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ALOS AVNIR-2 DIGITAL DATA ANALYSIS FOR TURBIDITY MAPPING IN SEMARANG COASTAL AREA, CENTRAL JAVA, INDONESIA

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ABSTRACT

This study aims to determine the spectral response of ALOS AVNIR-2 satellite's image on the turbidity of the waters and devise the algorithms for turbidity mapping in the coastal waters of Semarang City, Indonesia. The Remote Sensing Technology Center of Japan, RESTEC supported the ALOS AVNIR data and conducted the technical training on Application and Verification Project to support this research. The method used in this study is digital image processing and field survey. Digital image processing method including histogram adjustment for radiometry correction, rectification for geometry correction, cropping area of interest, masking the area for the separation of the mainland, statistical analysis to determine the spectral response of the image of water turbidity ($R^2 \geq 0.9$) and algorithm model evaluation by using the Mean Normalized Bias (MNB) as an indicator of systematic error and the Root Mean Square (RMS) as an indicator of random error (Ouillon et al., 2008). The results of statistical analysis showed that the red channel and green channel on ALOS AVNIR-2 has a relatively high spectral response of the turbidity level ($R^2 \geq 0.9$). The best algorithm model for the single spectral channel obtained from the red band with the MNB value is 22.65% and the RMS value is 32.09%. The best algorithm model for the dual channel spectral bands obtained from a combination of red and blue bands with the MNB value is 19.89% and the RMS value is 28.22%. Distribution of water turbidity levels in the waters of Semarang city has a range between 0.03 to 9.44 NTU.

Key words: ALOS AVNIR-2, Turbidity Mapping and Coastal Area

Introduction

The Coastal waters of Semarang city in Indonesia, has a relatively high turbidity levels. This turbidity levels shows the level of water clarity caused by the material elements and sediment suspension. Turbidity is caused by the process of sediment transport from the river and human activities located in coastal areas such as aqua culture, reclamation, and land management. Turbidity levels have an important role as indicators of sedimentation rates, aquatic productivity and water pollution. Therefore, monitoring of turbidity levels is important in the coastal waters, especially in the waters of the city of Semarang. Remote sensing technology was chosen because its advantages such as having a broad scope, the relatively short measurement time can be repeated, the data obtained is the latest data and the overall total cost of monitoring is relatively inexpensive (Prahasta, 2008).

This study aims to assess the spectral responses of satellite imagery ALOS AVNIR-2 on the turbidity of the waters and develop the algorithm models for mapping turbidity in the waters of the city of Semarang. Research sites located in the waters of Semarang city (6º54'0,36''-6°58'53,68'' S and 110°18'23,78''-

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110°28'9,92" E). The study was conducted in two stages, first is the collection of field data in the waters of Semarang which was held on August 7 - 9, 2010; then the second is data processing of ALOS AVNIR-2's image performed at the Laboratory of Marine Science, Diponegoro University, Semarang.

Method

The measurement of turbidity in the field was conducted on August 7 to 9, 2010. Determination of 50 research stations using the purposive random sampling method with interpreting the appearance of turbidity in satellite imagery ALOS AVNIR-2, taking samples of water using the water samples, water samples were then analyzed using Turbidimeter in Laboratory of Environment, Diponegoro University, Semarang.

The Remote Sensing Technology Center of Japan, RESTEC supported the ALOS AVNIR data and support the technical process trough the comprehensive ALOS training project in Indonesia, including fundamental and advanced training. Stages of satellite image data processing ALOS AVNIR-2 started with radiometric correction by histogram adjustment, geometric correction by rectification or by determining the Ground Control Point / GCP, cropping area of interest, separating the mainland and water body by a masking method, preparation of turbidity algorithms model, analysis of satellite imagery spectral response to turbidity and evaluation of turbidity algorithms model.

Preparation of the algorithm model is done by looking for correlations between spectral channels / bands (except for the fourth band) of satellite imagery ALOS AVNIR-2 with a turbidity value of the field data. Correlation value is used to view the relationship between the value of the turbidity in the field and the spectral channels values. The next step is to calculate the regression between the spectral channels values of satellite imagery ALOS AVNIR-2 with a turbidity value of the field to develop the models of turbidity algorithm. Regression method used are linear regression, polynomial, power, exponential, and logarithmic regression (Ouillon et al., 2008). The condition used as the preparation of turbidity algorithm model provisions level of the waters is that the R Square value must be greater or equal to 0.9 ($R^2 \geq 0.9$). The algorithm model is local and thematic. This study is limited to the preparation of two-band algorithm model and involves only three spectral channels of four spectral channels contained in the satellite imagery ALOS AVNIR-2.

Evaluation of turbidity algorithm model in this study using the method of statistical analysis based on several criteria used by Toole et al. (2000) and Darecki and Stramski (2004);

$$mean\,(x) = \overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i ,$$

$$stdev\,(x) = \left[\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2\right]^{1/2}$$

Based on the above equations, it can be derived the equations to calculate the Mean Normalized Bias (MNB) and Root Mean Square (RMS). MNB is an indicator of systematic, while RMS error is a random indicator of the algorithm model. Below is the equation for calculating the MNB and the RMS of the turbidity algorithm model (Ouillon et al., 2008):

$$MNB = mean\left[\frac{y_{alg} - y_{obs}}{y_{obs}}\right] * 100\%$$

$$rms = stdev\left[\frac{y_{alg} - y_{obs}}{y_{obs}}\right] * 100\%$$

Where y_{alg} is a variable obtained from the model of algorithm; y_{obs} is the turbidity value in the field (results of laboratory analysis). Slope, intercept and correlation coefficient (determinant coefficient of R^2) obtained from the calculation of linear regression between the algorithm models proposed and field turbidity data.

Results and Discussion

Turbidity values obtained from the data field varies between 0.09 to 9.53 NTU. The highest turbidity value (9.53 NTU) is located at station 9 (Figure 1) which is located at the river mouth of *Banjir Kanal Barat* river. In general, the higher turbidity values found at stations located close to the beach. Estuarine areas or areas near the coast line have a higher turbidity levels when compared to areas farther from shoreline. The existence of settlements or human activity in this area may be a reason for the high turbidity values, given the local population to make the river as a place of domestic waste disposal.

The algorithm model is based on the spectral response of satellite imagery ALOS AVNIR-2 on the level of turbidity by using a single band (single spectral channel) and the combination of two bands (dual spectral channels) with R Square value must be greater or equal to 0.9 ($R^2 \geq 0.9$). The study produced 3 models of algorithms from single spectral channel and 63 models of algorithms from dual spectral channels. Based on the results of analysis of the spectral response, 2 best algorithm models from single spectral channels and 4 best algorithm models from dual spectral channels were obtained (Figures 2 and 3).

According to Ouillon et al. (2008), model of the algorithm by using a combination of the two bands have a spectral response relatively higher of organic matter content than the model that uses only a band or a single spectral channel, which is very precise when used to view the turbidity waters rich in organic matter. Therefore, this study will only discuss the model of algorithm from multiple spectral channels. Formulation of the algorithm model is expected to provide the higher spectral responses than the single spectral channel algorithm model.

Based on the R Square value, the red channel has a higher spectral response to the turbidity waters with a value of R 2: 0.90 compared with the green channel, R2: 0.89 so that the best algorithm models from double spectral channels will have combination of two bands with a red channel as one of the variables. The highest R Square value is derived from a combination of the red channel and blue channel with the R2 value is 0.92.

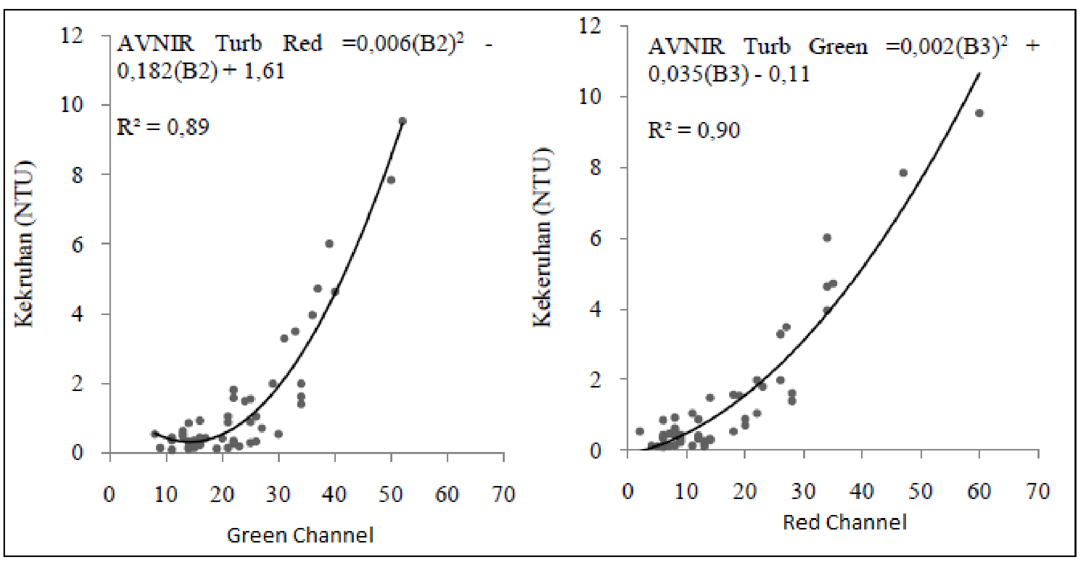

Figure 1. Best Algorithm Models Of Spectral Responses of a Single Channel

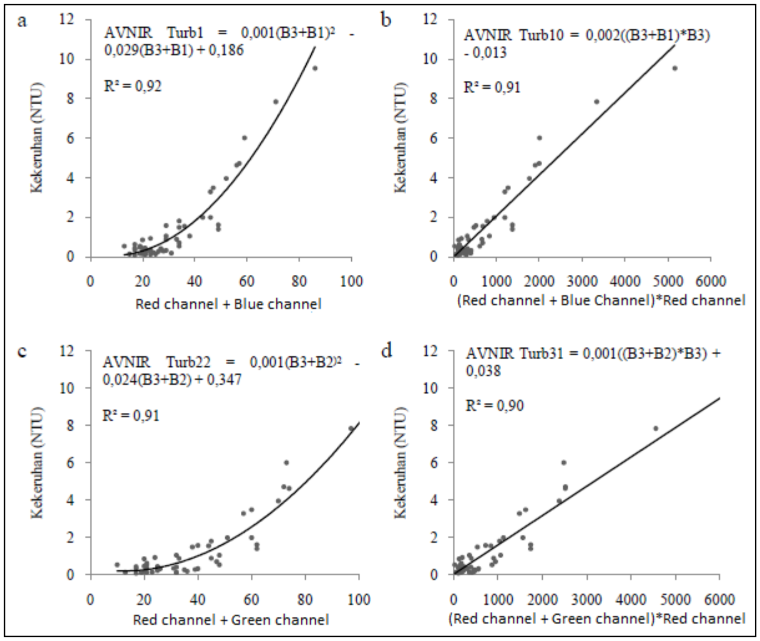

Figure 2. Best Algorithm Models Of Spectral Responses of Double Spectral Channels.

Based on the equation of regression obtained, then drafted 6 new algorithm models to see the level of water turbidity. These algorithm models are then evaluated or tested the goodness of the model by using the MNB and the RMS as an indicator of the algorithm model error (Table 1 and Table 2). The results of the best turbidity algorithm model from 70 models (AVNIR Turb10) obtained information about the spatial distribution of water turbidity level of the city waters, which has a range between 0.03 to 9.44 NTU (Figure 4). The results of modeling algorithm then classified based on the level of turbidity into several classes, class 0-1 NTU (very clear), class 1-2 NTU (clear), class 2-3 NTU (turbid), class >3 (very turbid). Based on visual interpretation, the areas with high turbidity levels are near the river mouth (*Banjir Kanal Barat* river, *Banjir Kanal Timur* river, *Sringin* river and *Babon* river), which is an area of the township and Tugu district of Semarang city. The information of distribution and classification level of turbidity is expected to be a reference to the management of the city.

Table 1. The results of evaluation of single spectral algorithm models

No.	Turbidity Algorithm Models	MNB (%)	RMS (%)	mean quadr erorr	Intercept	Slope	R^2
1	AVNIR Turb Red = $0,002(B3)^2 + 0,035\ (B3) - 0,11$	22,65	32,09	0,26	0,04	1,22	0,90
2	AVNIR Turb Green = $0,006(B2)^2 – 0,182(B2) + 1,61$	34,66	48,05	0,35	0,18	1,26	0,87

Table 2. The results of evaluation of double spectral algorithm models

Table 2. The results of evaluation of double spectral algorithm models

No.	Turbidity Algorithm Models	MNB (%)	RMS (%)	mean quadr erorr	Intercept	Slope	R^2
1	AVNIR Turb10 = $0,002((B3+b1)*B3) - 0,013$	19,89	28,22	0,25	0,02	1,85	0,91
2	AVNIR Turb31= $0,001((B3+b2)*B3) + 0,038$	20,62	29,16	0,26	0,03	1,41	0,90
3	AVNIR Turb22= $0,001(B3+B2)^2 - 0,024(B3+B2) + 0,347$	25,32	35,78	0,26	0,01	1,02	0,89
4	AVNIR Turb1= $0,001(B3+B1)^2 - 0,029(B3+B1) + 0,186$	33,23	46,87	0,28	0,36	2,21	0,89

The results above indicate that the best channels/bands for a single spectral channel model algorithm is in the red channel (Table 1). On ALOS AVNIR-2 satellite channels have red spectral domain between 0.61 - 0.69 μm. This is in accordance with the opinion of Ritchie et al. (1976), which says that the best spectral domain to model the turbidity algorithm is 0.60 to 0.80 μm while according to Novo et al. (1989) algorithm model of turbidity would be more optimum in the spectral domain from 0.60 to 0.65 μm. Ouillon et al. (2008) in his study in New Caledonia, Cuba and Fiji saying that the best spectral domain algorithm to model the turbidity present in the spectral domain from 0.50 to 0.60 μm and the second best model is in the domains 0.60 to 0.70 μm. The results of the spectral response of satellite imagery ALOS AVNIR-2 prove it, because the value of R^2 red channel and green channel is greater than 0.9 (R^2> 0.9).

Ardana and Mahendra (2008) proved that the domain of band 3 and band 2 in the satellite imagery ALOS AVNIR-2 has a high correlation to the level of water turbidity. But of course the combination of two bands or two-band model algorithms produce a better algorithm models of turbidity. The best algorithm model of dual spectral channel obtained from a combination of red and blue channels (AVNIR Turb1). Meanwhile, according to Somvanshi et al. (2011) in his research that uses methods Normalized Difference Turbidity Index (NDTI) states that the combination of the red channel and green channel has the best spectral response in the turbidity level mapping. However Ouillon et al. (2008) concluded that the best ratio for turbidity algorithm model is the red line and blue line or red channel and green channels. Based on the maps of distribution and turbidity levels of calcifications (Figure 3 and Figure 4), can be seen that the turbidity levels along the coast is relatively higher than the area far from the coast. The high level of turbidity in this area can be caused by the existence of settlements of the human population that make the river as a place of disposal of their domestic waste.

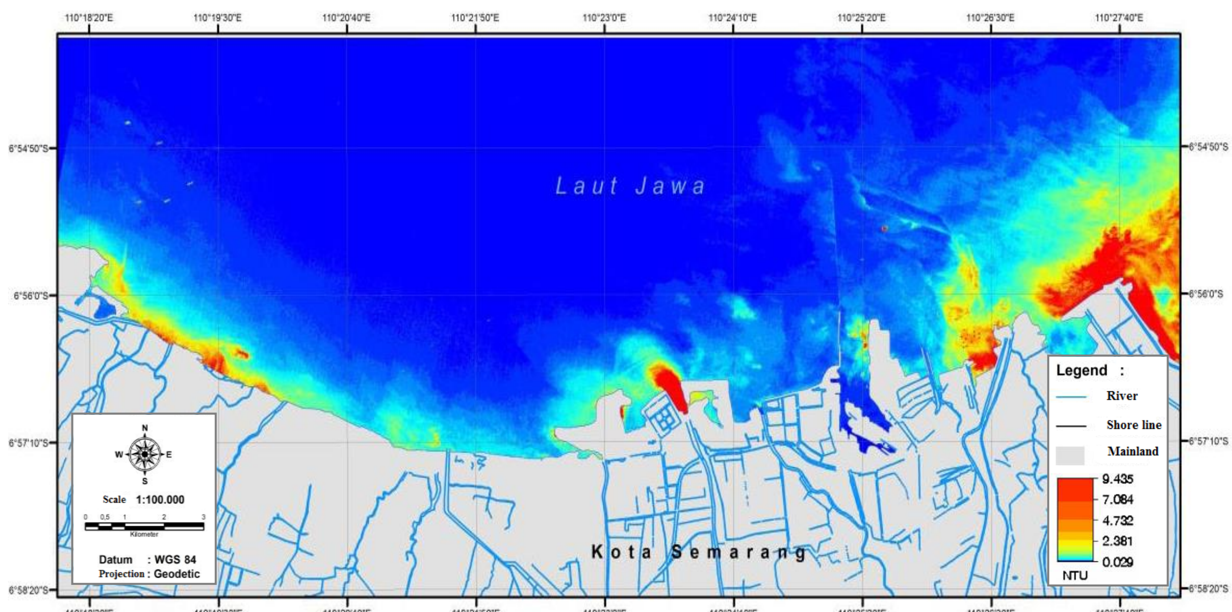

Figure 3. Turbidity Image in Coastal Waters of Semarang City

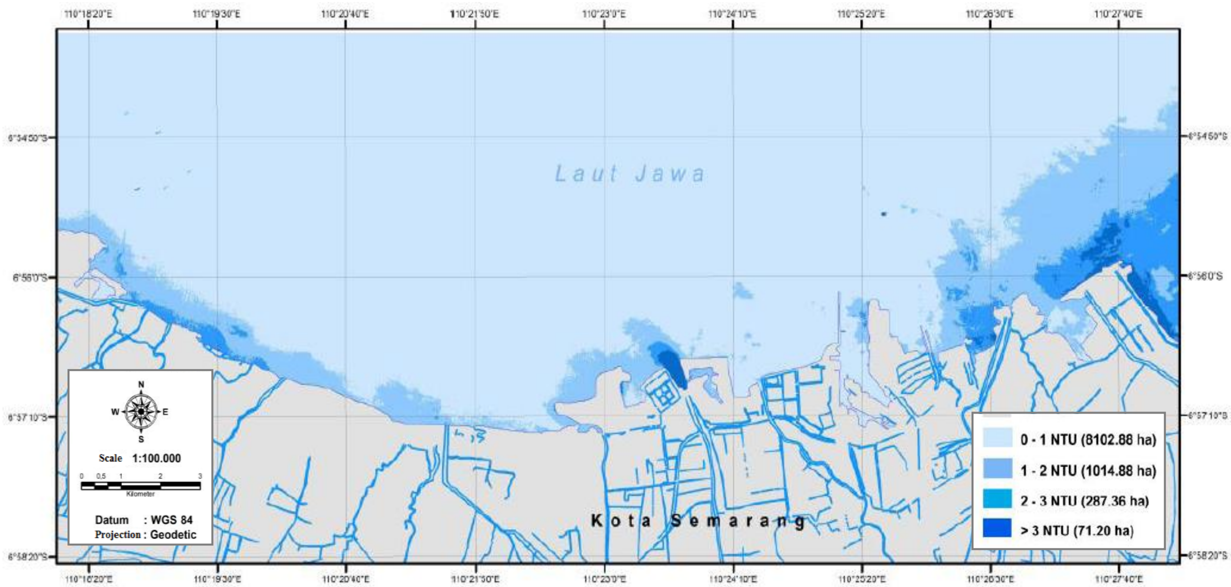

Figure 4. Turbidity Map in Coastal Waters of Semarang City

Conclusion

ALOS AVNIR data and the training that have been conducted by The Remote Sensing Technology Center of Japan, RESTEC were give significant contribution to this research. Several conclusions can be drawn from this study : the best single spectral channel algorithm is derived from AVNIR Turb Red model with systematic errors (MNB: 22.65%) and model error (RMS: 32.09%); the best multiple spectral channels algorithm models are derived from AVNIR Turb1 model with systematic errors (MNB: 19.89%) and model error (RMS: 28.22%); ALOS AVNIR-2 images have the high spectral response of the turbidity waters, especially the red spectral channels (R2 : 0.90) and the green spectral channels (R2: 0.89).

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