ASSESSMENT OF ATMOSPHERIC CORRECTION METHODS FOR OPTIMIZING HAZY SATELLITE IMAGERIES

PENILAIAN METODE KOREKSI ATMOSFIR UNTUK MENGOPTIMASI CITRA SATELIT BERKABUT

Umara Firman Rizidansyah[1*], Muhammad Buce Saleh[2], Antonius Bambang Wijanarto[3]
[1]Indonesian Agency for Meteorology, Climatology and Geophysics, Jl. Angkasa I No.2 10720 Jakarta
[2]Bogor Agricultural Institute, IPB Darmaga Bogor 16680
[3]Indonesian Agency for Geospatial Information, Jl. Raya Jakarta - Bogor KM. 46 Cibinong 16911
[*]*E-mail*: umara.firman@gmail.com

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ABSTRACT

The purpose of this research is to examine suitability of three types of haze correction methods toward distinctness of surface objects in land cover. Considering the formation of haze therefore the main research are divided into both region namely rural assumed as vegetation and urban assumed as non vegetation area. Region of interest for rural selected Balaraja and urban selected Penjaringan. Haze imagery reduction utilized techniques such as Dark Object Substration ,Virtual Cloud Point and Histogram Match. By applying an equation of Haze Optimized Transformation HOT = DN_{blue}sin( )-DN_{red}cos( ), the main result of this research includes: in the case of AVNIR-Rural, VCP has good results on Band 1 while the HM has good results on band 2, 3 and 4, therefore in the case of Avnir-Rural can be applied to HM. in the case of AVNIR-Urban, DOS has good result on band 1, 2 and 3 meanwhile HM has good results on band 4, therefore in the case of AVNIR-Urban can be applied to DOS. in the case of Landsat-Rural, DOS has good result on band 1, 2 and 6 meanwhile VCP has good results on band 4 and 5 and the smallest average value of HOT is 106.547 by VCP, therefore in the case of Lansat-Rural can be applied to DOS and VCP. in the case of Landsat-Urban, DOS has good result on band 1, 2 and 6 meanwhile VCP has good results on band 3, 4 and 5, therefore in the case of Landsat-Urban can be applied to VCP.

***Keywords** : Atmospheric effects, Haze elimination, rural vegetation area, urban non vegetated area, avnir and landsat*

ABSTRAK

Tujuan penelitian ini untuk menguji kesesuaian tiga jenis metode koreksi haze terhadap kejelasan obyek permukaan di wilayah tutupan vegetasi dan non vegetasi, berkenaan menghilangkan haze di wilayah citra satelit optis yang memiliki karakteristik tertentu dan diduga proses pembentukan partikel hazenya berbeda. Sehingga daerah penelitian dibagi menjadi wilayah rural yang diasumsikan sebagai daerah vegetasi dan urban sebagai non vegetasi. Pedesaan terpilih kecamatan Balaraja dan Perkotaan terpilih kecamatan Penjaringan. Tiap lokasi menggunakan Avnir-2 dan Landsat 7. Untuk mendapatkan hasil pengurangan kabut di kedua lokasi tersebut digunakan metode Dark Object Substraction (DOS), Virtual Cloud Point (VCP) dan histogram Match (HM) dengan persamaan nilai optimasi kabut HOT = DN_{blue}sin( )-DN_{red}cos( ). hasil penelitian ini sebagai berikut: dalam hal AVNIR-Rural, VCP memiliki hasil yang baik di Band-1 sedangkan HM memiliki hasil yang baik pada band-2, 3 dan 4 sehingga dalam kasus AVNIR-Rural dapat diterapkan HM. Dalam hal AVNIR-Urban, DOS memiliki hasil yang baik pada band-1, 2 dan 3 Sementara HM memiliki hasil yang baik pada band 4, sehingga dalam kasus AVNIR-Urban dapat diterapkan DOS. Dalam kasus Landsat-Rural, DOS memiliki hasil yang baik pada band-1, 2 dan 6, Sementara VCP memiliki hasil yang baik pada band 4 dan 5. Sehingga dalam kasus Landsat-Rural dapat diterapkan DOS. Dalam hal Landsat-Urban, DOS memiliki hasil yang baik pada band-1, 2 dan 6 sedangkan VCP memiliki hasil yang baik pada band-3, 4, dan 5. Sehingga dalam hal Landsat-Urban dapat diterapkan VCP. Semakin baik citra hasil koreksi semakin kecil nilai optimasi kabut, nilai rata–rata terkecil adalah 106,547 dengan VCP di Landsat-Rural.

Kata kunci : Efek atmosfer, eliminasi haze, daerah vegetasi rural, daerah non vegetasi urban, avnir dan landsat

1. Introduction

As one of the region traversed by the equator, Indonesia has become an area that has a tropical climate condition, with heavy rainfall and formation of cloud or haze phenomenon. The aforementioned condition would be obstacles to get rid of haze in optical satellite imageries, because of the importance of satellite data for mapping and environmental, monitoring will require technology that can take advantage of the hazy corrected image so it can be processed for the purposes of mapping and monitoring of the environment and natural resources, some methods or algorithms have been used to eliminate or reduce the effects of haze or cloud instance, this is exemplified by the use of dark object substraction [1,2] and histogram match [3].

Particles in the atmosphere composed of dust, smoke and so small water droplets that hovers in the air. Some of the causes of the formation of these particles are vehicular emissions, wood burning fires and industrial processes [4,5]. The aforementioned particles called haze, types of clouds that tend to be at a height of 6,500 feet or 2,000 m is a stratus cloud and haze can form when stratus clouds touch the ground surface while on the occurrence of haze can be defined as dust and smoke particles accumulate in relatively dry air. The process of haze formation affects the composition of haze as solid or liquid particles suspended in a gas as ingredient of aerosol, a wide range of phenomena namely Smog, fume, dust and other dry relative particle [6].

To detect and obtain the value of optimization [7],[8] has developed Haze Optimize Transformation equation which is assumed that pixel values in image are different in each band but highly correlated. Generally the blue band shows more scattering due to atmospheric haze than the other bands, the correlation between the blue and red bands decline by the presence of haze [9] , [10].

The Wavelength of spectral reflectance on each band have certain characteristic with an indication that the influence of a range of different bands has different result of hazy correction image on each of three method meanwhile the influence of the sources of haze formation on the three results of hazy correction image has different results therefore the objective of this research is to evaluate distinctive methods for optimizing hazy optical satellite imageries meanwhile the benefit of research is with vanishing haze the information contained in an optical satellite imageries can be clearly read and interpreted. Because the data are available only in the region Balaraja and Penjaringan therefore it should be used although other regions may have better characters for classification of urban and rural.

According to that, this research aimed not only for reducing or eliminating hazy satellite imageries on ground reflectance values of an images but also assess the significance of the results of the correction process compared to non-haze satellite imageries. To retrieve the results of the correction process used three methods namely Dark Object Substraction (DOS), Histogram Match (HM) and Virtual Cloud Point (VCP).

Results of atmospheric correction process is very important for optimizing hazy satellite imageries with regard to the object surface to the detection of changes in land cover and land use. By considering the differences in the formation process of haze therefore this research establish region of interest of each type of image and then divided into both regions: rural assumed as vegetation area and urban assumed as non vegetation area.

Data used in the atmospheric correction process in the form of two types of images: alos avnir2, landsat7. The reason for the two types of images are used based on the hypothesis that if the use of three methods gave similar results when applied to image different band ranges. Based on visual interpretation of the comparison of the three methods that VCP is better in rural and urban areas is shown by looking at the clarity of vegetation density in rural areas and Contour, hue and objects in urban areas and then there is a significant relationship in AVNIR-2 image of the image correction method (HM with DOS, DOS with VCP, and HM with VCP) and a significant relationship between the correction of three images with non-haze images in Landsat, as shown by the list of tables. based on the Z test that produces an image correction method has three significant differences. Based on the results table that the better the image correction results received from the values obtained from the optimization of Haze will be smaller, the best HOT average value was 106.547 by using Landsat-VCP in Rural.

2. Research Methods

Time and Location. This research is conducted at MIT (Master of Science In Information Technology) research laboratory, Bogor Agricultural University, SEAMEO BIOTROP, Bogor. For the aim of this research, two types of satellite imagery used namely AVNIR-2 and Landsat. Each type of satellite images selected two zones, Balaraja subdistrict assumed as rural and Penjaringan subdistrict assumed as urban which administratively inclusive into Tangerang district and Nothern Jakarta. That is described by Figure 1.

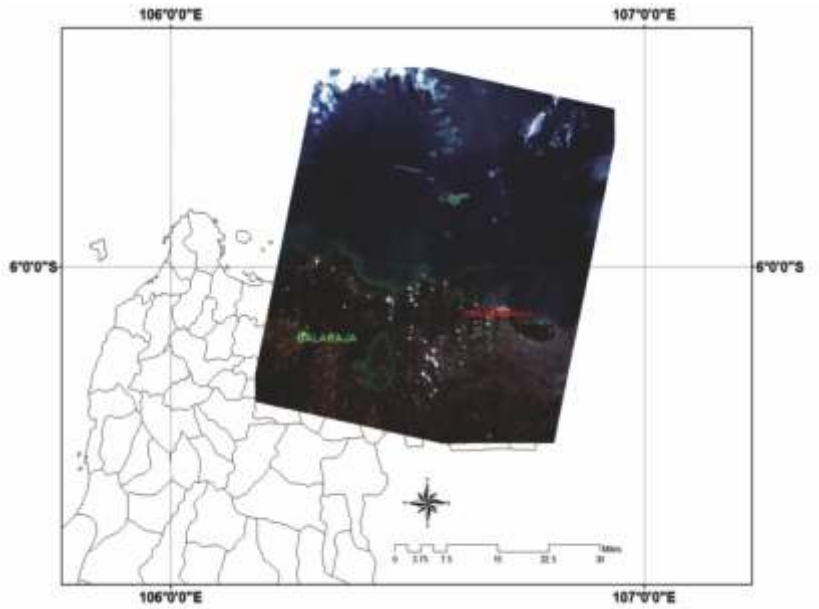

Figure 1. Research Area (Balaraja and Penjaringan subdistrict)

Table 1. Data Requirement

No	Satellite Imagery	Acquisition Date	Spatial Resolution	Source of Data
1	AVNIR-2 Urban Haze Rural Non-Haze	August 03, 2009	10 m	JAXA
2	AVNIR-2 Rural Haze Urban Non-Haze	Sept 15, 2008	10 m	JAXA
3	Landsat 7 Urban Rural Non-Haze	October 22,2002	30 m	http://glovis.usgs.gov/
4	Landsat 7 Urban Rural Haze	Sept 20, 2002	30 m	http://glovis.usgs.gov/

Research Area. Balaraja subdistrict as rural in Tangerang district and Penjaringan subdistrict as urban in Nothern Jakarta.

Required Tools. Some supporting hardware and software will be employed to accomplish this research as follow:

a. ENVI 4.7
   For the task of collecting, capturing, processing and analyzing the satellite image specified the use of this software. This imagery analysis software packages can open GeoTiff files
b. ArcGIS 10.1
   For the task of collecting, capturing, processing and analyzing the satellite image specified the use of this software.

Methods. In this study there are two stages that used the method of haze reduction and assessment methods corrected image.

Method of Haze Reduction. Referred to Figure 2 methods consist of three kinds of technique namely Dark Object Substraction (DOS), Virtual Cloud Point (VCP) and Histogram Match (HM). There are many stages for calculating of HOT. First, select a clear region and extract the fitting straight line of two visible bands (red vs blue) as the clear-skyline. Second, calculate the distance of each pixel from this clear-sky line (Eq. 1) as HOT (Eq. 2) [8]. Clear-sky line' (CL) : $b1\sin\Phi - b3\cos\Phi - a = 0$ (1) HOT= $b1\sin\Phi - b3\cos\Phi - a$ (2)Where Φ is slope angle of CL, a is the intercept of CL, b1 and b3 are bands.

Data Sources. The data used in this research are alos AVNIR-2, Landsat 7. West Java with path/row = 122/64. AVNIR-2 had four bands (blue, green, red, and near-infrared). It had a radiometric resolution of 8-bit and a recurrent period of 46 days. After converted into GeoTiff files can be easily uploaded into GIS software such as ArcGIS. The requirement data has been used in this research, consist of two kinds of satellite imageries namely

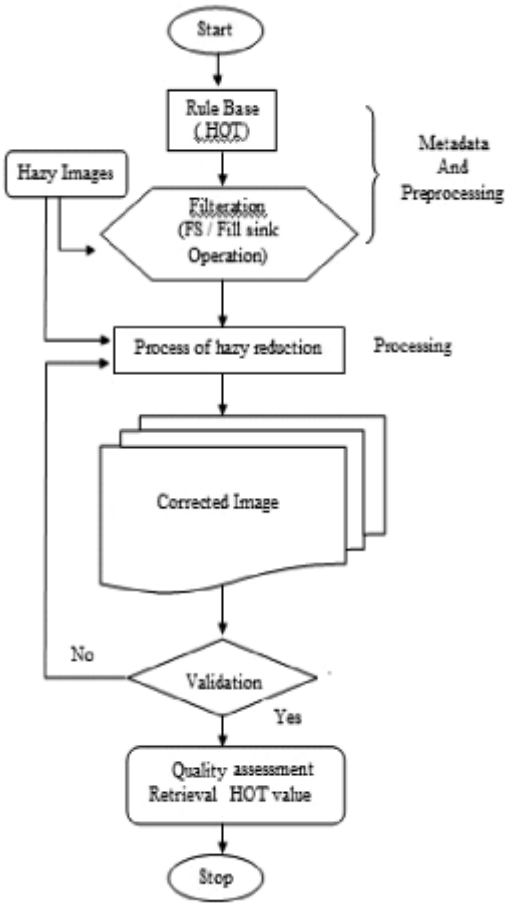

Figure 2. Procedure of Haze Reduction

Dark Object Subtraction. The earth's shadow on all surfaces will be completely black both land and sea in the absence of the influence of atmospheric, making it difficult to distinguish. Therefore, the dark object produces zero radiance in all wavelengths, if the image has a value above zero, it indicates that the scattering of the atmosphere have contributed to the reflectance of object. The darkest pixel in an image should have a DN of zero. if not, it's because of the influence of atmospheric path radiance (scattered light) that tend to increase value to the DN [1],[11], [12]. The pixels containing the lowest DN values selected from the image and the selected value is reduced by the DN values across the scene to reduce the effect of scattering.

Histogram match. In principle, this algorithm subtract the bias for each histogram. at visible wavelengths the minimum value was higher because it is influenced by atmospheric scattering, but at wavelengths that have a greater influence of atmospheric absorption can reduce the brightness so that the value of the band tends to be zero. Therefore each histogram starts at zero and the darkest pixels should have zero reflectance. If this value exceeds zero value then the value is calculated as the offset and correction is done by reducing the entire value on the channel with the offset [13].

Virtual Cloud Point. Due to aerosol multiple scaterring, dark objects of the surface reflectance will increase in the meanwhile bright objects of the surface reflectance will be reduced. Based on these understanding concerning to multiplicative effect of haze, we determine haze thickness by dividing the overall area of haze into several discrete for vary different thickness of haze, by lower and upper bound values determination and regression function then VCP obtained as the thickest haze of each band, (upperpercentiles=100-lower percentiles) [7], [14]. The workflow can be described on Figure 3.

Methods of Quality Assessment.

The method of assessment of the haze corrected image is done by using the following criteria:

a. Assessment of the appearance of the correction image visually: Comparison visually done well between corrected image to non haze image.
b. Comparison with correlation analysis: a comparison made between corrected image to the original image or non-haze image.
c. Comparison of the distribution of the value of digital corrected image with the z test: a comparison made between corrected image to non-haze image.

Assessment of image correction methods in AVNIR-2. In the evaluation of the AVNIR-2 is not used comparison of non-haze image,it is because there are changes in land cover between the haze and non-haze image due to the wide range of time periods and climate change, instead of image correction results in each method compared with the image of haze with the hope of getting the different results between the two images is, to get the image of the comparison between the three methods to test the correlation, getting away, or the smaller the value, the better the results [15]. to test the significance of differences between the two correction image (DOS vs HM, DOS vs VCP and HM vs VCP) z test will be used by requisite standard deviation is known, have a normal distribution and large sample size [16], [17].

Assessment of image correction methods by non-haze images in Landsat 7. Z-test assume that to make a comparison of two mean correction image and non-haze image in Landsat 7 performed band by band, band 1 until 6 in correction image compare to band 1 until 6 in non-haze image. By performing layer stacking the aforementioned images we use two Sample z test for comparing two means with the following formula (Eq. 3).

$$z = \frac{\bar{x}_1 - \bar{x}_2 - \Delta}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} \quad (3)$$

3. Result and Discussion

The following is the result of reducing or removing hazy satellite imageries in the urban and rural with 3 haze reduction method

In case of Rural area on Avnir-2. Based on region of interest (ROI) sampling in rural area and by using method of haze reduction, it can be obtained the Figure 4.

On AVNIR-Rural haze elimination process is done using DOS, HM and VCP. the results are shown in Figure 4. The stacking process is then conducted on three types of image, between the results in AVNIR-rural image by using the method of DOS vs. haze imagery in AVNIR-Rural, results in AVNIR-rural image by using the method of HM vs. Haze imagery in AVNIR-Rural and result in AVNIR-rural image by using the method of VCP vs. haze imagery in AVNIR-Rural. Result of stacking in three types of image correlation test are done and obtained the value as in Table 2.

Visually from the comparison of the three methods that HM is better on rural areas is indicated by looking at the area that is clarity vegetation density.

Concern to correlation table 2 that VCP on band 1 is the best on AVNIR-Rural meanwhile HM on band 2, 3 and 4 is the best on AVNIR-Rural. Based on the results in Table 3 using the Z test that image correction method comparison results are different.

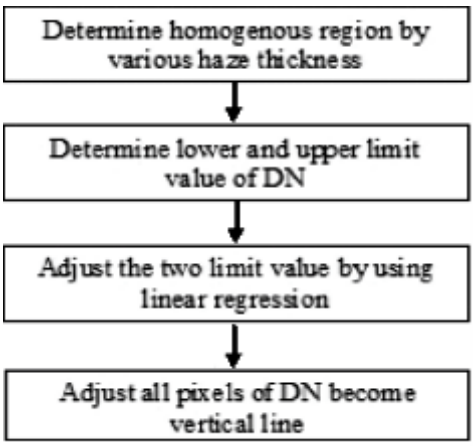

Figure 3. Structure of Virtual Cloud Point

Table 2. Results of the correlation calculation on AVNIR imagery in rural area

Band	DOS	HM	VCP
1	0.53	0.52	0.51
2	0.83	0.62	0.80
3	0.89	0.68	0.91
4	0.94	0.70	0.97

Table 3. Results of the Z calculations on AVNIR imagery in rural area

Band	DOS vs HM	DOS vs VCP	HM vs VCP
1	419.91	181.73	537.90
2	417.46	166.03	543.63
3	564.77	80.65	616.31
4	433.80	275.01	203.81

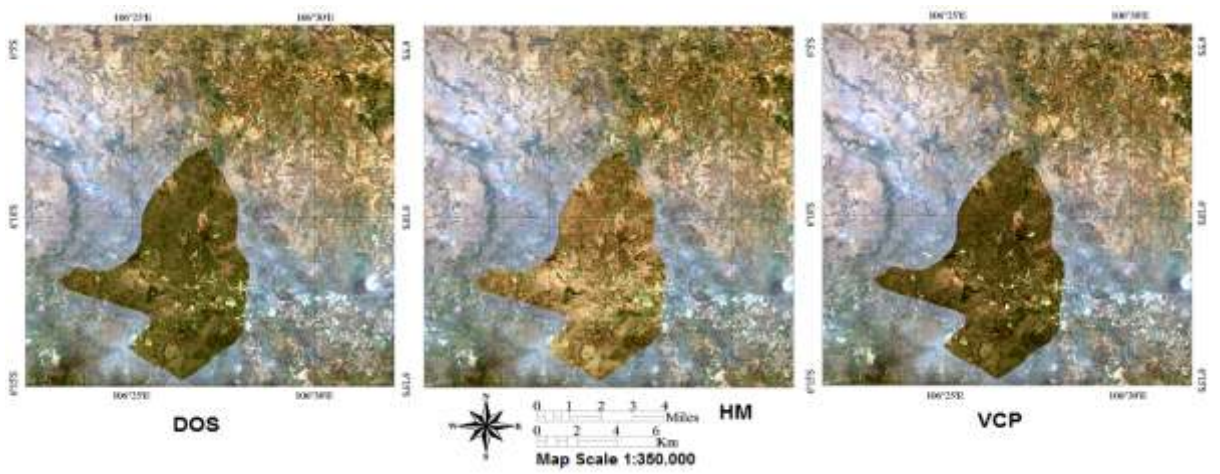

Figure 4. Balaraja on the results of three method in Avnir2

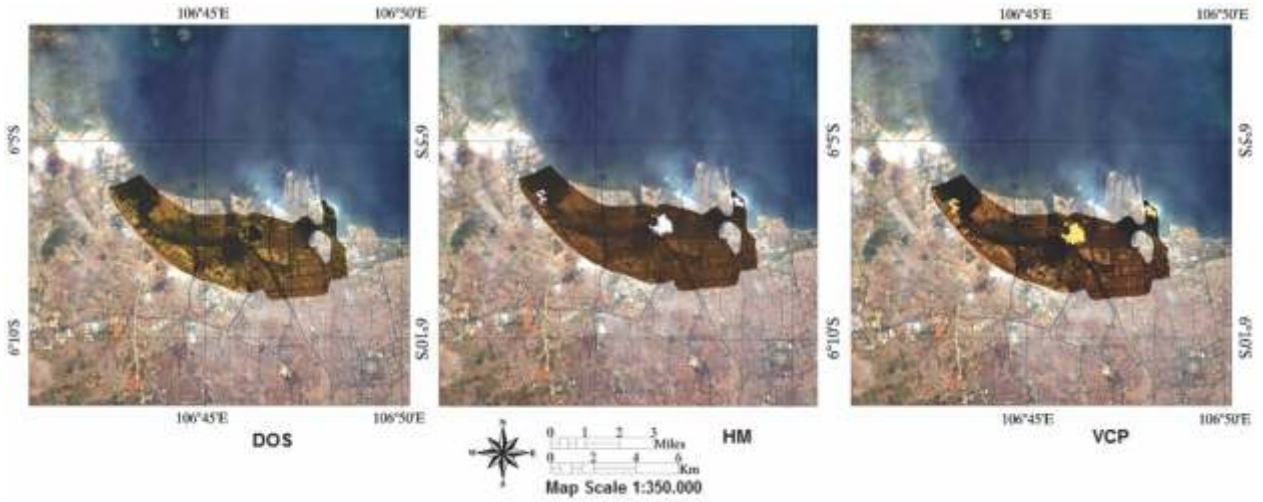

Figure 5. Penjaringan on the results of three method in Avnir2

In case of Urban area on Avnir-2. Based on region of interest (ROI) sampling in Urban area and by using method of haze reduction, it can be obtained the Figure 5.

On AVNIR-Urban haze elimination process is done using DOS, HM and VCP. the results are shown in Figure 5. The stacking process is then conducted on three types of image, between the results in AVNIR-Urban image by using the method of DOS vs. haze imagery in AVNIR-Urban, results in AVNIR-Urban image by using the method of HM vs haze imagery in AVNIR-Urban and result in AVNIR-Urban image by using the method of VCP vs haze imagery in AVNIR-Urban. Result of stacking in three types of image correlation test done and obtained the value as in Table 4.

Visually based on a comparison of three methods showed that VCP is better in Avnir-2 urban areas. Based on correlation of table 4 that DOS on band 1, 2 and 3 is the best on AVNIR-Urban meanwhile HM on band 4 is the best on AVNIR-Urban. Based on the results in Table 5 by using the Z test that image correction methods comparison results are different.

Table 4. Results of the correlation calculations on AVNIR imagery in Urban area

Band	DOS	HM	VCP
1	0.17	0.79	0.72
2	0.35	0.78	0.83
3	0.43	0.77	0.90
4	0.77	0.38	0.98

Table 5. Results of the Z calculations on AVNIR imagery in Urban area

Band	DOS vs HM	DOS vs VCP	HM vs VCP
1	93.88	8.07	90.25
2	1.01	151.54	84.17
3	10.83	46.78	44.81
4	177.08	542.87	428.13

In case of Rural area on Landsat 7. Based on region of interest (ROI) sampling in rural area and by using method of haze reduction, it can be obtained the Figure 6.

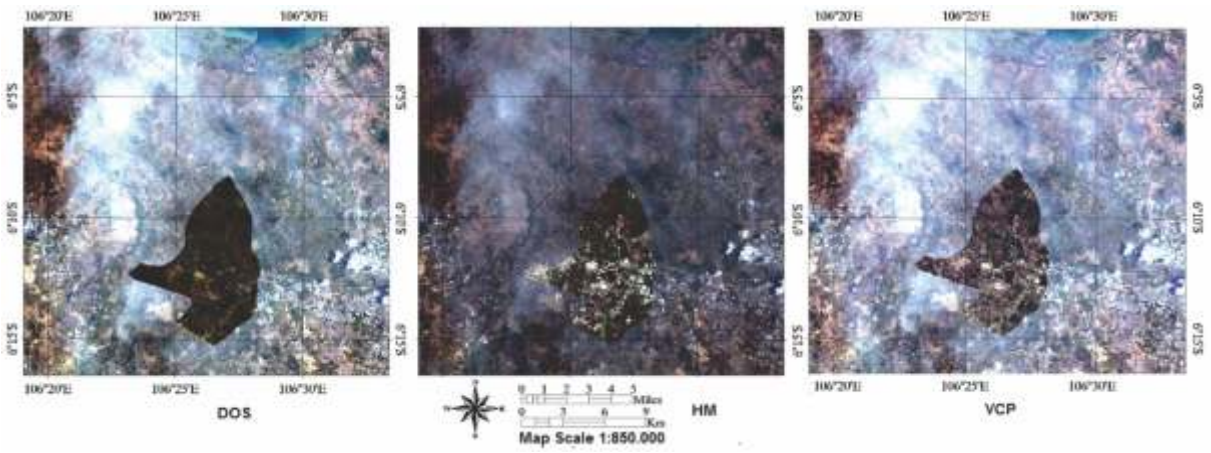

Figure 6. Balaraja on the results of three methods in Landsat 7

On Landsat-Rural haze elimination process is done using DOS, HM and VCP. the results are shown in Figure 6. The stacking process is then conducted on three types of image, between the results in Landsat-Rural image by using the method of DOS vs non-haze imagery in Landsat-Rural, results in Landsat-Rural image by using the method of HM vs non-haze imagery in Landsat-Rural and result in Landsat-Rural image by using the method of VCP vs non-haze imagery in Landsat-Rural. Result of stacking in three types of image correlation test done and obtained the value as in Table 6.

Visually from the image correction can be assessed that the VCP look better and contrast. Refer to table we get the result 6.

There is a significant relationship among DOS, HM and VCP image corrections with the Non-haze image in each band. From the use of three methods that DOS on band 1, 2 and 6 is the best on Landsat-Rural meanwhile VCP on band 4 and 5 is the best on Landsat-Rural.

Based on Table 7 that the comparison of the average of each band on the three methods obtained Zcount> Ztable, with a significance level of 95% 2-way test values obtained Ztable 1.96, so the hypothesis is fulfilled that every band on the three methods lies in the rejection of Ho and could be concluded that the average band on the three methods are different. Meanwhile based on Table 8 hypothesis is fulfilled that every band on the three methods lies in the reception of Ho and could be concluded that the average band on the three methods are equal.

In case of Urban area on Landsat 7. Based on region of interest (ROI) sampling in Urban area and by using method of haze reduction, it can be obtained the Figure 7.

Table 6. Results of the correlation calculations on Landsat imagery in rural area.

Band	DOS	HM	VCP
1	0.66	0.45	0.64
2	0.76	0.48	0.68
3	0.79	0.55	0.80
4	0.49	0.33	0.55
5	0.72	0.52	0.77
6	0.77	0.53	0.77

Table 7. Results of the Z calculations on Landsat Imagery in Rural area

Band	DOS $_{vs}$ HM	DOS $_{vs}$ VCP	HM $_{vs}$ VCP
1	27.80	70.81	67.69
2	19.08	171.17	99.12
3	36.99	116.55	65.76
4	131.80	64.67	88.99
5	114.53	177.02	81.34
6	122.59	296.72	171.37

Table 8. Results of the Z calculations on Landsat Imagery by Non-Haze in Rural area

Band	DOS $_{vs}$ NH	HM $_{vs}$ NH	VCP $_{vs}$ NH
1	541.21	311.67	593.16
2	353.05	264.68	485.45
3	37.30	254.60	345.65
4	190.72	31.00	102.96
5	73.26	176.00	227.53
6	89.94	196.40	353.22

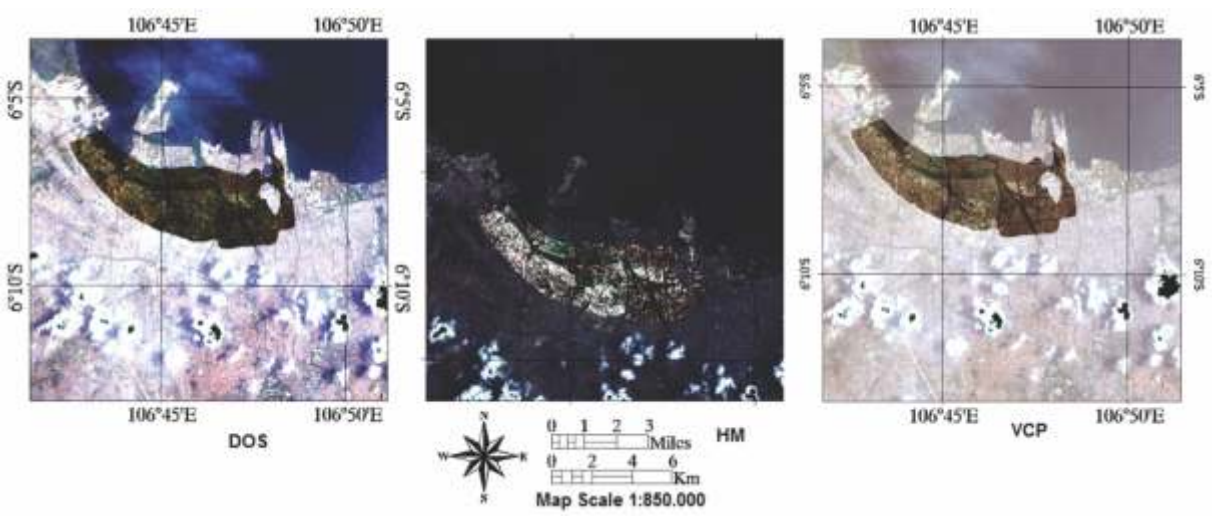

Figure 7. Penjaringan on the results of three method in Landsat 7

On Landsat-Urban haze elimination process is done using DOS, HM and VCP. the results are shown in Figure 7. The stacking process is then conducted on three types of image, between the results in Landsat-Urban image by using the method of DOS vs non-haze imagery in Landsat-Rural, results in Landsat-Urban image by using the method of HM vs non-haze imagery in Landsat-Rural and result in Landsat-Rural image by using the method of VCP vs non-haze imagery in Landsat-Rural. Result of stacking in three types of image correlation test done and obtained the value as in Table 9.
Based on visual interpretation of the comparison of the three methods that DOS is better in landsat 7 Urban is shown by looking at the clarity in image can be identified contours, hue and objects in Urban.

There is a significant relationship among DOS, HM and VCP image corrections with the Non-haze image in each band. From the use of three methods that DOS on band 1, 2 and 6 is the best on Landsat-Urban meanwhile VCP on band 3, 4 and 5 is the best on Landsat-Urban.

Based on Table 10 that the comparison of the average of each band on the three methods obtained Zcount> Ztable, with a significance level of 95% 2-way test values obtained Ztable 1.96, so the hypothesis is fulfilled that every band on the three methods lies in the rejection of Ho and could be concluded that the average band on the three methods are different. Meanwhile based on Table 11 hypothesis is fulfilled that every band on the three methods lies in the reception of Ho and could be concluded that the average band on the three methods are equal.

In case of HOT. In this research by using the haze optimize equation and calculate average value produced HOT average value tables.

Table 9. Results of the correlation calculations on Landsat imagery in Urban area

Band	DOS	HM	VCP
1	0.61	0.16	0.54
2	0.71	0.21	0.65
3	0.80	0.31	0.80
4	0.77	0.38	0.88
5	0.86	0.51	0.90
6	0.90	0.47	0.81

Table 10. Results of the Z calculations on Landsat Imagery in Urban area

Band	DOS vs HM	DOS vs VCP	HM vs VCP
1	46.21	393.41	133.45
2	9.64	398.09	148.75
3	42.28	283.85	105.89
4	78.59	335.33	169.05
5	252.00	514.84	268.38
6	200.98	519.20	318.07

Table 11. Results of the Z calculations on Landsat Imagery by Non-Haze in Urban area

Band	DOS vs NH	HM vs NH	VCP vs NH
1	293.16	113.43	456.93
2	151.37	107.10	393.36
3	42.28	88.42	287.61
4	241.26	101.20	86.28
5	189.36	33.30	257.39
6	86.00	96.93	364.58

Table 12. Results of HOT Calculation

Categories	DOS	HM	VCP
Avnir-Rural	135.41	149.83	132.72
Avnir-Urban	130.55	134.64	129.60
Landsat-Rural	113.10	112.81	106.55
Landsat-Urban	130.59	132.66	108.48

Based on the results in Table 12 that the better the image correction results received from the values obtained from the optimization of Haze will be smaller, the best HOT average value was 106.547 by using Landsat-VCP in Rural.

Assessment of descriptive qualitative visually. In assessing how effectively the result of the elimination of haze using three methods (DOS, HM, VCP) required the recognize of objects on land cover, in this case there are three places are known as the object as a comparison among the results of image correction, in Figure 8 red cycle refers to the three places that represent the similarity of the comparison of three correction images namely: Marina Indah, Damai Indah Golf, Jl Tol Sedyatmo.

Figure 8. Penjaringan subdistrict recognition

4. Conclusions

The use of three correction methods appeared to have different results.

Differences in land cover conditions (rural and urban) requires a different correction methods can be appropriate with one method or more than one method. The difference in the spectral range (AVNIR and Landsat) requires a different correction methods can be appropriate with one method or more than one method. Use of HOT value to assess the quality of the result image correction can be used, but not enough.

Provide a minimum of five types of imagery in areas assumed as the urban and rural regions with a five image pairs haze and non-haze image so it can be the result of the ability of the three methods.

There needs to be an effort classification types and characteristics of satellite imagery by considering a range of wavelengths and different resolutions so that the correction of three methods (DOS,HM and VCP) is becoming more effective and efficient.

For further research is necessary to develop methods, algorithms, or new modeling that can eliminate the influence of the range of land-cover period of time so that image correction results can be compared better with non-haze image.

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