Correlation Analysis of PM10 Air Pollution with NDVI (Normalized Difference Vegetation Index) Based on Landsat-8 and Sentinel-2A Satellite Images. (Case Study: Bandung City, West J...

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Correlation Analysis of PM10 Air Pollution with NDVI (Normalized Difference Vegetation Index) Based on Landsat-8 and Sentinel-2A Satellite Images.

(Case Study: Bandung City, West Java)

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Abstract

Abstract. Dust particulates in the air Suspanded Particulate Matter (SPM) is a mixture of various organic and inorganic compounds with small diameters ranging from <1 micron - 500 microns. Pertikulat (PM10) is an air particle that is less than 10 microns in size. This study correlates the NDVI vegetation index with PM10 in Bandung, West Java in 2001 - 20019 from these results show the relationship between NDVI and air pollution index is negative or inversely proportional, which means the higher (+) NDVI, the air pollution index decreases (-) with a confidence level of 39.35% in 2001, 45.13% in 2006, 60.04% in 2011, 36.83% in 2016, 50.71% in 2019 and 46.96% in 2018 and 48.96% in 2019 with Sentinel. Thus, the NDVI index can be used to obtain air pollution information that indicates if the NDVI index value in the extraction will get a correlation value between Landsat 8 satellite images and Sentinel 2A where the correlation results on field measurements are Landsat at 68.93% and Sentinel 90.15%.

***Keywords**: PM10, Landsat 8, Sentinel 2A, NDVI, Correlation.*

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1. Introduction

The bandung City Climate. But in the last few years the season has increased, also the rainy season is longer than usual. In the past few years, the rainy season has been felt longer in the city of Bandung. Naturally, the city of Bandung is classified as a fairly cool area. During 2012, the highest temperatures in the city of Bandung reached 30.9 ° C which occurred in September. The lowest temperature in Bandung in 2012 was 17.4 ° C, namely in July (Diskominfo Bandung, 2017).

Based on the Government Regulation of the Republic of Indonesia Number 41 article 1 paragraph 1 of 1999 air pollution is defined as a decrease in air quality so that the air experiences a decline in quality in its use which ultimately cannot be used properly according to its function. In air pollution is always related to sources that produce air pollution, namely moving sources (generally motorized vehicles) and immovable sources (generally industrial activities) (DG of Government Regulation, 2005).

The airborne dust particulate Suspended Particulate Matter (SPM) is a very complicated mixture of the largest variety of organic and inorganic compounds in air with a very small diameter, ranging from <1 micron to a maximum of 500 microns. The dust particulate will be in the air for a relatively long time in a loose state in the air and into the human body through the respiratory tract (Darjono, 2014). Particulates (PM2.5) are air particles that are smaller than 2.5 microns (micrometers). Threshold Value (NAB) is the concentration limit of air pollution that is allowed to be in ambient air. NAB PM2.5 = 65 µgram / m3 (BMKG, 2019).

The Minister of Environment Regulation No.12 / 2010 mentions about implementation of air pollution control in the area there are 5 (five) the parameters are CO, PM10, NO2, SO2, O3. Continuous with the regulation, (Lohani, 1986) states that air pollution divided into two, namely particles and gases. Pollutant particles can be either total suspended particulate / total suspended particle (TSP) particle diameter up to 100µm; particles less than 10µm (PM10), and particles less than 2.5µm (PM2,5) in diameter, whereas pollutant gases can be Sulfur dioxide (SO2), Nitrogen dioxide (NO2), Carbon monoxide (CO), Oxidant / Ozone surface (O3), and others. (Ministry of Environment and Forestry, 2018).

To see the spatial distribution of air pollution can use remote sensing technology using satellite image data, one of which is satellite imagery Sentinel-2A and Landsat, this image data can identify PM2.5 and PM10 air pollution by converting DN values to images to reflectance. (Waradi, 2018).

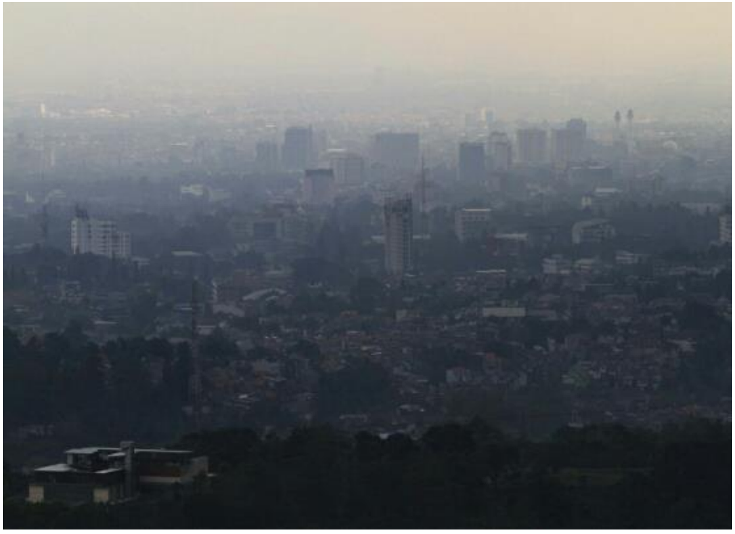


Figure 1. Bandung City Air Pollution
(Ramdhani, 2016)

2. Metodologi

2.1 Method

The research methodology used is data collection on the website of usgs.gov and Copernicus.esa beginning with geometric correction on digital images must be done because the possibility of satellites making recording errors is quite high (geometric distortion). To reduce this geometric distortion, repositioning is needed in accordance with the existing coordinate system, this activity is usually called orthorectification. This orthorectification can be done by several methods, one of the orthorectification methods is Rational Functions (RF). In this RF method orthorectification uses Data Ground Control Point (GCP) and Digital Elevation Model (DEM). Accuracy of the results of this correction is determined by the amount of GCP involved and the spread of GCP evenly when the geometric correction process (Manhut, 2017).

2.2. Research Data and Location

The data used in this study are 8 Landsat Image data in May 2001 - 2019 and Sentinel 2A Satellite Imagery in May 2018-2019, Bandung City administrative boundary map. Landsat 8 and Sentinel 2A imagery are the main data that will be used to determine the distribution of the vegetation index and drought in Bandung while the administrative boundary map, and pocket pollutant data matters as supporting data to see the boundaries and conduct validation tests and analysis of objects affected by Pollution air. Description of research data can be seen in table 1.

Table 1. Data used

Data	*Information*	*Source*
Citra Landsat 8	17 Mei 2001 23 Mei 2006 5 Mei 2011 13 Mei 2016 22 Mei 2019	www.earthexplorer.usgs.gov
Citra Sentinel-2A	14 Mei 2018 19 Mei 2019	www.scihub.copernicus.esa
Map of Bandung City Administrative Limits	Scale 1: 50,000	www.tanahair.indonesia.go.id
Pocket pollutant data Matter	CSV format	Observation results April 14 - May 12 2019

In this study using Landsat 7, Landsat 8 and Sentinel 2A imagery where each satellite image has different spectral specifications, to produce NDVI, TVDI, PM10, and PM2.5 calculations, it is necessary to calculate Bands contained in these satellite images. . As in the picture below, the specifications of satellite imagery will be used in this study.

Table 2. Specifications of Landsat 8 and Sentinel 2A satellite imagery.

Landsat 8-OLI			Sentinel 2A-MSI		
Bands	Wavelength (μm)	Resolution (m)	Bands	Wavelength (μm)	Resolution (m)
1 Coastal/Aerosol	0.43-0.44	30	1 Coastal/Aerosol	0.43-0.46	60
2 Blue (B)	0.45-0.51	30	2 Blue (B)	0.44-0.54	10
3 Green (G)	0.53-0.59	30	3 Green (G)	0.55-0.58	10
4 Red (R)	0.63-0.67	30	4 Red (R)	0.65-0.68	10
			5 Red edge 1 (RE1)	0.70-0.72	20
			6 Red edge 2 (RE2)	0.73-0.75	20
			7 Red edge 3 (RE3)	0.77-0.79	20
5 Near infrared (NIR)	0.85-0.88	30	8 NIR	0.76-0.90	10
			8a NIR narrow (NIRn)	0.86-0.88	20
			9 Water vapour	0.94-0.96	60
9 SWIR/cirrus	1.36-1.39	30	10 Shortwave infrared/cirrus	1.36-1.39	60
6 Shortwave infrared 1 (SWIR-1)	1.57-1.65	30	11 SWIR-1	1.54-1.68	20
7 Shortwave infrared 1 (SWIR-1)	2.10-2.29	30	12 SWIR-2	2.08-2.32	20
8 Panchromatic	0.50-0.68	15			

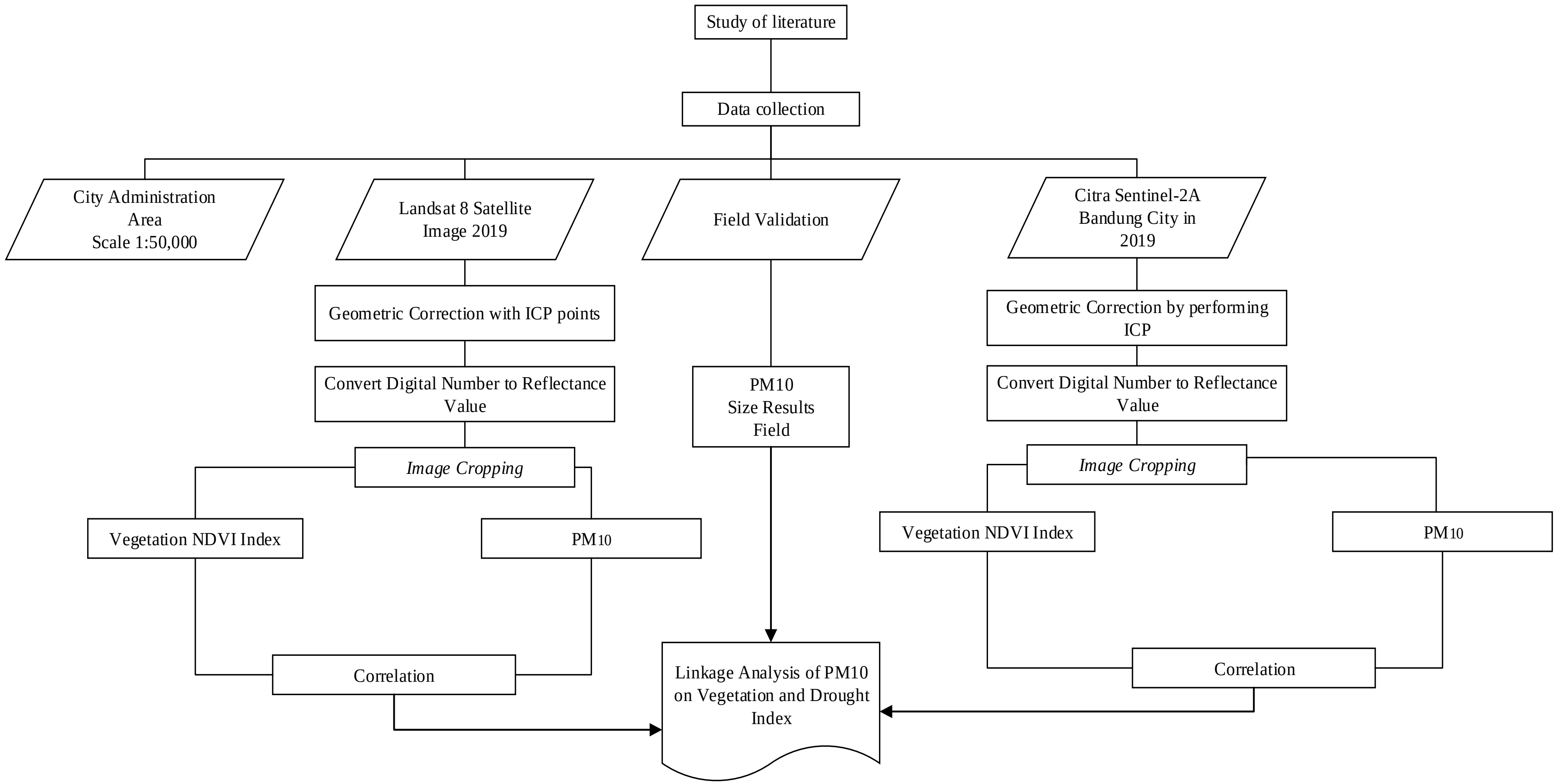


Figure 2. Flowchart Methodology

Data on Landsat 8 and Sentinel 2A Bandung City can be downloaded on NASA's USGS official website page www.earthexplorer.usgs.gov. The results of downloading Landsat 8 and Sentinel 2AKota Bandung data, which can be seen in Figure 2 and Figure 3:

Figure 3. Citra Satellite Landsat 8 area of Bandung

Figure 4. Bandung City Administrative Limits

From the results of the Landsat Image 8 May 2011 there were no clouds while in May 2016 there were a few clouds in the South and East areas of Bandung. This is because Landsat 8 and Sentinel 2A images have relatively wide coverage so it is difficult to obtain cloud-free images in one recording. Especially in Indonesia, where most of the territory is tropical and is the location of clouds. The reason for choosing Landsat Image 8 in May 2001-2019 is because researchers want to know the phenomenon of changes in air pollution that occurred in 2001-2019 and caused climate change since the last 3 years in the city of Bandung. (S.T, 2009).

2.3 Data Processing

Landsat and Sentinel 2A images that have been downloaded, of course, have experienced a shift, because the satellite orbit is very high and the field of view is small, causing geometric distortion. As a result of this geometric error, the pixel position of the satellite data does not match the actual position (latitude and longitude). To eliminate this error, a geometric correction is needed to reposition the pixel position in such a way that a transformed digital image of the object on the surface of the earth can be seen by the sensor. At this stage of the study, a geometric correction was made using ICP (Independent Control Point). ICP or accuracy test points as quality control points of objects by comparing the coordinates of the model.

2.3.1. Radiometric Correction

Radiometric correction was undertaken to correct the pixel values so those can match the actual values, considering atmospheric disturbance factor as the primary source of error. The Atmospheric effect causes the value of object reflection on the surface of the earth recorded by the sensor is not the original value, but it becomes larger due to the scattering or smaller due to absorption process (Danoedoro, 2012) The radiometric correction process is first converting Digital Number to Radians, then converting radians to reflectance values. This study uses the FLAASH method in the radiometric correction process.

2.3.2. Geometric Corretction

To remove geometric distortion that causes a mismatch between object imagery position and object actual position, it is necessary to have a geometric correction. It establishes the pixel position of imagery to the actual position. In this study, geometric correction is carried out by the image to image method where Landsat-8 become the base/reference to determine GCP on Landsat which will be corrected geometrically.

2.3.4. Calculates the NDVI value

Normalized Difference Vegetation Index (NDVI) Algorithm

At this stage data processing is carried out using the Normalized Difference Vegetation Index (NDVI) method to produce a vegetation index. (Carlson Td., 1997).

$$\mathbf{NDVI} = \frac{(\boldsymbol{NIR-Red})}{(\boldsymbol{NIR+Red})}$$

Table 3. NDVI Classifications

NDVI	Classification Class
-1.0 - 0.12	No Vegetation
0.12 - 0.22	Very Low Vegetation
0.22 - 0.42	Low Vegetation
0.42 - 0.72	Medium Vegetation
0.72 - 1	High Vegetation

TVDI calculations are calculated based on the parameter values that have been obtained from the linear regression relationship between NDVI values and land surface temperature using the TVDI algorithm(Sandholt et al., 2002) as follows:

$$\mathbf{TVDI} = \frac{\boldsymbol{Ts-Tsmin}}{(\boldsymbol{a+bxNDVI-Tsmin})}$$

Table 4. TVDI Classification

TVDI	Classification Class
0 - 0.2	Wet
0.2 - 0.4	It's rather wet
0.4 - 0.6	Normal
0.6 - 0.8	Somewhat dry
0.8 – 1	Dry

2.3.3 Cropping

Cropping is done so that data processing is more focused on the observed area to simplify the imagery analysis.

2.3.4 PM_{10} algorithm

To calculate PM10 concentration with satellite imagery, PM10 algorithm is used as in the following formula (Nhu Hung Nguyen, 2014)

$$\mathbf{PM10 = ax\ R\lambda 1 + ajR\ \lambda 2 + a2R\ \lambda 3} \quad (1)$$

The parameters used in the algorithm are;

ax = Aerosol Optical Thickness value (AOT)
Rλ1 = Band reflectance value used
The value of Aerosol thickness was obtained from NASA's official website, AERONET. The reflectance values used are the reflectance values of the red, green, and blue (RGB) bands.

3. Results And Discussion

3.1. PM10 (Particulate Matter) in Bandung City basic on Landsat 8

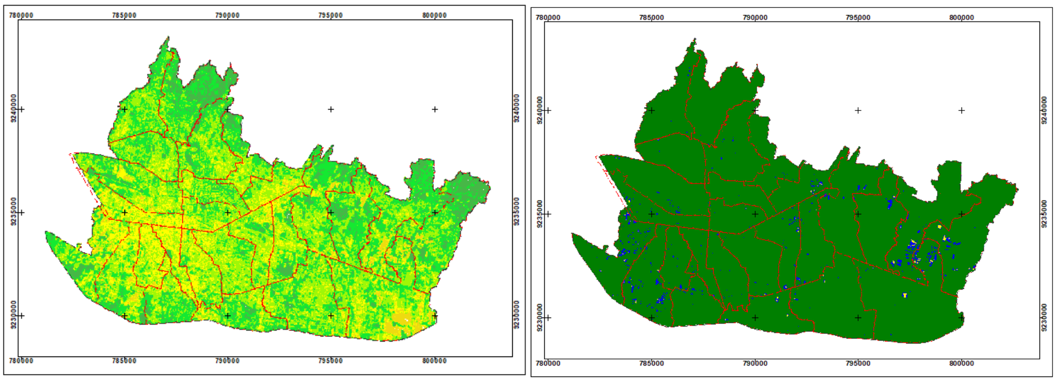


Figure 5. Results of NDVI and PM10 of 2001

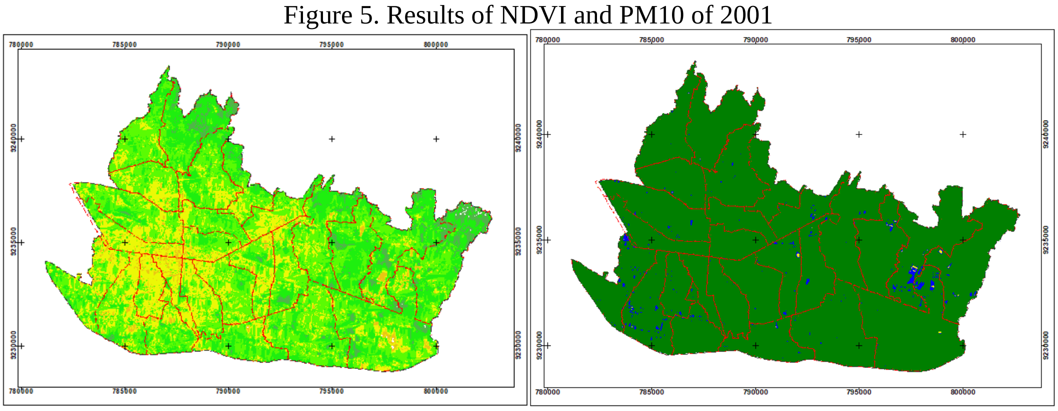


Figure 6. Results of NDVI and PM10 of 2006

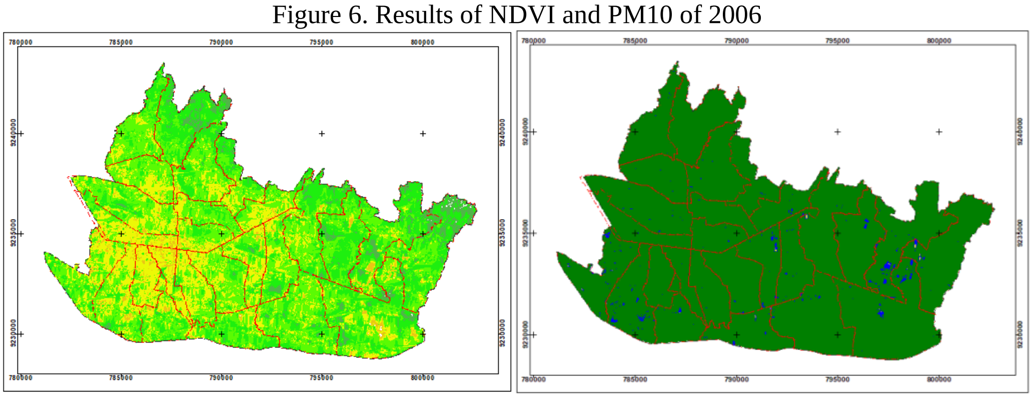


Figure 7. Results of NDVI and PM10 of 2011

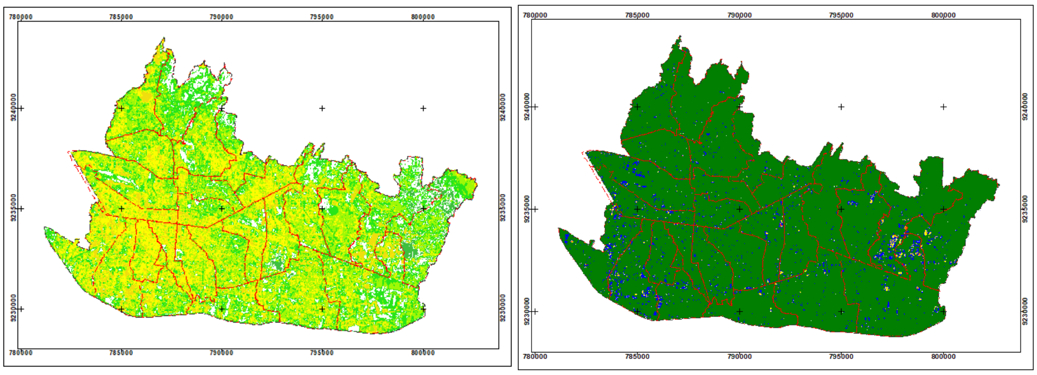


Figure 8. Results of NDVI and PM10 of 2016

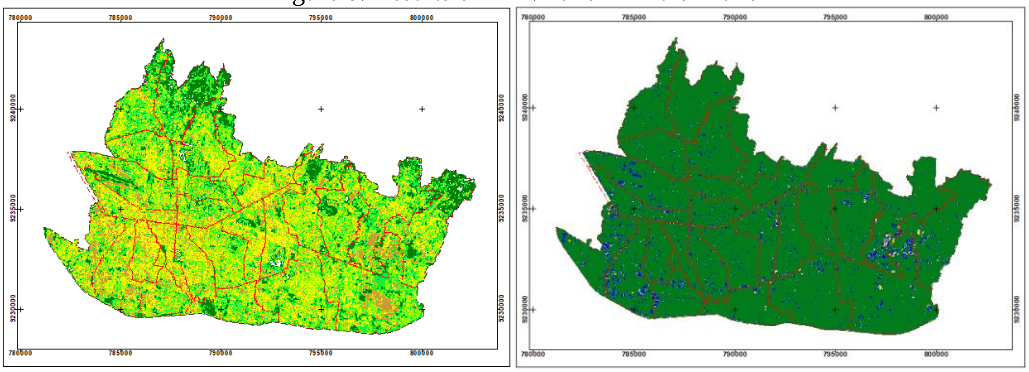


Figure 9. Results of NDVI and PM10 in 2019

Classes of air quality level based on the range of values referring to the Pollutant Standard Index are classified to different colors. The health Class is visualized in green, the moderate class is visualized in blue, the unhealthy class is visualized in yellow, and the hazardous class is visualized in red, and very hazardous calss is visualized in black. Based on the result of PM_{10} management, there is the difference of PM_{10} distribution. As shown in Figure 3 ,the dominant PM_{10} distribution is classified as healthy class with PM_{10} range of 0-50 µg/m³ visualized in green. However, it also shows that the distribution of moderate class in blue with PM_{10} range of 51-100 µg/m³ significantly increases from 2001 to 2019.

3.2. PM10 (Particulate Matter) in Bandung City basic on Sentinel 2A.

NDVI and PM10 Sentinel 2A 2018 year and 2019 year gets results 2 data likely visual :

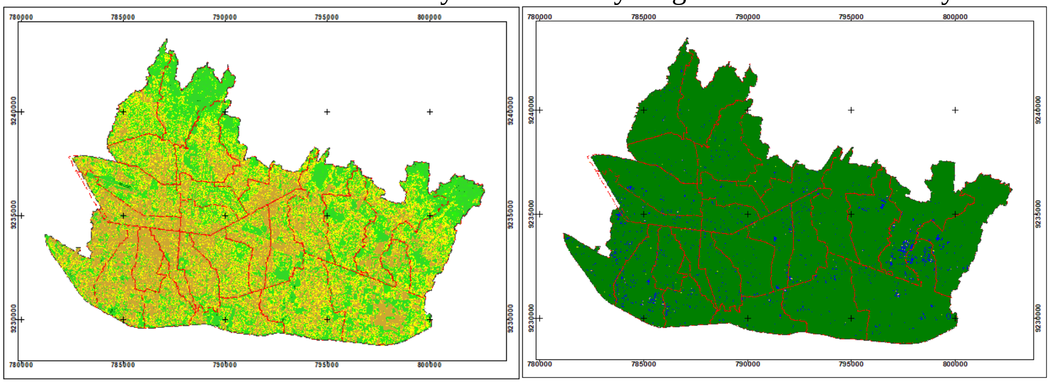


Figure 9. NDVI and PM10 results in Sentinel 2A 2018

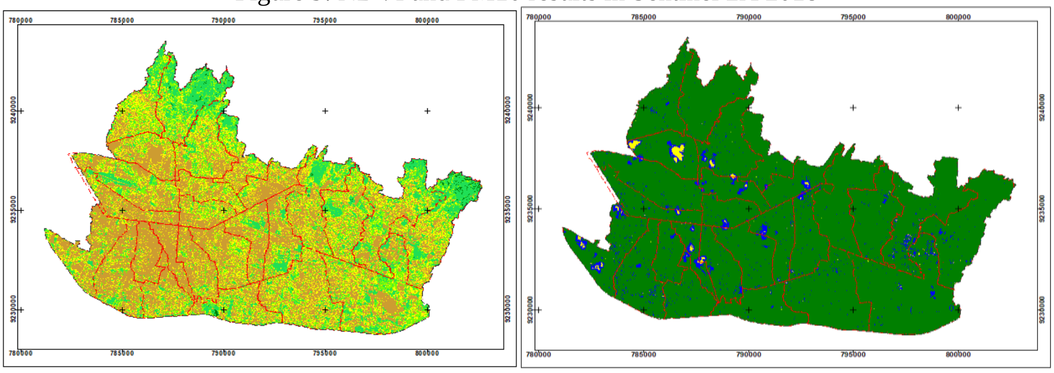


Figure 10. NDVI and PM10 results in Sentinel 2A 2019.

3.3. PM_{10} Validation Using Pocket $PM_{2.5}$ Sensor

Besides the use of remote sensing technology with Landsat imagery, this study also uses measuring device to obtain PM10 concentrations in Bandung. The device is *Pocket* $PM_{2.5}$ sensor obtained from The University of Tokyo. The following is the distribution of PM_{10} based on the ground measurement.

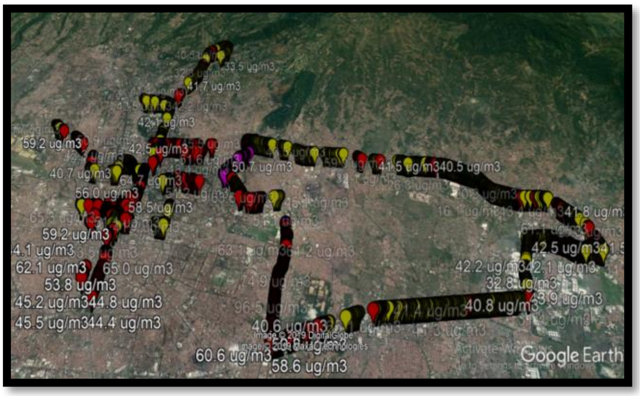


Figure 11. Distribution of PM10 from ground measurements

3.3. Correlation of PM_{10} Ground Measurement with NDVI from Landsat Satellite Image Processing.

Based on the result of Landsat Imagery and PM_{10} of ground measurement, Linear regression is analyzed to find out the correlation between those variables using the sample in table 2. The following is the result of linear regression analysis between PM_{10} of ground measurement in 2019 and PM_{10} of Landsat Imagery in 2019;

Relationship of Linear Regression NDVI Vegetation Index with air pollution 10 µg PM10. From the results of processing NDVI Vegetation index and PM10 air pollution can be found the correlation between the two by looking for the value of the variable by taking a sample of 25 points. Following are the results of the NDVI and PM10 linear regression in May 2001 - 2019:

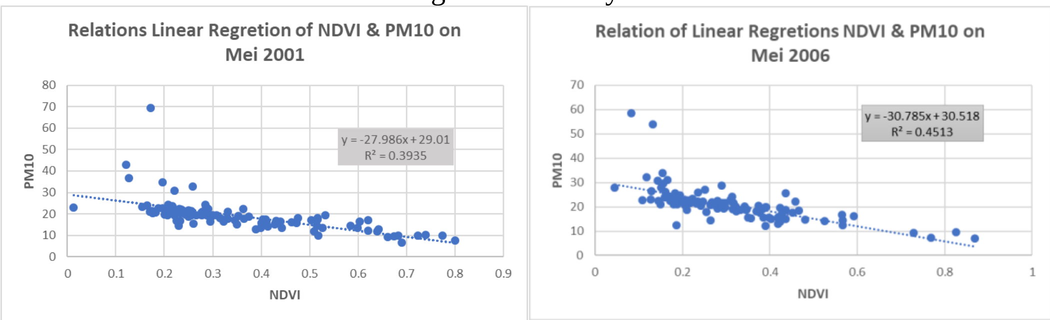


Figure 12. Relationship of Linear Regression NDVI and PM10 2001 and 2006

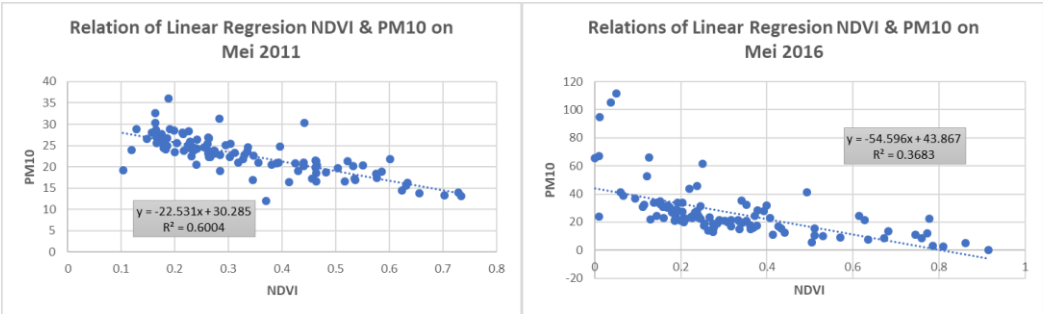


Figure 13. Relationship of NDVI and PM10 Linear Regression 2011 and 2016

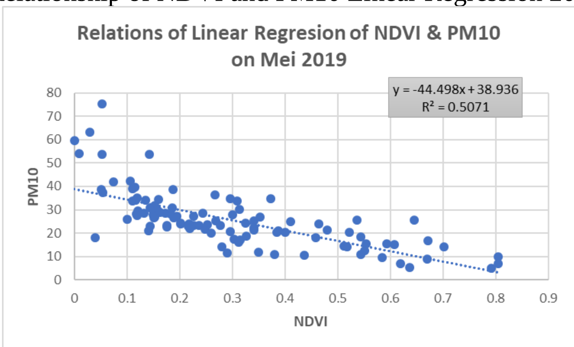


Figure 14. Relationship of Linear Regression NDVI and PM10 2019.

The scatterplot results are known that the regression coefficient value is negative, where the higher the density of vegetation index, the air pollution value of 2.5 µg PM10 will be higher. The equation of the coefficient of determination in May 2001 was 0.3935, in 2006 it was 0.4513, in 2011 it was 0.6004, in 2016 it was 0.3683, in 2019 it was 0.5017 which had the understanding that the effect of the vegetation index on PM10 was an average of 39.35% in 2001 , 45.13% in 2006, 60.04% in 2011, 36.83% in 2016, 50.17% in 2019.

3.3. Correlation of PM_{10} Ground Measurement with NDVI from Sentinel 2A Satellite Image Processing.

Then based on satellite image processing to get the value of NDVI and PM10 Sentinel 2A in 2018 and in 2019 the results of the 2 data are as follows visually:

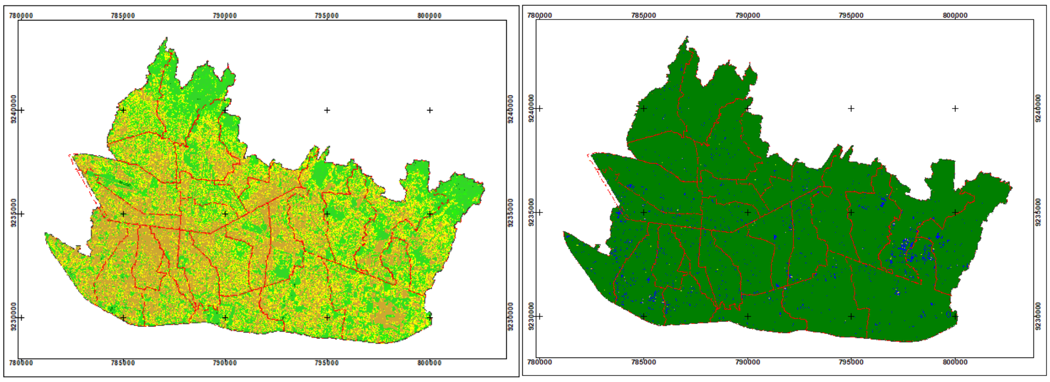


Figure 15. NDVI and PM10 results in Sentinel 2A 2018

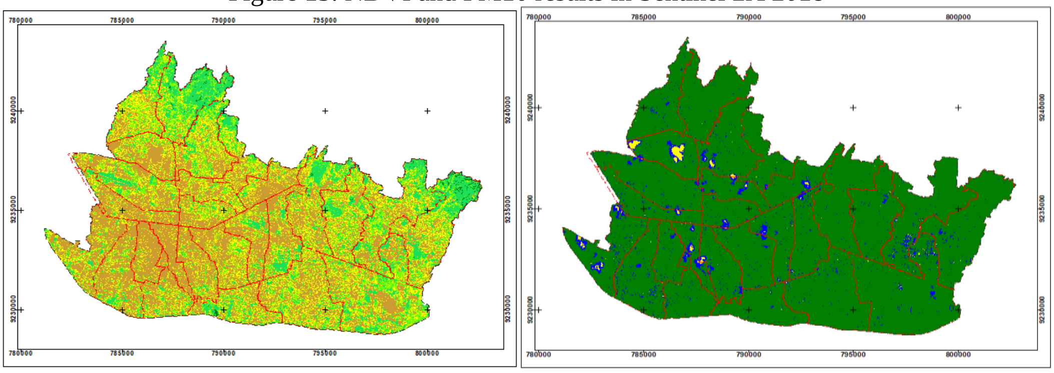
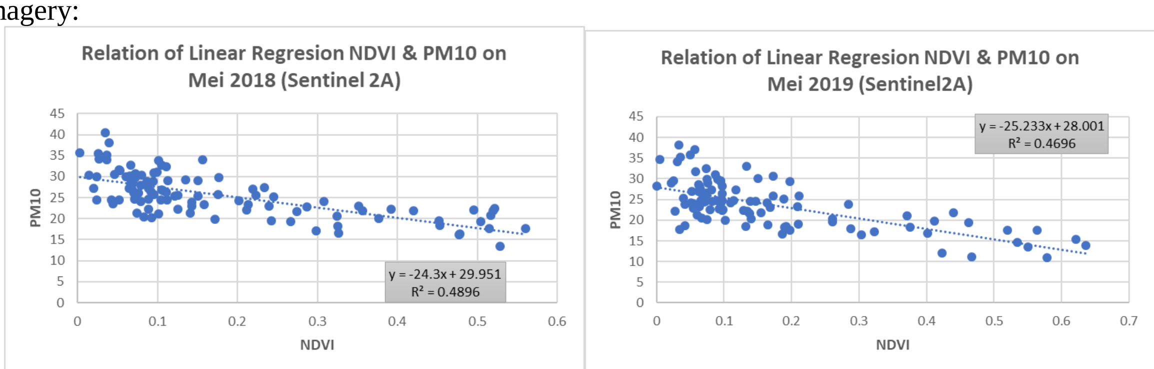


Figure 16. NDVI and PM10 results in Sentinel 2A 2019

Relationship of Linear Regression NDVI Vegetation Index with air pollution 10 μg PM10. From the results of processing NDVI Vegetation index and PM10 air pollution can be found the correlation between the two by looking for the value of the variable by taking a sample of 100 points. Following are the results of NDVI and PM10 linear regression in May 2018 - 2019 based on Sentinel 2A satellite imagery:



Gambar 4 1. Hubungan Regresi Linear NDVI dan PM10.

Scatterplot results are known that the regression coefficient value is negative, where the higher the density of vegetation index, the air pollution value 10 μg PM10 will be higher. The equation of the coefficient of determination in May 2018 is 0.4896, 2019 is 0.4696 which has the understanding that the effect of vegetation index on PM10 on average is 48.96% in 2018, 46.96% in 2019.

4. Conclusions

4.1. Conclusions

Based on the results of this study it can be concluded that the Analysis of PM10 Air Pollution Correlation with NDVI (Normalized Difference Vegetation Index) and Based on Landsat-8 and Sentinel-2A Satellite Imagery is as follows:

1. Vegetable Index NDVI is divided into 5 classes, namely: no vegetation, very low vegetation, low vegetation, medium vegetation, high vegetation based on the distribution pattern in the city of Bandung has decreased vegetation index in several districts in the city of Bandung. Especially in areas that are dense with settlements and buildings. For the distribution patterns the PM10 indexes follow the distribution patterns of the vegetation and drought indexes where in areas lacking vegetation and the large drought index there are large PM10 pollution values.
2. Based on the calculation of the linear regression correlation of the two correlations obtained for PM10 from Sentinel 2A satellite imagery is 0.9015 and for PM10 from Landsat 8 satellite imagery is 0.6893, which means that for sentinel 2A has a correlation level of 90.15% and for satellite imagery Landsat 8 has a level of 68.93% correlation so it can be concluded that the correlation between the correlation between PM10 Sentinel 2A and pocket PM10 is (Very Strong). the correlation between PM10 Landsat 8 and pocket PM10 is (Medium).

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