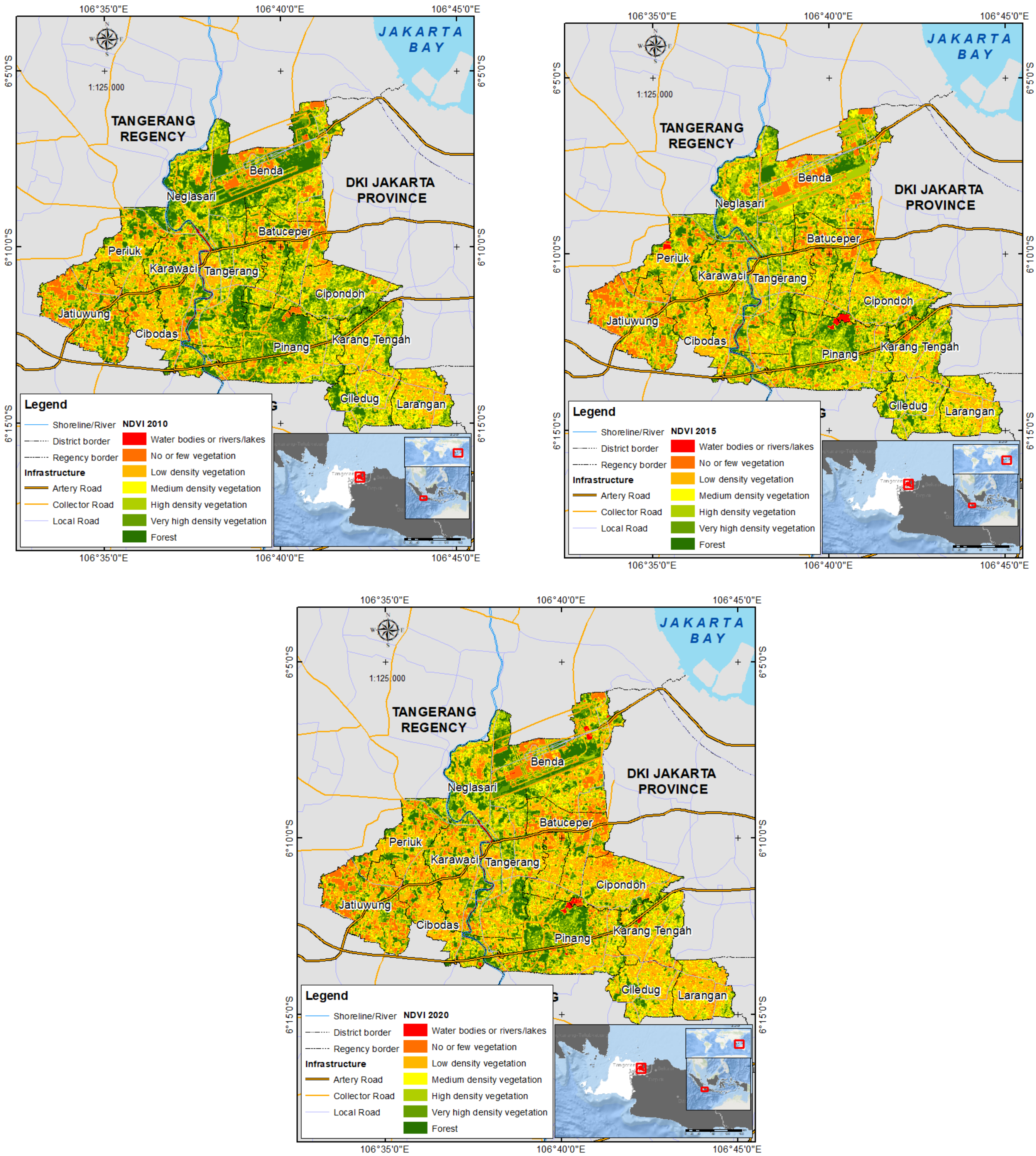

Figure 7. Changes in the area and distribution of vegetation (NDVI) during the last 10 years in Tangerang city (top Left: 2010; top right: 2015; bottom: 2020)

classified the level of thermal comfort as 21 ≤ THI ≤ 24 = 100% of respondents felt comfortable, 24 <THI ≤ 27 = 50% of respondents, while THI> 27 = 0%. This showed that the level of thermal comfort in the city for the last 20 years is still within the range of significant comfortable, although it has decreased. Therefore, until 2020, the city is grouped with a comfortable level of thermal comfort based on the THI value classification, which is around 26°C.

The movement pattern of changes and the correlation of THI variables, vegetation, and population in Tangerang City over the last 20 years (Figure 9) is in line with the previous report (Ganebnykhl, 2019) which stated that thermal comfort in an area is influenced by temperature and humidity. It also stated that temperature is a climatic factor, which affects human comfort, therefore, excessively high or low values will interfere with human activities. According to Hayati et al. (2013), the extent and density of vegetation affect micro-climatic conditions, namely air temperature and humidity, which impact the level of comfort. Meanwhile, areas in urban that are not balanced with sufficient green zones will affect micro-climate change in these areas and worsen environmental conditions (Oliveira et al., 2011). Green areas in urban areas play a role in influencing several elements of the microclimate to make it

Table 3. Physical Environment Spatial Pattern Characteristics of Tangerang City in 2020

Districts	Humidity	Building Density (%)	Order of Building (%)	RTH (%)	Road Accessibility index	Road Connectivity Index	Traffic Density	Disaster Hazard (Flood)	Population Density (per m^2)
Benda	79,657	17,2112	0,3139	44,28	0,3453	1,6777	0,2024	0,9826	17635,14
Neglasari	80,175	35,3516	0,4136	43,13	0,2997	1,5961	0,3923	1,0000	7425,37
Pinang	81,100	42,1906	0,4056	39,67	0,2539	1,5054	0,7495	0,9976	10022,09
Periuk	81,000	40,0438	0,4372	37,62	0,2660	1,5310	0,2422	0,9984	15805,45
Batuceper	81,108	53,6186	0,2303	33,52	0,2848	1,5621	0,5721	0,9910	8950,60
Tangerang	81,215	52,2767	0,5413	24,97	0,2939	1,5846	0,6106	0,9989	11793,35
Karawaci	81,238	49,4288	0,3573	24,58	0,2752	1,5491	0,4164	1,0000	13418,69
Cipondoh	81,250	52,7633	0,3603	23,03	0,2900	1,5759	0,7284	0,9983	18430,37
Jatiuwung	81,465	17,5227	0,3051	19,38	0,2923	1,5834	0,3957	0,9989	8655,79
KarangTengah	81,328	58,9723	0,2847	15,09	0,2813	1,5592	0,8880	0,9879	13867,14
Cibodas	81,286	52,9637	0,4648	14,36	0,2975	1,5935	0,5761	0,9838	16190,01
Ciledug	81,720	70,3133	0,2766	12,10	0,2946	1,5829	0,4078	0,9964	23305,02
Larangan	82,000	78,1646	0,3032	9,28	0,3097	1,6154	0,5873	0,9927	22150,32

Table 4. Temperature Heat Index, Vegetation, and Population

Year	THI (^{0}C)	Vegetation Area (Ha)	Total population (person)
2000	26.2752	11073.68	1311746
2005	26.4653	9114.04	1531666
2010	26.6278	7630.29	1797715
2015	26.6506	5064.07	2047105
2020	26.8582	4468.10	2274000

Source: BMKG & BPS

better and weaken or reduce the negative effects of increasing air temperatures in the region (Gomez et al., 2004). It was discovered that (Hamdani & Susanti, 2017) population density affected land use and increased air temperature in Malang from 1991 to 2016 by 49.6% on temperature changes and 50.4% increase by other variables.

This showed that changes in spatial patterns due to urbanization can affect air quality and the comfort of living. Therefore, with the continuing urbanization, there will be an increase in the THI value for the quality of the residential environment to reduce the level of thermal comfort. There is a need to consider the vegetation in DKI Jakarta and South Tangerang City, which are adjacent areas where the two cities have reduced green open space conditions. The increase in THI in Tangerang City due to changes in spatial patterns of vegetation and population density in the last 20 years is to reduce the present and future sense of comfort for activities in and around residential areas. This pattern will be applied to other cities in Indonesia because the changes in the area and distribution of vegetation as well as the population were in line with the city, although the rate of change is different. Therefore, serious attention needs to be given to the vegetation conditions and population control program for Tangerang and other cities.

Spatial environmental quality index per district

The level of quality of the physical environment of each district is assessed based on the magnitude of the spatial characteristics index, as shown in Table 5. These include building density, building regularity, and vegetation indices, road accessibility and connectivity, traffic and population density, as well as disaster potential index. This implies the higher the index value for each characteristic of the spatial pattern, the better the environmental capacity and function of the community.

The spatial pattern characteristic analysis results showed that the spatial environment quality index per district has varying values. The spatial environment quality index (IKLS) described the level of carrying capacity of the physical environment to provide comfort and health in residential areas. It implies the higher the IKLS value, the more comfortable and healthier the area. Regional environmental comfort (IKLS) is described from the earth's surface temperature and air humidity. The value is influenced by the percentage of green open space/vegetation, building and population density around the area. The transportation factors and industrial activities, which are described in form of accessibility, connectivity, and traffic congestion also contribute to the level of air quality. The increasing number of residential and industrial areas triggers the development of road networks, accessibility, connectivity, and traffic congestion. This indicates the smaller the vegetation area and the wider the built-up area, which increases earth's surface temperature, and decreases air humidity. Meanwhile, the comfort level of the regional environment will decrease. The statistical analysis results showed that air humidity had a significant correlation with the spatial environmental quality index (r = - 0.878), which indicated that the higher the spatial environmental quality index (IKLS), the lower the air humidity level. It was also

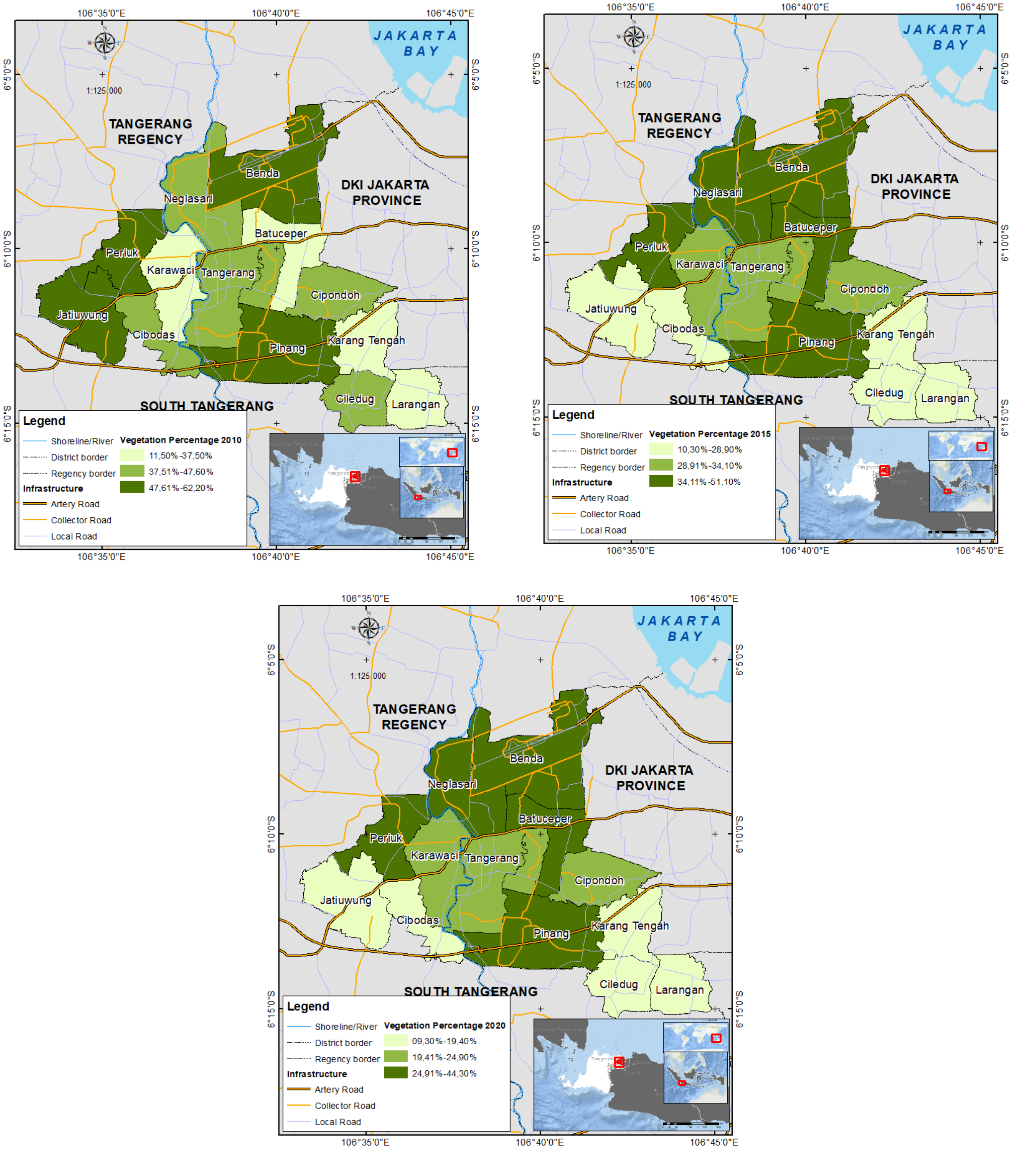

Figure 8. Percentage of Vegetation during the last 10 years in Tangerang City
(top left: 2010; top right: 2015; bottom: 2020)

discovered that air humidity and spatial environmental quality index correlated significantly with vegetation and building density levels. The level of road accessibility correlated with the connectivity of the area, while the two spatial variables have a low significant correlation with the humidity variable and the spatial environmental quality index for the settlements.

Based on the results of the IKLS analysis (Table 5), the IKLS can be grouped into three classes, namely the group I with index values ranging from 73.85 to 78.25, group II from 69.55 to 73.84, and group III ranging from 65.25 to 69.54. The grouping into 3 classes was processed using the Natural Breaks Map-Based method available on GEODA. The Natural Breaks Map method applies a nonlinear algorithm to group data in one dimension to maximize homogeneity within the data group to produce the class with the most significant internal similarity (Anselin, 2020), where the group with a higher average value indicated the better IKLS. Based on the IKLS value, Benda and Neglasari Districts have better spatial environmental quality indexes than other sub-districts. Meanwhile, the spatial environment quality index in Ciledug, Larangan, and Karang Tengah Sub-districts are

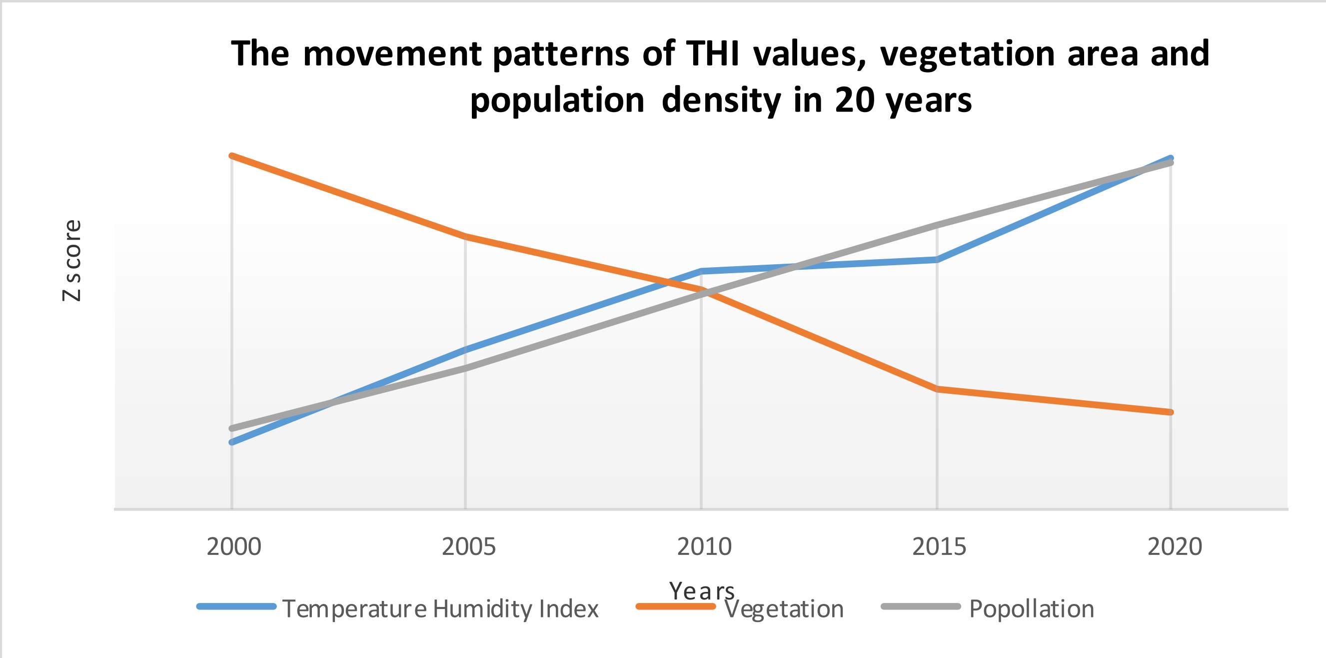

Figure 9. Changes in the movement pattern of THI values, vegetation, and population density over the last 20 years

Table 5. Spatial Environment Quality Index and its Components

District	Humidity	IKB	ITB	IVeg	IAKS	IKOV	IKLL	IPB	IKP	IKLS
Batuceper	79.892	9.67	8.51	10.60	9.72	9.62	9.74	10.54	11.08	69.85
Benda	81.343	11.73	9.46	11.48	12.46	12.38	11.59	11.90	9.37	77.98
Cibodas	79.714	9.71	11.18	9.03	10.29	10.37	9.72	11.72	9.65	71.30
Ciledug	79.280	8.73	9.04	8.84	10.16	10.11	10.56	9.67	8.25	65.25
Cipondoh	79.750	9.72	9.99	9.74	9.95	9.95	8.97	9.36	9.21	66.93
Jatiuwung	79.535	11.71	9.36	9.44	10.05	10.12	10.62	9.27	11.14	71.59
Karang Tengah	79.672	9.37	9.13	9.09	9.56	9.55	8.17	11.05	10.11	66.47
Karawaci	79.762	9.91	9.96	9.86	9.28	9.30	10.52	9.08	10.20	68.81
Larangan	79.000	8.28	9.34	8.61	10.85	10.89	9.67	10.26	8.48	65.49
Neglasari	80.825	10.70	10.60	11.38	10.39	10.43	10.64	9.08	11.38	74.18
Periuk	80.000	10.44	10.87	10.93	8.86	8.87	11.39	9.35	9.73	71.57
Pinang	79.900	10.31	10.51	11.10	8.31	8.26	8.86	9.47	10.87	69.44
Tangerang	79.785	9.74	12.05	9.90	10.13	10.15	9.55	9.26	10.52	71.15

Information:

IKB: Building Density Index
ITB: Building Regularity Index
IVEg: Greenness/Vegetation Index
IAKS: Road Accessibility Index
IKOV: Road Connectivity Index
IKLL: Traffic Density Index
IPB: Disaster Potential Index
IKP: Population Density Index
IKLS: Spatial Environmental Quality Index

relatively different compared to others. Considering the advantages and disadvantages or variations in the value of the spatial variables in the 13 Districts of Tangerang City and the value of IKLS, the rate of population addition and thermal comfort, the direction of spatial development per district are grouped into three areas as follows (Figure 10).

1. Areas with Group I IKLS include Benda and Neglasari Districts that have spatial characteristics with a building density index of less than 35%, a vegetation area above 40%, a low traffic density than other sub-districts, and a high population density of 7500-17000 per km^2. The development of these areas is directed at maintaining the area of green open space and controlling urbanization. Moreover, it is necessary to maintain the land use-resistant composition to prevent its conversion into an industrial area, since the two sub-districts are directly adjacent to Soekarno-Hata International Airport.
2. Areas with Group II IKLS include Batuceper, Cibodas, Jatiuwung, Periuk, and Tangerang Districts, and are characterized by building density levels ranging from 40 –53%, vegetation area between 23-39%, and population densities ranging from 9000–19000 per km^2, with an elite residential area, a business and trade district. Therefore, the development of this area aims to add public green open space as an ecological and architectural function in form of green roads along arterial and primary collector roads. It is also necessary

Table 6. Correlation of humidity and between spatial variables

		Humidity	IKLS	KpB	Veg	Aks
Humidity	Pearson Correlation	1	-.878**	-.712**	-.843**	-.421
	Sig. (2-tailed)		.000	.006	.000	.152
	N	13	13	13	13	13
Spatial Environmental Quality Index	Pearson Correlation	-.878**	1	.840**	.741**	.642
	Sig. (2-tailed)	.000		.000	.004	.030
	N	13	13	13	13	13
Building density (KpB)	Pearson Correlation	-.712**	.840**	1	.663*	.189
	Sig. (2-tailed)	.006	.000		.014	.536
	N	13	13	13	13	13
Vegetation (Veg)	Pearson Correlation	-.843**	.741**	.663*	1	-.006
	Sig. (2-tailed)	.000	.004	.014		.983
	N	13	13	13	13	13
Accessibility (Aks)	Pearson Correlation	-.421	.642	.189	-.006	1
	Sig. (2-tailed)	.152	.030	.536	.983	
	N	13	13	13	13	13
Connectivity (Kov)	Pearson Correlation	-.403	.639	.188	-.031	.998**
	Sig. (2-tailed)	.172	.033	.538	.920	.000
	N	13	13	13	13	13

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

to improve the existing green open space by adding shade trees using cover plants that can absorb pollution, such as *Angsana* (Rosewood/*Pterocarpus indicus*), *Trembesi* (Monkeypod tree/*Samanea saman*), and *Tanjung* (*Mimusops elengi*), and other types of ornamental plants to beautify the city. Furthermore, there is a need to control the expansion of residential and business areas to control urbanization and increase the population.

3. Areas with Group III IKLS include the Districts of Pinang, Ciledug, Cipondoh, Karang Tengah, Karawaci and Larangan. These areas have a building density ranging from 50 to 78% and a minimum vegetation area that ranged from 9 to 15%. Therefore, additional green open space is required to increase IKLS, which is directed as a social function and ecological function in green open space for parks and urban forests covering various recreational and sports facilities, or in form of a green belt. The choice of plant types includes shade crops that produce much oxygen, such as "*Ketapang Kencana*" (*Terminalia mantaly*), flamboyant trees (*Delonix regia*), "*Tanjung*" (*Mimusops elengi*), and "*Kiara Payung*" (*Filicium decipiens*), and ornamental plants for beauty and grass. Due to the high population and building density, it is not advisable to expand settlements and increase the population, even when it is possible to refuse some of the built areas into RTH.

Based on the analysis of the area and improving the quality of the physical environment by increasing the capacity of thermal comfort in Tangerang City, the main solution is controlling urbanization and settlement expansion, and adding green open space. This is in line with the results of Nurhidayat & Marwasta (2018), where high air temperatures cause elevated THI values, which can be reduced by implementing good settlement governance. This can be realized through the arrangement and addition of green open space, which is proven to reduce air temperature and the THI value of an area. According to Minister Regulation No. 7 of 2007 on the Arrangement of Green Open Space for Residential Areas, one of the benefits of green open space is to improve the microclimate of a region. Theoretically, the addition of green open space is crucial because vegetation has a significant influence on ecological aspects such as microclimate and thermal comfort. The trees also absorb solar radiation, provide shade, and carry out transpiration to lower air temperature and increase air humidity. In Indonesia, this phenomenon showed that increasing the population and economic development of a region will indirectly change land use. The expansion of settlements and industrial or business areas will accelerate the process of land-use change or reduce the area of vegetation such as a decrease in agricultural land, fields, shrubs, and forests. Land conversion from green open space to developed land has led to the emergence of the Urban Heat Island (UHI) phenomenon in urban areas, therefore, the percentage of vegetation cover is the most important factor to reduce the effect of UHI (Wibowo et al., 2013; Zhou et al., 2011). Meanwhile, assuming the conversion of vegetation land to non-vegetation is continuously allowed in the long term, it can lead to changes in the microclimate, which will affect several major cities in the country. The results indicated that the Eco-settlement concept still requires a lot of time to be achieved in the future. Therefore, further studies of a kind and massive nature are needed to prepare an integrated model and system for improving environmental quality. This is because eco-settlement is not a concept built on only one or various aspects, but a system. Eco-settlement is a

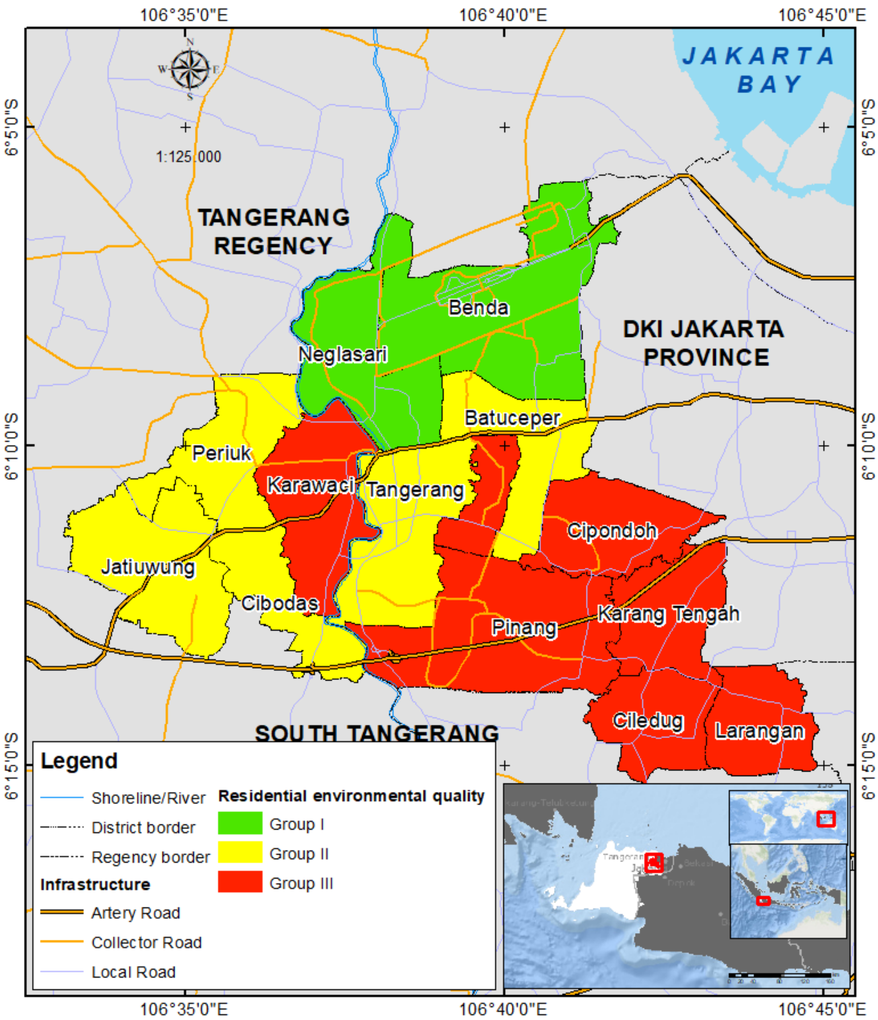

Figure 10. Map of environmental quality assessment results in each sub-district in Tangerang City

settlement arrangement concept by harmonizing social, economic, and ecological aspects toward ecosystem sustainability supported by a capable institutional system (Suryani, 2016). This indicates to support a capable system in the future, an investigation of spatial characteristics in several cities with high population densities needs to be carried out.

4. Conclusion

This study showed that in the last 20 years, the temperature heat index (THI) of Tangerang City, Indonesia, has increased by 0.583°C, while the area of vegetation has decreased by 6605.58 hectares, and the population increased by 962254 people. The changes in vegetation area and population significantly affect variation in THI. Although the current thermal comfort index for the city is still in a fairly comfortable range (<27°C), there is a need to control over decreasing vegetation area and increasing population. The changes in the characteristics of spatial patterns significantly affected variation in THI in the city, namely building density, vegetation area, accessibility, and road connectivity. The spatial environmental quality index (IKLS) has a positive correlation with the level of humidity, therefore, the higher the IKLS value, the greater the humidity and the lower the air temperature.

Generally, Tangerang City still requires planning in terms of regional development to improve environmental quality. Therefore, the direction of development is recommended to control the level of urbanization and expansion of settlements as well as the need for additional green open spaces, specifically in the Districts of Pinang, Ciledug, Cipondoh, Karang Tengah, Karawaci, and Larangan.

Based on these results, it is recommended that the Regional Government of Tangerang City establish sustainable policies and disseminate information to the public about the addition of green open spaces and controlling urbanization. Furthermore, the assessment of the environmental quality index based on the spatial pattern characteristic approach needs to be refined by adding to the socio-economic variables of the community in the study location.

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