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Factors Affect of Urban Heat Island from City form and City Function in Downtown Surabaya City (UP. Tunjungan)

Evlina Noviyanti
Departement of Architecture
Sepuluh Nopember Institute of Technology
Indonesia

Adjie Pamungkas
Departement of Urban and Regional Planning
Sepuluh Nopember Institute of Technology
Indonesia

Eko Budi Santoso
Departement of Urban and Regional Planning
Sepuluh Nopember Institute of Technology
Indonesia

***Abstract*—Surabaya City has a fluctuating temperature increase from 1980 to 2014, with a concentrated spatial pattern from north to south, namely the downtown area. BMKG's data explains that Surabaya has an average surface temperature of 36ºC in October 2014, as well as daytime temperatures at the location point Tunjungan Plaza, Pasar Turi and Jl. Pahlawan, which is up to 41°C. More than 26°C of Temperature Relative Humidity (THI) would create an uncomfortable environment. Urban Heat Island (UHI) can be seen by the city form and city function. City form is determined by the geometry, material usage, and open green space. While the city function can be seen from energy use, water use, and pollution of an area. As an economy strategic area and urban core activity, it is important to determine the cause of rising temperatures, by knowing the city influence the form and function of the temperature of the surface of the city which resulted in the CBD area UHI Surabaya, which is UP.Tunjungan.**

The research's methods are mapping the surface temperature of Surabaya's CBD area (UP, Tunjungan) with TIRS (Landsat 8), analyzing the characteristics of city form and city function (of UP. Tunjungan), then analyzing factors affects the surface temperature by multiplying linear regression analysis. The average allowance ranged between 30.12 - 35.71ºC. Temperature in excess of 33^{0}C indicates the occurrence of UHI. The hottest temperatures are in the area of dense settlement and trade service. Green space may decrease the local temperature from 1,13-1,76ºC, while rivers may decrease local temperature 0,88-1,72^{0}C. Temperature surface of UP. Tunjungan has tendency of having higher temperatures during the day rather than the average temperature in the daylight and night. UHI is caused by the SVF value, the extent of the river, building height, CO_2 emissions of settlement activities, transport and trade and service.s

Keywords—City Form; City Function; Land Surface Temperature; UHI.

I. INTRODUCTION

Climate change is the change in climate that is attributable directly or indirectly to human activity causing global changes in atmospheric composition and in addition also be changes to natural climate variability observed in the period that can be compared [1]. The increasing of urbanization, land use change and human's activities are taking a big part in requiring enormous energy of the city. Emissions of heat from urban surface materials cause temperature differences between urban and non-urban areas. This situation, commonly called the urban heat island (UHI) [2]. Part of this energy is lost as heat and this heat accumulates because trapped by the urban structure (building height, building materials, urban structure, the size of the city, the urban greenhouse effect) [3]. If the average seen decades the average temperature of Surabaya fluctuating temperature increase as can be seen in Fig 1 below.

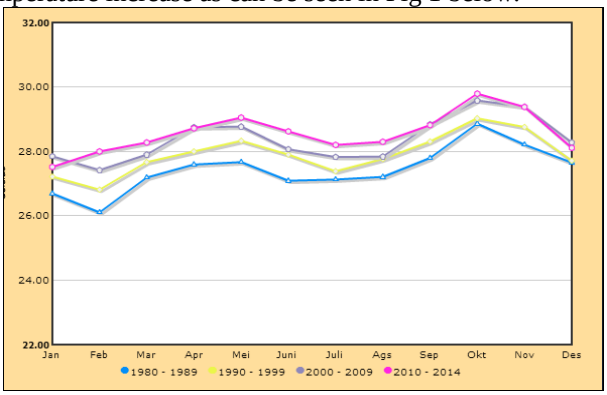

Fig 1. Average Temperature Fluctuations in Surabaya from 1980 to 2014

The temperature difference between the parts of the city with other parts such as the tendency of the polar summer in some locations such as the street in front of Tunjungan Plaza, Pasar Turi and Jl. Hero daytime temperatures can reach 41 ° C while the minimum temperature reached 26 ° C, which tend to be in the center of the city and decrease the temperature further away from the city center [4]. According to BMKG's data (Badan Metereologi, Klimatologi, dan Geofisika), Surabaya's current temperature reaches 36ºC on October 24th 2014. Based on the classification of satellite imagery in 2011 classification of the surface temperature of land Surabaya based research [5] almost 58% area in the city of Surabaya has a surface temperature> 32ºC, and mentioned that the temperature of the land surface (SPD) in the city of Surabaya in 1994 , 2000 and 2011 has the same spatial pattern relative to the development of urban areas, where high wiayah SPD (region UHI) tends to be concentrated in the center of

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the city from north to south. Rising temperatures in urban areas creates an uncomfortable environment for the community [6]. This is evidenced by Tursilowati states that the visible inconvenience for air temperature Surabaya has Temperature Relative Humidity (THI)> 26 [7], where more than 26 is a zone of discomfort in Surabaya.

The research object viewed from two major causes of urban heat island that forms the town or city form (material, geometry, greenspace) and the function of the town or city function (energy use, water use, pollution) [8].

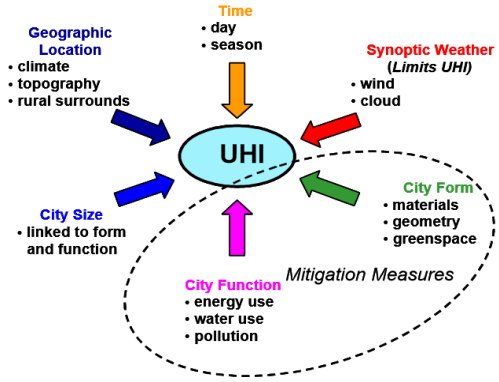


Fig 2. City Function and City form in Mitigation Measures for the scope of research Source: Oke (Pers.comm.)

It is important to know what factors that affect urban heat island. The first analytical stage is determining the surface temperature, then analyzing characteristics of city form and city function, and last is analyzing factors that affect urban heat Island.

II. METHODOOGY

A. *Population*

The analytical unit is shown as pixels of a grid 1 km x 1 km = 1 km^2, or 10 hm x 10 hm = 100 Ha. There are 28 analytical units which includes the administrative unit of UP. Tunjungan (CBD area of Surabaya).

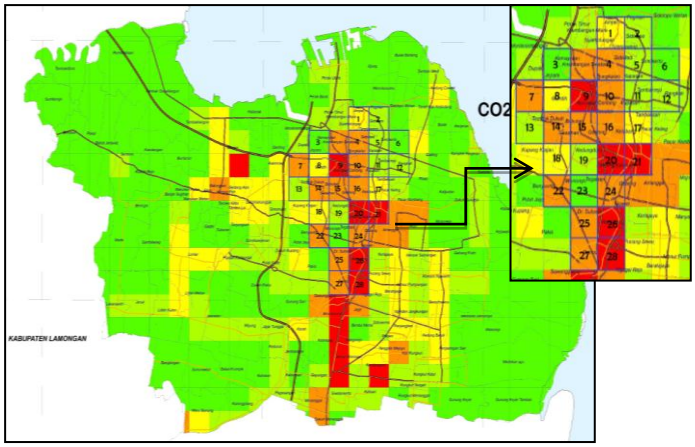


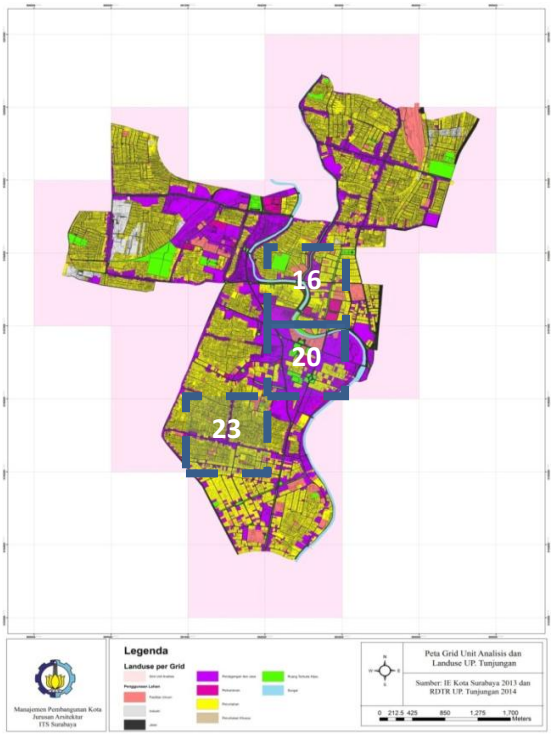
Fig 3. 28 Grid of Population in unit analysis

B. *Sample*

The sampling technique is using the probability proportionate method to ~~size~~ measure sampling, or commonly known as proportional random sampling method in UP. Tunjungan. Proportional random sampling method is developed ~~of~~ methods of (cluster sampling) where the sample size can be determined by assuming grouping sample and distributed evenly throughout the group in accordance with the ratio of the size sub-populations between units samples (Semendison, 2006).

Sampling using cluster sampling technique by means of sampling by the group, through two stages: stage 1 and stage 2. Stage 1 is from 28 the number of Grid, taken 3 Grid based on the dominance of land use which mix used land use dominance, dominance of trade and services, as well as the dominance of settlements in UP. Tujungan's grids namely 16, 20, and 23.

Second Stage regrouping 3 grid by grouping types of single use, double use and mixed use in the land use In a selected grid which are sub-grid Grid 16 289 units, as well as on the grid 20 and grid 23 (sub-grid box size 60x60).



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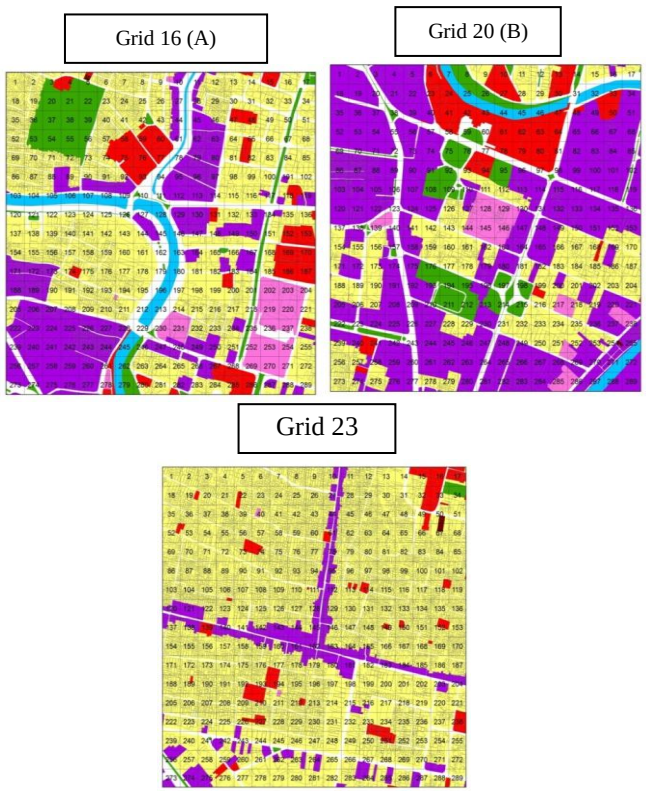
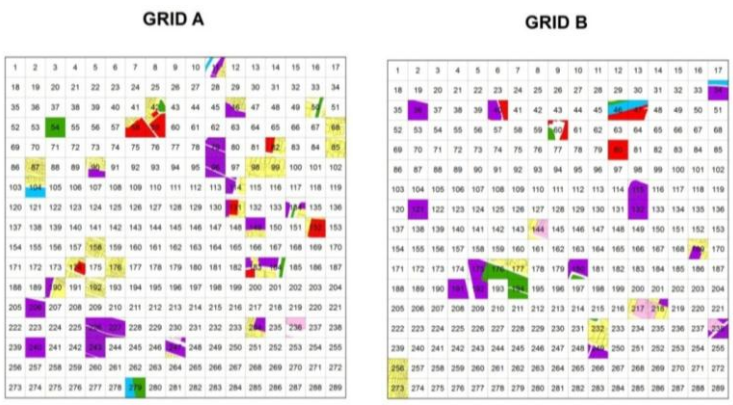


Fig. 4 Grid of Sample in unit analysis

Subsequently determined sampling locations as many as 90 points in every code grouping land use so that the resulting image dots sampling on grids A, B , C, as in the image below. Based on three the location of the sample grid (A, B, and C) grouped in a single land use, two types of land use, and land use on any 3 sub grid, the sheer number of sub-grid of 867 (289x3). Grouping aimed as a basis in obtaining samples ~~in~~ for each group. For example in 867 sub grid, there are 122 sub grids with the use of single use (trade and services), so that the sample formula, the number of samples for trade and services is at 13 points randomly selected sub grid.



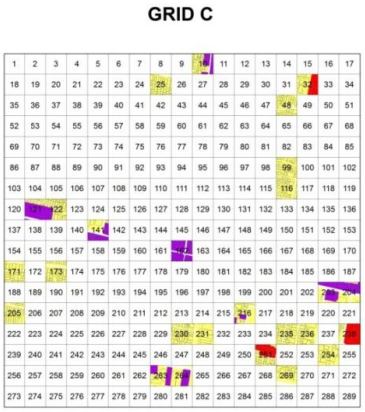


Fig 5. Subrid of Sample Grid in unit analysis based on the grouping of the single used, double used, dan mixed used

C. Stages of Analysis

TABLE 1 Stage of Analysis

No	The Analysis Stage	Data Input	Analysis Tools	Output
1.	Mapping the surface temperature in the CBD area of Surabaya (UP. Tunjungan)	Variables from literature review	TIRS (Landsat 8) dan Arc Gis Software	Knowing the surface temperature in UP. Tunjungan, so as to obtain a map of the surface temperature on each sub grid sample areas
2.	Analyzing the characteristics of city form and city function in the CBD area of Surabaya (UP. Tunjungan)	Variables were obtained from literature review	descriptive statistics	Characteristics city form and function resulting from observation and secondary survey, which was then analyzed to produce detailed information in the form of pie charts
3.	Determine the factors that affect the temperature of the surface based on the city form and city function	Result from the 1st and 2nd analysis	Minitab, Regression analysis and interpretation of results	Knowing the city of variables influence the form and function of the city Y is the surface temperature, which is then amplified by the interpretation of results.

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D. Mapping the Surface temperature in The CBD area of Surabaya

TIRS sensors (Landsat 8) is able to record data on the Earth's surface heat radiance thermal infrared spectrum. The information on the heat radiance thermal spectrum is strongly influenced by the surface temperature and emissivity of the object. The higher temperature of an object, the higher intensity of radiance is. Thermal sensor radiance information captured and stored in digital form number (DN) with a range of 0 until 255 (8bit) for data TM / ETM + and 0 to 65536 a. (16 bit) for data TIRS. Here is a list of 9 bands contained on OLI sensor. In the land surface temperature measurement used software ArcGIS 10, the phasing:

1. Download an image of Landsat 8 in September 2013, on earthexplorer.usgv.gov
2. Install the software ArcGIS 10
3. Clipping using raster processing namely Grid research areas A, B, C (which there has been cut into 60x60m)
4. Band-clipping 2,3,4,5,10 from raster to shp.
5. Looking for NDVI (sensitivity level RTH) with a range of values (-1 until 1)
6. Mapping temperature using 10 bands of image data of September 2013, capable of measuring thermal by entering constants or formulations through "Raster Calculator", with the following phases:
   a. Using the formula so that there is constant LST results in the form of constant radians
      0.0003342 * Band10 + 0.1 ----------> (1)
   b. sing the formula constants that are the result of LST in the form kelvin
      1321.08 / Ln (774.89 / "Band10Radiance" +1) - 272.15 ----------> (2)
   c. Looking for value "e" of the data NDVI
      Calculate PV (Proportion of Vegetation) with the formula:
   - Pv = (NDVI-NDVImin / NDVImax-NDVImin) 2
     PV of the data used to know value of e
   - e = 0.004Pv + 0986
   d. Then the last stage resulted LST Landsat 8 in the form Celsius (using constants)
      LST = BT / 1 + W * (BT / p) * Ln (e) ---------> Formula Land Surface Temperature
      Where p = 14380
   e. Creating Measuring Sub Grid 60x60 meters on each sample ~~ie~~ 16,20,23 in each grid are 289 sub grid)
   f. Then sort the temperature data at sub grid 1-289 on each grid to see the distribution of surface temperature.
   g. LST processed to re-enter on any grid so that every sub grid contained in the surface temperature value 4
   h. Do zonal statistical process to obtain temperature values at each sub grid 60x60

E. Analyzing the Characteristics of City Form and City Function in The CBD area of Surabaya (UP. Tunjungan)

Descriptive statistic are methods relating to the collection and presentation of a range of data to assess the quality of data is a type of variable, summary statistics (mean, median, mode, standard deviation, etc), distribution and pictorial representation (charts), with no formula probabilistic any (Walpole, 2993 Correa-Prisant, 2000; Dodge, 2006).

Descriptive statistical analysis was conducted to determine the characteristics of city form and city-related function on every variable that is inside. The data of the first 90 samples carried out the preparation of a frequency distribution table for each variable, where the frequency distribution table is an analysis of the ~~process of~~ grouping data into categories that indicate data amount in each category. At a later stage the presentation of the frequency distribution for each variable city form and city function presented in the form of graphs, pie charts and radar. Then the final stage of descriptive statistics is calculating to conclude the characteristics of the data.

F. Determine The Factors That Affect The Temperature Of The Surface Seen From The City Form And City Function

Multiple linear regression analysis is used to obtain the influencing factors. It determines the effect of multiple independent variables (x) to one dependent variable (y). The general equation is:

$$Y = a + b1 + b2\ X1\ X2 + ... + bn\ Xn$$

Where :
Y = the dependent variable
X = the independent variable
a = constant intercept
b = regression coefficient on the independent variable

The stages of multiple linear regression analysis in this study is to test the classic assumption (normality test, multicoloniarity and heteroscedasticity test) and hypothesis testing, where the stages will be using the program Minitab. With variable independent increased use of electrical energy (X1), CO2 emissions activities of settlement (X2), emission CO2 trade and services (X3), emission CO2 office complex (X4), emission CO2 road transport (X5), the percentage of water infiltration into the soil (X6), road length using asphalt (X7), road length using paving (X8), the density of the road network (X9), distance between buildings (X10), the average height of buildings (X11), building density (X12), the value of SVF (X13), the percentage of green space (X14), residential area (X15), area trade and services (X16), area office complex (X17), area public facilities (X18), the extent of the area through which the river flows (X19), the extent bozem or rainwater (X20). And variable independent (Y) is the surface temperature in the CBD area of Surabaya (UP. Tunjungan).

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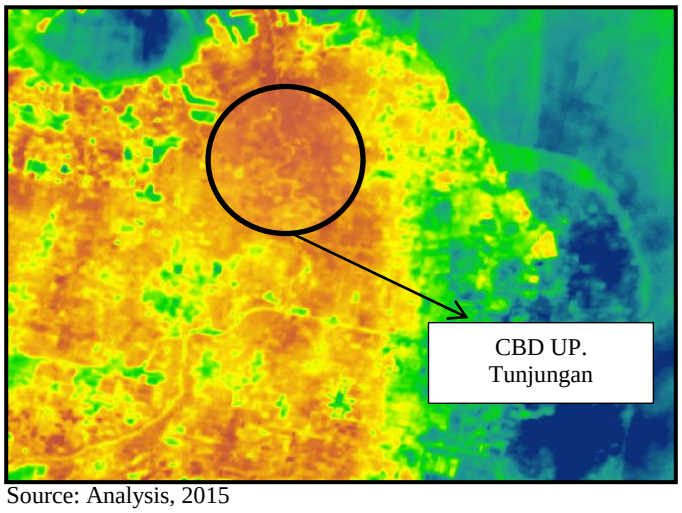
III. DISCUSSION

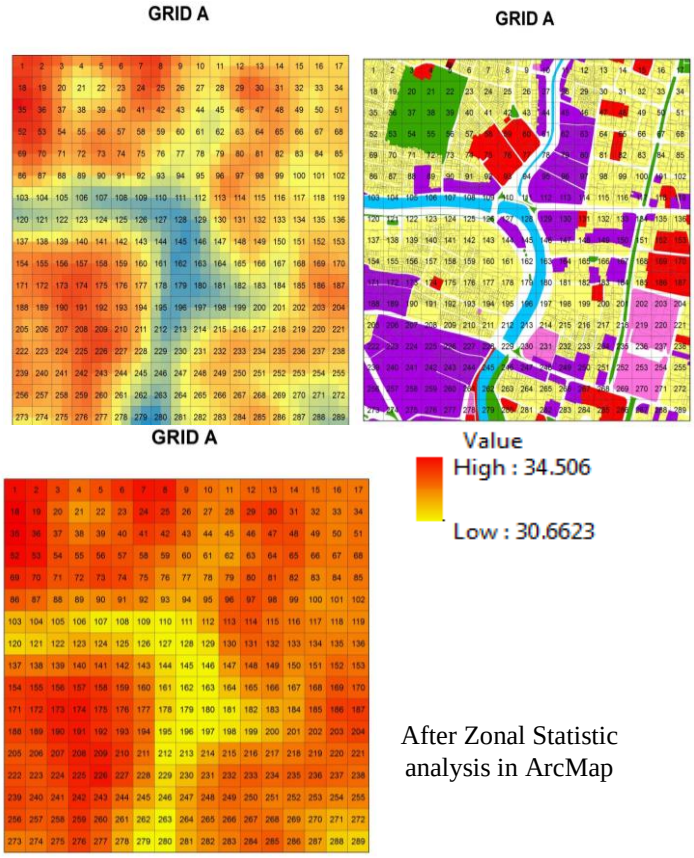
A. *Land Surface Temperature in UP. Tunjungan (CBD Surabaya)*

Surface temperatures in the figure below 1.6 indicates that the downtown area has a fairly uniform distribution of temperature and concentrated in the downtown area to area development unit of Tanjung Perak.



Source: Analysis, 2015

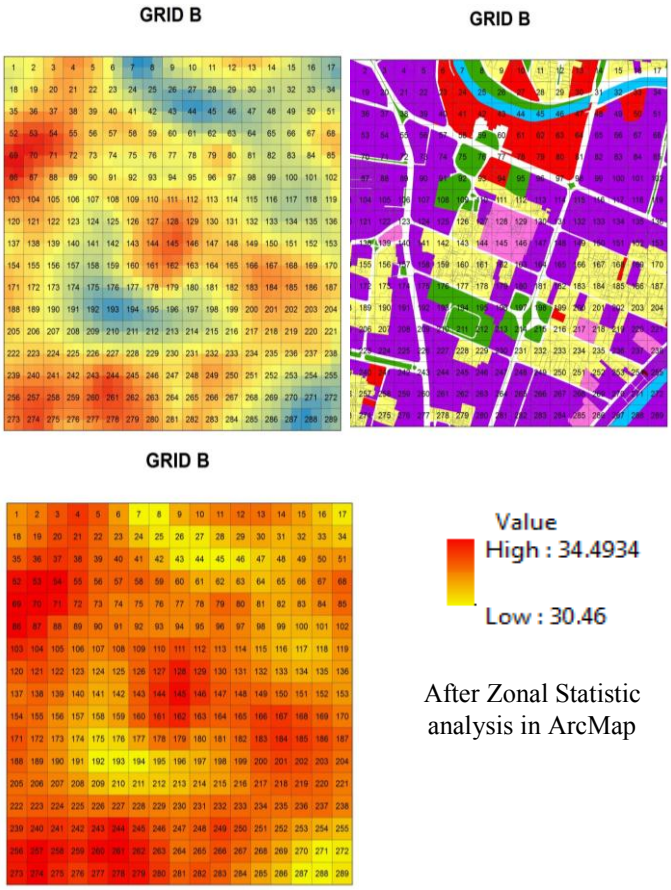
Downtown area has a surface temperature in each sub-grid diverse research areas, temperatures ranged from 30.12 to 35.71 ° C. This condition is an average temperature that occurred in the morning, noon, and night.



After Zonal Statistic analysis in ArcMap

Source: Analysis, 2015

A grid is a representative selection of the location with the dominant land use mixed use. Based on the analysis of temperature LST on the grid A has the highest temperature in UP. Tunjungan is 34.50ºC and the lowest temperature is 30.66ºC. Grid A shows the tendency of warmer temperatures or high temperatures found in a central area of trade and services as well as the center of densely populated settlements, in this case where the river becomes an important point in a decrease in the temperature of the surrounding region, it appears that the watershed have temperatures cooler than the surrounding area.



After Zonal Statistic analysis in ArcMap

Source: Analysis, 2015

Grid B is a representative selection of the location with the dominant land-use trade and services. Based on the analysis of temperature LST on the grid and had the highest temperature of 34.49ºC and the lowest temperature is 30,46 ºC. On the grid and seen that the trend of warmer temperatures or high temperatures in the central business district and intensive services as well as the center of densely populated settlements, in this case the presence of green space and the river become an important point in decreasing temperature of the surrounding region. It appears that the watershed has a cooler temperature than the surrounding area.

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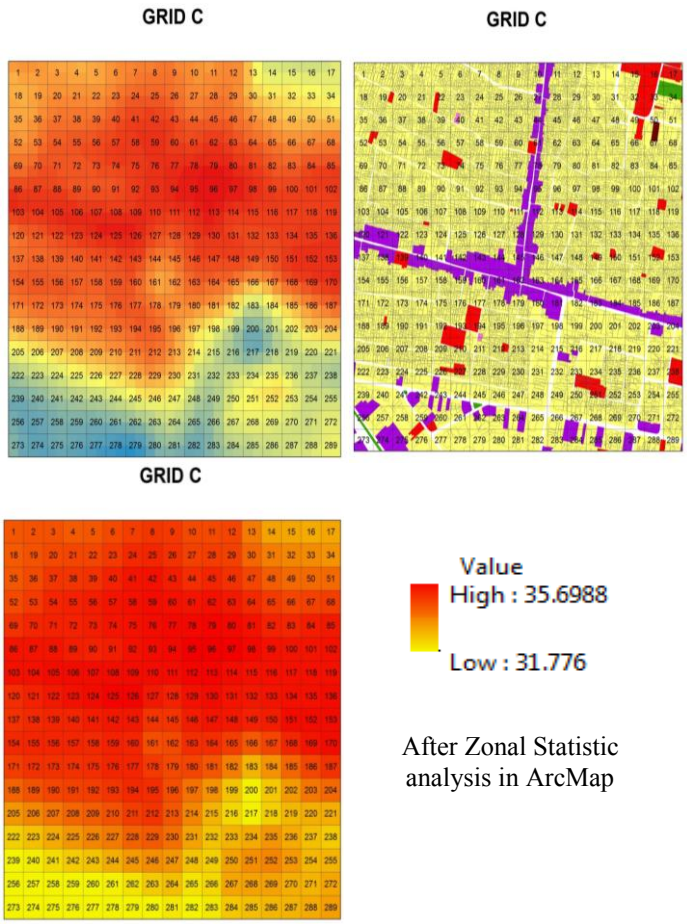
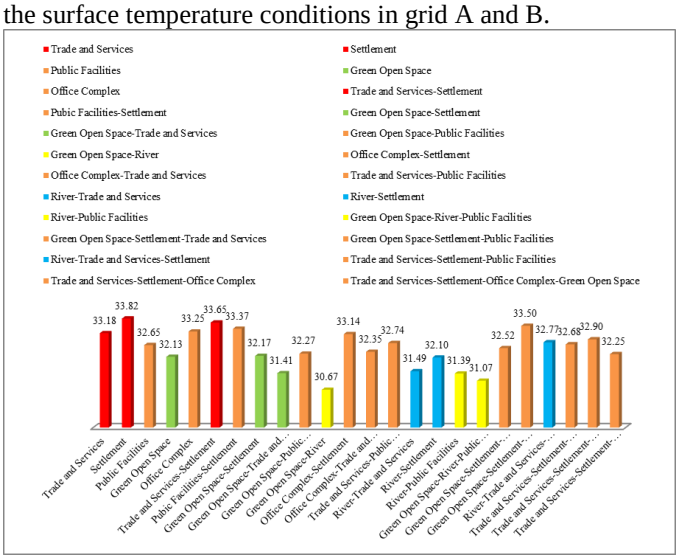


After Zonal Statistic analysis in ArcMap

Source: Analysis, 2015

Grid C is a representative selection of the location with the dominant land use settlements. Based on the analysis of the grid C temperature LST had the highest temperature is 35.69ºC and the lowest temperature is 31.77ºC. On the grid C seen that the trend of warmer temperatures or high temperatures found in the central region of the center of densely populated settlements, in this case the presence of green space and RTH median of the road becomes an important point in a decrease in temperature, but its existence minimal, so the conditions in the area of grid C to hotter than the surface temperature conditions in grid A and B.



: The group with the lowest temperature Order

: The group with the highest temperature Order

: Temperature comparator land use in the presence of green space to the group Highest Temperature

: Temperature comparator land use with the watershed of the Group Highest Temperature

TABLE 2. Temperature Decreasing Affected By Land Use Green Open Space

No.	Group	Starting Temperature (ºC)	Effect Of The Green Open Space Land Use (ºC)	
			Starting Temperature	Decrease In Temperature
1	Settlement	33,82	32,17	1,65
2	Settlement-Trade and Services	33,65	32,52	1,13
3	Trade and Services	33,17	31,41	1,76

Source: Analysis, 2015

TABLE 3. Temperature Decreasing Affected By Land Use Presence River

No.	Group	Starting Temperature (ºC)	Effect Of The River Land Use (ºC)	
			Starting Temperature	Decrease In Temperature
1	Settlement	33,82	32,10	1,72
2	Settlement-Trade and Services	33,65	32,77	0,88
3	Trade and Services	33,17	31,49	1,68

Source: Analysis, 2015

It can be concluded that, a land use with the highest temperature that is subgrid settlement, subgrid trade and services, as well as settlements that have the highest surface temperature would be cooler if its contain streams which capable of lowering the surface temperature of about 0.88 to 1, 72ºC. The existence of land use in the group of double use or mixed use which are green open space inside make subgrid at the sample location is becoming colder, than at locations of undeveloped land in the absence of open green space in it, such as the use of land with the highest temperature that is settlements and trade and services that have the highest surface temperature will be colder and lower the temperature almost 1,13-1,76 ºC. The existence of undeveloped land in which there are rivers and open space green meal will lower the temperature 3,15-2,50ºC Based on the overall results of testing on multiple regression residuals assumptions, it can be concluded that the residual has met the assumption of independent, normally distributed, and does not meet the assumption of identical or possess residual heterogeneity.

B. CharacteristicCity Form and City Function in UP. Tunjungan (CBD Surabaya)

City Function

- The optimum soil water infiltration was on land use infiltration RTH with a power of 48% (standard)
- CO2 emissions of the average office 0.01104 ton / year
- The use of electrical energy in land use of commerce and services, namely in hotels, offices and malls
- Nearly 70% on every sub-grid sample areas have

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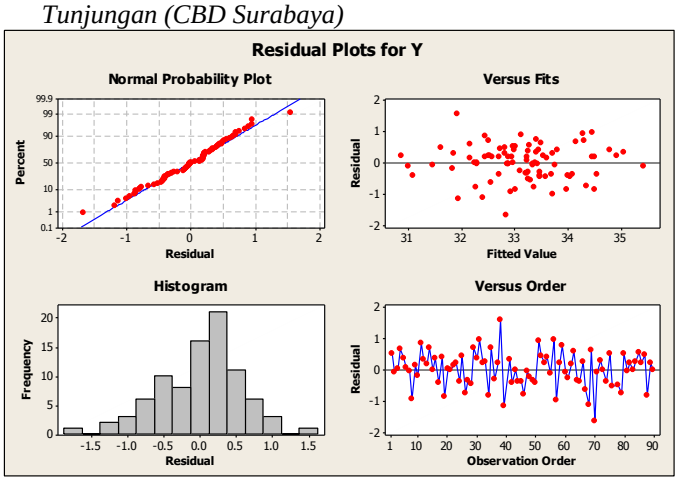
emission's settlement, which indicates the dominance of land use in the form of settlements. Average emissions settlements is 3,331 tons / year, the minimum value is 00:00 tons per year, while maximum emission of settlement activity is 8.274 tons / year

- Almost 45% of the data obtained in each sub-grid region of the samples had emission trade and services. Emissions trading and the largest services based on the sample data contained in ~~mall~~ Tunjungan Plaza Mall 1-5 as well as the hotel. Average emission of trade and services area is 0.1279 tons / year, the minimum value is 0:00 tons per year, while the maximum emission of trade and services area is 1.6476 tons / year
- Average emissions of office is 0.01104 tonnes / year, the minimum value is 0:00 tons per year, while the maximum emissions from the activities office is 0.4352 tons / year

City Form

- Nearly the whole pavement in UP. Tunjungan using asphalt pavements
- Paving pavement found in the village, as well as the path to the park jaan
- Green space area, the largest tomb in the form Peneleh, parks achievement, and solar parks, gardens, expression
- The river that passes through UP. Tunjungan is Kalimas River, where, a wide cross-section of the river surface Kalimas River between 20-35 m with a depth of 1-3 meters. River depth is at least in the region until the tile Monkasel
- The building has an average height of 8.44 meters, 8 meters or 2 floors are commonly found in residential land use settlement or settlement with medium or large plots. For the minimum altitude is 0 meters contained in parks or green space areas. The maximum height reached 60 meters, which is the form of the hotel building.
- The average height of the highest buildings are in category 0, is there is no distance between buildings

C. Factors That Influence the Urban heat Island in UP. Tunjungan (CBD Surabaya)



The equation obtained is:

$$Y = 33.8 - 1.54\ X13 - 0.0379\ X11 - 0.000794\ X19 + 0.000096\ X5 + 0.0944\ X2 + 0.538\ X3$$

Based on the results of linear regression analysis, there are six variables that affect surface temperatures in UP. Tunjungan. With the current value of the constant temperature is 33.8 0C. X13 influential variable is the value of the SVF (sky view factor), X11 is the average height of the buildings, X19 river area, X5 is the CO_2 emissions of the transportation, X2 is the CO_2 emissions of settlements, and X3 is the CO_2 emissions trade and services.

a. Sky View factor (SVF)

Sky view factor influence negatively, if the initial temperature will be reduced to 32,260C 33,80C, theoretically explained that the sky view factor close to 1 indicates the more sky that can be seen, the number 1 indicates the sky visible 180 degrees, so versa closer the number 0, indicating that the sky becomes less and less visible or not visible. Based on the simulations carried out by looking at the sky more visible (simulated with the number 1) which can reduce the temperature by 1.54 degrees Celsius, from the initial temperature 33,80C.

b. Average Height Of Buildings (X11)

Based on the results of the regression model generated, the height of the building into points in a decrease in temperature, which negatively affects the increase in surface temperature, which is based on simulation of every high-rise building which is as high as 8 meters (2 floors) on a certain building, will reduce surface temperatures in the area, From the initial temperature 33,80^{o}C be 33,49^{o}C.

c. River Area (X19)

Area of the river has a negative influence on the surface temperature, where any rise in the river area ha, which simulated the existence of an additional 1,000 m^2 area of the river, it will decrease the temperature of the surface from 33.00 to 33.80 the initial temperature. This condition almost lowers the temperature by 1^{0}C.

d. CO_2 Emission of Transportation (X5)

In simulated simulation if there is an increase of 25 tons / year of emissions from transportation activities, it will cause the initial temperature should increase to 33.8024 33.8 ^{o}C.

e. CO_2 Emission of Settlements (X2)

CO_2 emissions settlements have a role in increasing the temperature of the surface where, if there is an increase simulated 20 ton / year of emissions, it will cause the initial temperature should be 35.68 to 33.8 ^{o}C. In the existing condition, dense settlement in Grid C (23) has coined the maximum temperature at which the above conditions 35,6^{o}C.

f. CO_2 Emission of Trade and services (X3)

CO_2 emissions trade and services have a role in the increase in surface temperature, whereby if there is a simulated increase of 5 ton / year of emissions, it will cause the initial temperature should be 36.49 to 33.8 ^{o}C.

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IV. CONCLUSION

Downtown area has a surface temperature in each sub-grid diverse research areas, temperatures ranged from 30.12 to 35.71°C. This condition is an average temperature that occurred in the morning, noon, and night. Watershed decrease the surface temperature of settlement and also trade and services area from 0,88 to 1,72ºC. Area with green open space land use decrease the surface temperature of settlement and trade and services area from 1,13 to 1,76ºC. The existence of undeveloped land in which there are rivers and open space green meal will ~~lower~~ decrease the temperature from 3,15 to 2,50ºC.

Based on the linear regression analysis results, there are six variables that affect surface temperatures in UP. Tunjungan. Those are X13 SKV (sky view factor), X11 is the average height of the buildings, X19 is river area, X5 is the CO_2 from the transportation emissions, X2 is the CO_2 from the settlements, and X2 is the CO_2 emissions trade and services. Sixth influential factor with 10% confidence interval.

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