DETECTION OF ACID SLUDGE CONTAMINATED AREA BASED ON NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI) VALUE

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Abstract. The solid form of oil heavy metal waste is known as acid sludge. The aim of this research is to exercise the correlation between acid sludge concentration in soil and NDVI value, and further studying the Normalized Difference Vegetation Index (NDVI) anomaly by multi-temporal Landsat satellite images. The implemented method is NDVI. In this research, NDVI is analyzed using the remote sensing data on dry season and wet season. Between 1997 to 2012, NDVI value in dry season is around – 0.007 (July 2001) to 0.386 (May 1997), meanwhile in wet season NDVI value is around – 0.005 (November 2006) to 0.381 (December 1995). The high NDVI value shows the leaf health or thickness, where the low NDVI indicates the vegetation stress and rareness which can be concluded as the evidence of contamination. The rehabilitation has been executed in the acid sludge contaminated location, where the high value of NDVI indicates the successfull land rehabilitation effort.

Keywords: *Acid sludge, Contamination, Normalized Difference Vegetation Index (NDVI)*

1 INTRODUCTION

The often occurrence of soil contamination is heavy metal and mineral pollution from oil waste. Heavy metal pollution is a kind of serious problem experienced by several countries. Heavy metal from a dense oil waste is known as acid sludge. The disposed acid sludge to soil will not directly degraded, but it will stand still in the disposal environment, and therefore accumulation of such material will take place. The high concentration of acid sludge in soil will generates a phytotoxic for crops. The accumulation of acid sludge in agricultural fields will not only pollute the environment but it can affect food quality and subsequently will impact human health. This contaminant effect on crop will lead to vegetation susceptibleness. The high concentration of acid sludge in soil is one of main factor hampering the vegetation growth in affected areas. The existence of acid sludge also influence soil decomposition process which will affect the fertility of soil as well as its productivity.

The detection of acid sludge affected field is an important step to anticipate and early countermeasure to avoid contamination spread and hazard of environment surrounding the acid sludge disposal. For the time being, detection and monitoring of oil acid sludge contaminated field take place by field analysis and laboratory analysis which time consuming and requires an expensive cost. The present development of technology enable the monitoring of waste contaminated area without even touching the analyzed objects. This technology is known as remote sensing technology. The superiority of remote sensing technology is wide coverage, real time (up to date), availability of good historical data, and spectral characteristic providing possibility to monitor condition of acid sludge contaminated area. Several research show the remote sensing data, especially thermal infra red canal capable to detect the acid sludge contaminated area. But for Indonesian case, where the waste contamination has no wide area, the further comprehensive research is required.

Generally the use of vegetation index by the application of Normalized Difference Vegetation Index (NDVI) through the processing of remote sensing data, combining the red spectral and infra red shows the widely used index for land identification for burned area as well as vegetation covered land such as forest or plantation area (Viedma *et al.,* 1997; Pereira 1999; Chuvieco *et al.*, 2002).

The previous research is through the evaluation and monitoring of heavy metal content in the soil by integrating the chemical measurement and Landsat 7 ETM+ remote sensing data. The applied method in this research is NDVI and NDVI anomaly. The NDVI value is obtained from the index ratio which is dependent of vegation reflectancy change between red band and Near Infra Red (NIR) band. The reflectant value in red band will decreases along the increase of chlorofil absorption, where the NIR band is very sensitive against the green level of vegetation. NDVI is a parameter of biomass condition which indicates the health or the thickness of leaf. The low NDVI shows the stress of vegetaion and the density of rare vegetation (D'Emilio 2012).

The research for toxicious and hazardous waste B3 is also conducted by Slonecker (2010), where the research studied the environmental problem which influence the life of human and and ecology caused by the B3 disposal. The use of remote sensing for detection of B3 may apply several method, among others the use of NDVI method where the NDVI value is obtained from the red band and NIR band through the application of Landsat TM images.

The reserach in the same location has been conducted by the application of rededge method (Haryani *et al.,* 2013), which shows the use of redegde is still difficult for mplemetation for the use of low to middle resolution such as landsat.

In addition, the research (Kooistra *et al.,* 2004) which has been conducted to study the relation between vegetation reflectancy and the increase of Ni, Cd, Cu, Zn and Pb metal concentration shows that the relation between soil concentration and vegetation reflectancy give the similar result with Difference Vegetation Index.

Based on the above cases, it is necessary to handle the waste contaminated area. This research is particularly focused to B3 acid sludge contamination monitoring in hinterland area. This research will detect the acid sludge contaminated area, at the contamination occurrence and post occurrence after a remedial of environmental condition. Detection and monitoring is worked out by the use of historical remote sensing data (multidate), where the development of contamination is visible.

The goal of the research is to analyze the correlation between acid sludge concentration in soil with NDVI value, and to study the NDVI anomaly from satellite images. The presented hypothesis is the higher NDVI value will decrease the acid sludge contamination. This happen because the effort of remedial for acid sludge contaminated soil take place.

2 MATERIAL AND METHOD

2.1 Data and Location

The applied data for the research of acid sludge pollution is Landsat TM data (Thematic Mapper) and Landsat ETM + (Enchanced Thematic Mapper Plus) with path 116, row 061, covering Landsat data of 1995 – 2012. The location of detection of acid sludge contamination is Balikpapan, East Kalimantan. The applied data in this research are 19 scene Landsat data on path/row 116/061. The data take place on 20 December 1995, 31 May 1997, 5 July 2001, 6 August 2001, 14 February 2002, 21 May 2002, 21 March 2003, 28 August 2003, 2 December 2003, 2 November 2004, 16 July 2005, 18 September 2005, 18 September 2005, 5 November 2005, 23 December 2005, 8 November 2006, 16 March 2007, 29

December 2007, 8 May 2009 and 3 July 2012.

2.2 Method

Preprocessing of satellite image, comprising data correction according to analysis standard. Data preprocessing include geometric correction, radiometric correction and spectral value normalization for multitemporal data. The data correction aims to minimaze/eliminate the position error and the spectral value due to the difference of recording time, in order to obtain more consistent and accurate result.

Further processing such as classification of land cover in the study area as well as the calculation of NDVI and NDVI anomaly. Classification method used is digital multispectral classification on Landsat image. Based on the results obtained classification results vegetated areas and non vegetated.

The implemented method is Normalized Difference Vegetation Index (NDVI), that is a comparation between spectral red (R.) minus Near Infra Red (NIR) divided by the sum of Spectral Red (R.) and Near Infra Red (NIR). The processed Spectral Band has the reflectance data, and from this value the NDVI is calculated and mapped. The index ratio depends on vegetation reflectance change between red electromagnetic spectrum length and near infrared. NDVI formula (Collin *et al.*, 1983, Horler *et al.*, 1980; Guyot *et al.*,1992; Ray *et al.*, 1993; Baret *et al.*, 1991; Carlson *et al.*, 1991; Tucker, 2001) are as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED} \qquad (2\text{-}1)$$

Meanwhile the NDVI anomaly formula (D'Em ilio et al, 2012) is as follows:

NDVI Anomaly=NDVI–mean NDVI (2-2)

Where NIR is reflectance value of near infrared channel (B4) and RED is the reflectance value of red channel (B3). Red reflectance will decreases along the increase of chlorophyll absorption where the near infrared reflectance dependent on the leaf structure and will decrease along the decrease of green crop biomass, so that the NDVI is highly sensitive to the type, density and condition of vegetation coverage. The high NDVI can shows the health or the thickness of leaf, and the low NDVI shows the vegetation stress and vegetation sparse. At all season NDVI is calculated by the average of NDVI from two seasons, dry season and wet season. From mean NDVI for each season, then NDVI anomaly is calculated. NDVI values and NDVI anomaly every seasons is then compared with remedial process, to determine the relationship between NDVI and acid sludge contamination. The flowchart of research implementation as indicated in Figure 2-1.

NDVI value is classified based on the season, because the calculation result of NDVI value from the imagery analysis on dry and wet season will be significantly different, caused by the moistured soil due to the water inundation. The similar condition is also worked out by Mariagrazia D'Emilio in 2012 who conducted the monitoring of heavy metal in the contaminated area using Landsat ETM+ image during spring (May 13), summer (June 4) and autumn (September 18).

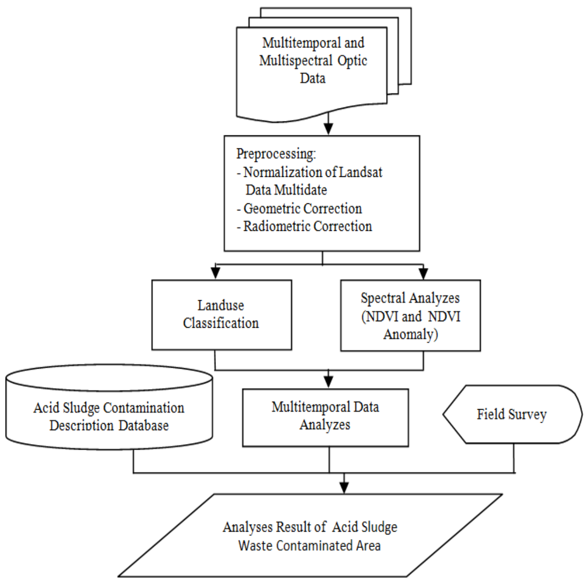

Figure 2-1: Flowchart of Research

3 RESULT AND DISCUSSION

The previously conducted research by D'Emilio M., 2012 monitored the heavy metal in soil, using NDVI method and NDVI anomaly from red band and NIR band of Landsat 7 ETM+ data, where NDVI is a parameter which indicates the health of vegetation. The result of low NDVI value shows the vegetation stress and the density of rare vegetation indicating that the heavy metal content in soil still high, and in the contrary, the high NDVI value shows the healthy and good density of vegetation which means the heavy metal content in soil is low.

Normalized Difference Vegetation Index (NDVI)

The Landsat data analysis for detecting the acid sludge contamination uses multitemporal data, covering the Landsat data from 1995 to 2012. In analysis for calculating the NDVI, it is separated between the data in dry and wet season.The dry season data spanned between March to August, meanwhile the wet season take place between September to February. The observation point of acid sludge contamination consists of 30 location (polygon), but it decreases to 25 location after the next plotting due to the occurrence of some point where it is combined into one polygon with other point.

The location point of acid sludge contamination observation are 30 points, but after plotting only 25 points are applicable (polygon), resulted from the facts that several points are included in the same polygon, among others: point E7 and F4, point E6 and F2 and F3, point E5 and F1, point A4 and E3. Meanwhile in point A area there are 8 points (A1 to A8), in point B area are 6 points (B1 to B6), point C area are 3 points (C1 to C3), in point D area are 2 points (D1 to D2), in point E area are 7 points (E1 to E7), in point F area are 4 points from F1 to F4 (Pertamina, 2012). The acid sludge contamination location point denoted in blue circle (Figure 3-1) and further is plotted in Landsat RGB 321.

Figure 3-1: Location point of acid sludge (above) and Plotting of location point in contamination (below)

Figure 3-2 and 3-3 are the example of NDVI image and NDVI anomaly on August 6, 2001, where the red circle shows the location of acid sludge research area in Balikpapan, East Kalimantan Province. Vegetation types in the study area is grass or reeds. In the research area, the NDVI value on August 6, 2001 is around 0.093 to 0.295, where the low value of NDVI represents the remaining existence of contamination, meanwhile the high value of NDVI shows the trend to normal condition or the decreasing of contamination level.

NDVI Result on Dry Season

In the dry season, the NDVI value from 1997 to 2012 is fluctuated as shown in Table 3-1. The NDVI range value is – 0.016 to 0.386 in 1997, – 0.007 to 0.306 in 200, – 0.077 to 0.335 in 2003, 0.041 to 0.326 in 2005, 0.066 to 0.313 in 2007, 0.049 to 0.353 in 2009 and 0.092 to 0.305 in 2012.

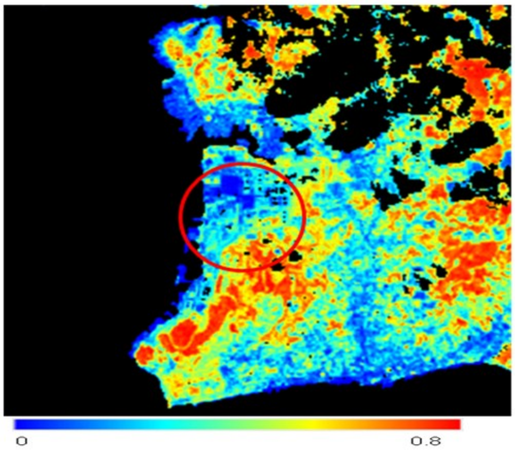

Figure 3-2: NDVI (6 August 2001)

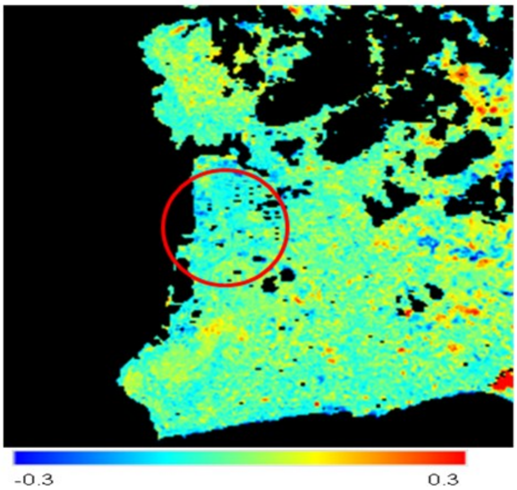

Figure 3-3: Anomaly of NDVI (6 August 2001)

The high NDVI value enable to show the health or the thickness of leaf, while the low NDVI value shows the stress and rareness of vegetation (D'Emilio *et al.*, 2012). The low NDVI represents the existence or potential occurrence of contamination (D'Emilio *et al.*, 2012). The NDVI value in dry season pattern 1 to pattern 6 in Table 3-1 shows the lowest NDVI in pattern 1 with the value of – 0.148 locate in point B1 location, and the highest NDVI reaches 0.386 in pattern 5 occurred in D1 location.

Based on the pattern in the graph, the obtained result of data processing of NDVI is categorized into 6 pattern (Figure 3-4). In Figure 3-4, the value of NDVI in pattern 1 indicates a Ca CO3 neutralization take place on 2003 so the NDVI value increased along with bioremediation process (Pertamina, 2012). The NDVI in 2005 also increase due to solidification activities in 2004 and 2005. In 2006 bioremediation and solidification is conducted and therefore the 2009 NDVI is higher compared with 2007 (Pertamina, 2012). Again in 2012 the NDVI value increases, possibly by the insitu blockage of acid sludge expansion in main flare.

The practiced mitigation method of contamination in the field by Pertamina RU-V Balikpapan was started in 1980 until 2010. In 1980 the acid sludge was neutralized by means of dredging to 6 meter depth and then backfiled with soil. In 2003 a trial of bioremediation was conducted for 300 m^3 but failed, and in 2004 a solidification was trialed for batako but also failed, in 2005 the trial for solidification for 750 m^3 asphalt, and in 2006 a bioremediation for 3950 m^3 was conducted. Further, in 2009 –2010 the stop of acid sludge expansion was conducted insitu at the main flare (Pertamina, 2012).

Table 3-1: NDVI Value in pattern 1 to 6

Pattern	**NDVI Value**		**Location of the**	**Location in the**
	Lowest Value	**Highest Value**	**Lowest NDVI**	**highest NDVI**
Pola 1	-0.148	0.305	B1	E2
Pola 2	0.043	0.294	C1	C3
Pola 3	0.132	0.369	E6F2F3	D2
Pola 4	0.139	0.371	B5	B4
Pola 5	0.045	0.386	B3	D1
Pola 6	0.128	0.336	A6	A6

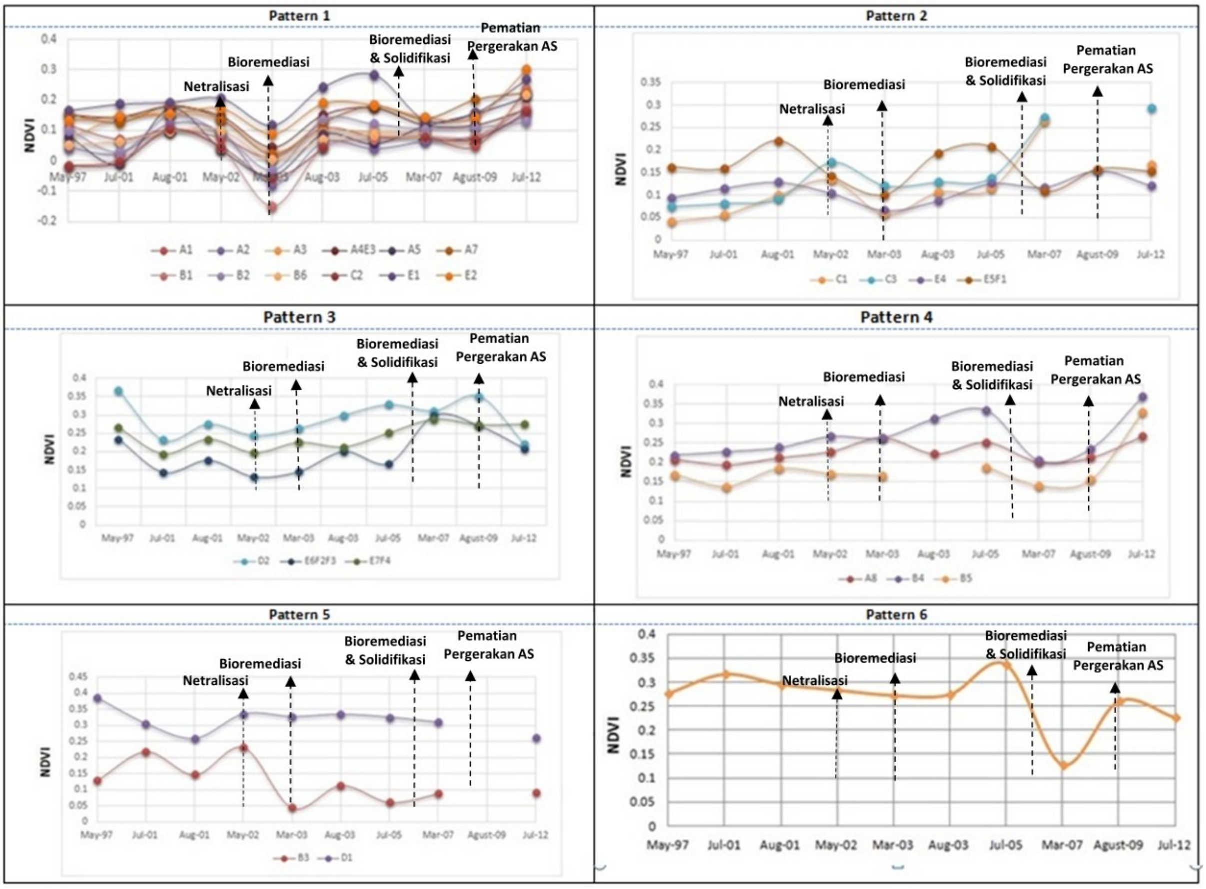

Figure 3-4: Graph of NDVI value in dry season

In Figure 3-4, the graph of pattern 2 which consists of C1, C3, E4, E5 and F1, the NDVI value increased from 1997 to 2001 but decreased in 2002. In 2007 to 2012 there are 2 location with increased NVI, C1 and C3, meanwhile location E4, E5 and F1 are decreasing in 2007. NDVI graph in pattern 3 Figure 3-4, which consists of D2, E6, F2, E7 and F4 shows the NDVI value decreased from 1997 to July, and start ascending in August 2001. In 2002 to 2009 NDVI increased, possibly by an effort for recovery of environment condition, among others by neutralization, bioremediation and solidification, meanwhile in 2012 NDVI is slightly slowing down.

NDVI graph in pattern 4 Figure 3-4, which consists of A8, B4 and B5 shows the NDVI value increased from 1997 to 2005, possibly by an effort for recovery of environmental condition by neutralization, bioremediation and solidification. In 2009 to 2012 it slightly uptrend, where in 2009 to 2010 an environment recovery effort take place as insitu blockage of acid sludge expansion in main flare. The NDVI graph in pattern 5 in Figure 3-4 in 2001 decreased and reversal uptrend in 2002. In March 2003 the NDVI decreased and reversal uptrend in August 2003 due to bioremediation. The NDVI in 2005 at point B3 and D1 slightly decreased. Meanwhile it slightly decreased in 2007-1012 for point D1. In the pattern 6 of Figure 3-4, point 6 shows that NDVI value in 1997 to 2001 ascending in trend but slightly decreased from 2001 to 2003. In 2003 to 2005 it uptrend again.

NDVI Result on Wet Season

The data processing in rainy season between month of October to February shows the following result. In the wet season, the NDVI value from 1995 to 2007 is fluctuated. The range NDVI value is – 0.013 to 0.381 in 1995, 0.16 to 0.308 in 2002, 0.18 to 0.331 in 2003, 0.113 to 0.282 in 2004, 0.035 to 0.302 in 2005, -0.005 to 0.296 in 2006 and 0.029 to 0.294 in 2007. The NDVI value in the wet season has pattern 1 to 6 in Table 3-2 that shows the lowest level in pattern 3 with – 0.013 value at point C2, meanwhile the highest value is 0.381 in pattern 6 at point D2.

The result of data processing for NDVI is categorized into 6 pattern (Figure 3-4). Graph 1 shows that from 1995 to 2002 a Ca CO3 neutralization take place and NDVI value increased at point A2, A3, A5, A7, B1, B2, B4, except point D1 exhibites a descending value. The NDVI in 2002 to 2004 increase for all point locations, possibly the effect of a bioremediation. In 2004 to November 2005 the NDVI value decrease again. In 2005 to December 2007 it increased for all location, possibly the effect of the bioremediation and solidification in 2006. In pattern 2 of the graph, almost all of location points exhibite an increased value during 1995 to 2002, possibly by an effort of environment recovery by neutralization in 2002, except point location B5 which is downtrend from 1995 to 2003. In 1995 to 2003 the NDVI value of all location points decreas, and reversal uptrend in 2004 except location point B3 which decreases and reversal uptrend in 2005. In 2007 the NDVI value for all location points decrease, possibly relate to none environmental recovery.

In pattern 3 of the graph, at location point of E6, F2, F3, E7, F4, C 1, C2 and C3 the NDVI increased during 1995 to 2002, and further in 2002 to 2003 there are a decrease at some points of E7, F4, E6, F2 and F3, meanwhile some points experienced an increasing value at C1, C2 and C3. In 2004 to September 2005 the NDVI value increased, but reversing down in September 2005 to 2007 at all point. In pattern 4 of the graph, NDVI value at location point of A6, B6 , E5 and F1 increased during 1995 to 2002, except B5 slightly decreased. In 2002 to 2003 there are a decrease of NDVI for all point but reversal uptrend in 2004 to November 2005, meanwhile in December 2005 to December 2007 all location point experiencing a decreased value.

In pattern 5 of the graph, at location point of A4, E3 and E1 the NDVI increased during 1995 to 2002, possibly by an effort of environment recovery by neutralization in 2002, and further in 2002 to 2003 there are an increase at points E1, but decrease happen in point A4 and E3. In 2003 to November 2005 the NDVI value increased at all point, possibly by an environment recovery effort through solidification in 2005, but reversing down in November 2005 to November 2006. The NDVI value increased again in November 2006 to December 2007, possibly by an environment recovery effort through bioremediation and solidification in 2006.

Table 3-2: NDVI value, pattern 1 to 6

Pattern	NDVI value		Point of highest	Lowest value
	Lowest value	Highest value	NDVI	NDVI
Pattern 1	-0.005	0.353	B1	D1
Pattern 2	0.005	0.293	B6	A8
Pattern 3	-0.013	0.327	C2	C3
Pattern 4	0.073	0.326	E5F1	A6
Pattern 5	0.102	0.253	A4E3	E1
Pattern 6	0.245	0.381	D2	D2

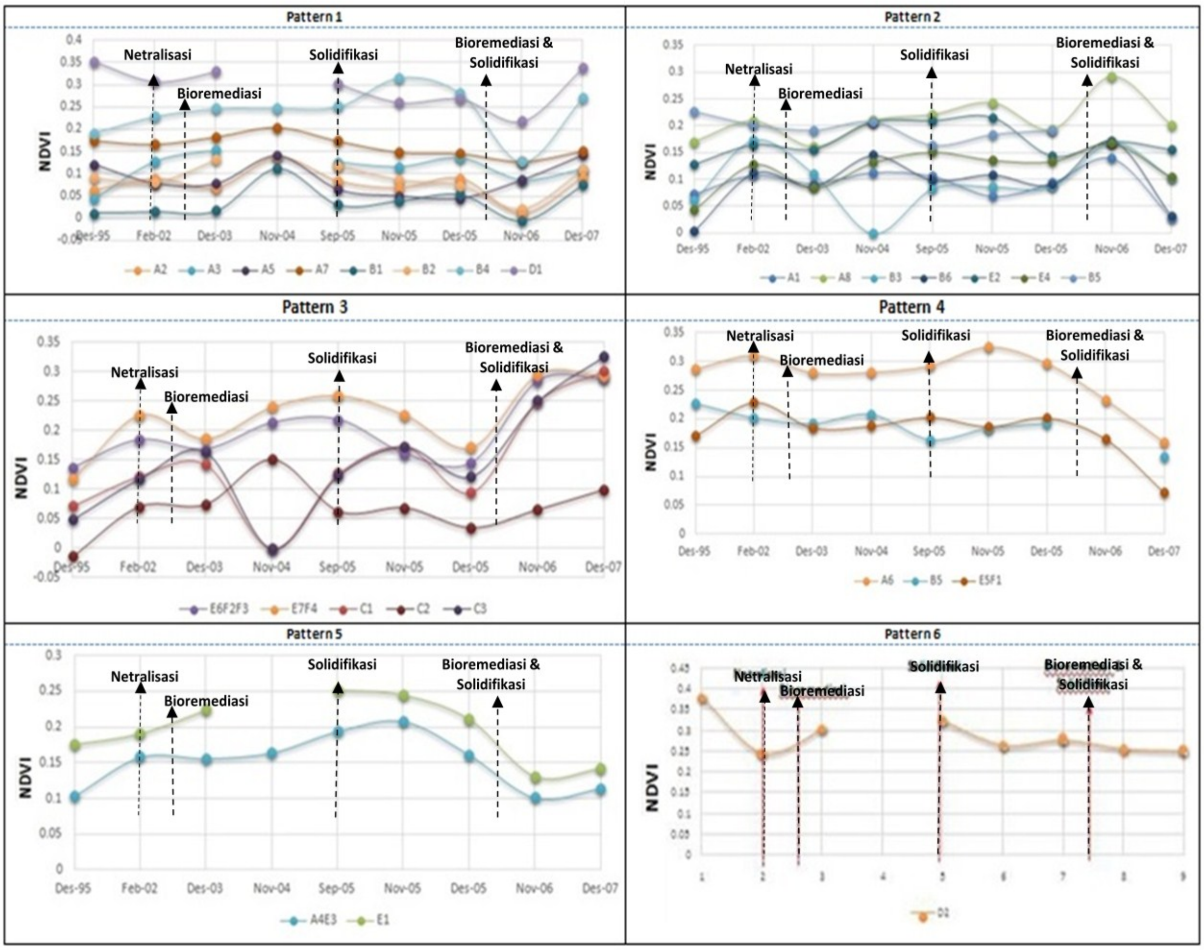

Figure 3-4: Graph of NDVI value in the wet season

Based on field data from the progress report of recovery for acid sludge contaminated field in 2012, several methods have been implemented for acid sludge contamination handling in Balikpapan from 1980 to 2010. Several efforts have been conducted, among others an acid sludge neutralization and 6 m depth dredging followed by soil refill in 1980, a neutralization with $CaCO_3$ in 2002, bioremediation trial with 300 m3 UP-V in 2003 (failed), trial for solidification brick in 2004 (failed), bioremediation of 3950 m3 and solidification (converted to asphalt) 750 m3 in 2006, in situ blockaging of acid sludge expansion in main flare in 2009 to 2010.

NDVI Anomaly

Analysis of NDVI anomaly is based on substraction of NDVI value and mean NDVI in each seasons. The result of NDVI anomaly in location points A1, A2, A3, A4, A5, A7, B1, B2, B6 and C2 is shown in the following graph, where in May 2002 there was an environmental recovery effort by neutralization and bioremediation in March 2003. Further bioremediation and solidification was conducted in 2007, and blockaging of acid sludge expansion in 2010 and 2011. The sample of NDVI anomaly is shown 2 b where the anomaly has range – 0.3 to 0.3. The higher of NDVI anomaly (positive value) indicate the better condition of contaminated area.

NDVI Anomaly in dry season

In Figure 3-5, pattern 1 of NDVI anomaly in dry season, during 1997 to 2012 the NDVI was fluctuated: around – 0.117 to 0.039 in 1997, increased to around 0.06 to 0.088 in 2001, and decreased to around – 0.095 to -0.193 due to environment recovery through neutralization in March 2003. A recovery effort by bioremediation in 2003 increased the value up to around -0.044 to 0.070 in June 2005. A recovery effort by bioremediation and solidification in 2007 increased the value up to around 0.133 to 0.143 in 2012.

The result of anomaly analysis pattern 2 in dry season at location point C1, C3, E4, E5 and F1 (Figure 3-5) indicate a flat graph even though fluctuated between 2001 to 2007, where NDVI anomaly decreased from 2001 to 2003, at around – 0.002 to – 0.018, meanwhile some portion increased to 0.149 and some portion decreased to – 0.052 in 2003 to 2007. NDVI anomaly changed in 2012 to around – 0.007 to 0.14. The NDVI anomaly pattern 3 in dry season in Figure 3-5, as shown in 6 observation points from 1997 to June 2001 experiencing a decreasing value from 0.093 to – 0.058. Meanwhile in May 2002 to 2007 was slightly fluctuated but in average increased to around – 0.015 and 0.101 in 2007. Further from 2007 to 2012 NDVI anomaly decreased to around – 0.069 to 0.033 in 2007 to 2012.

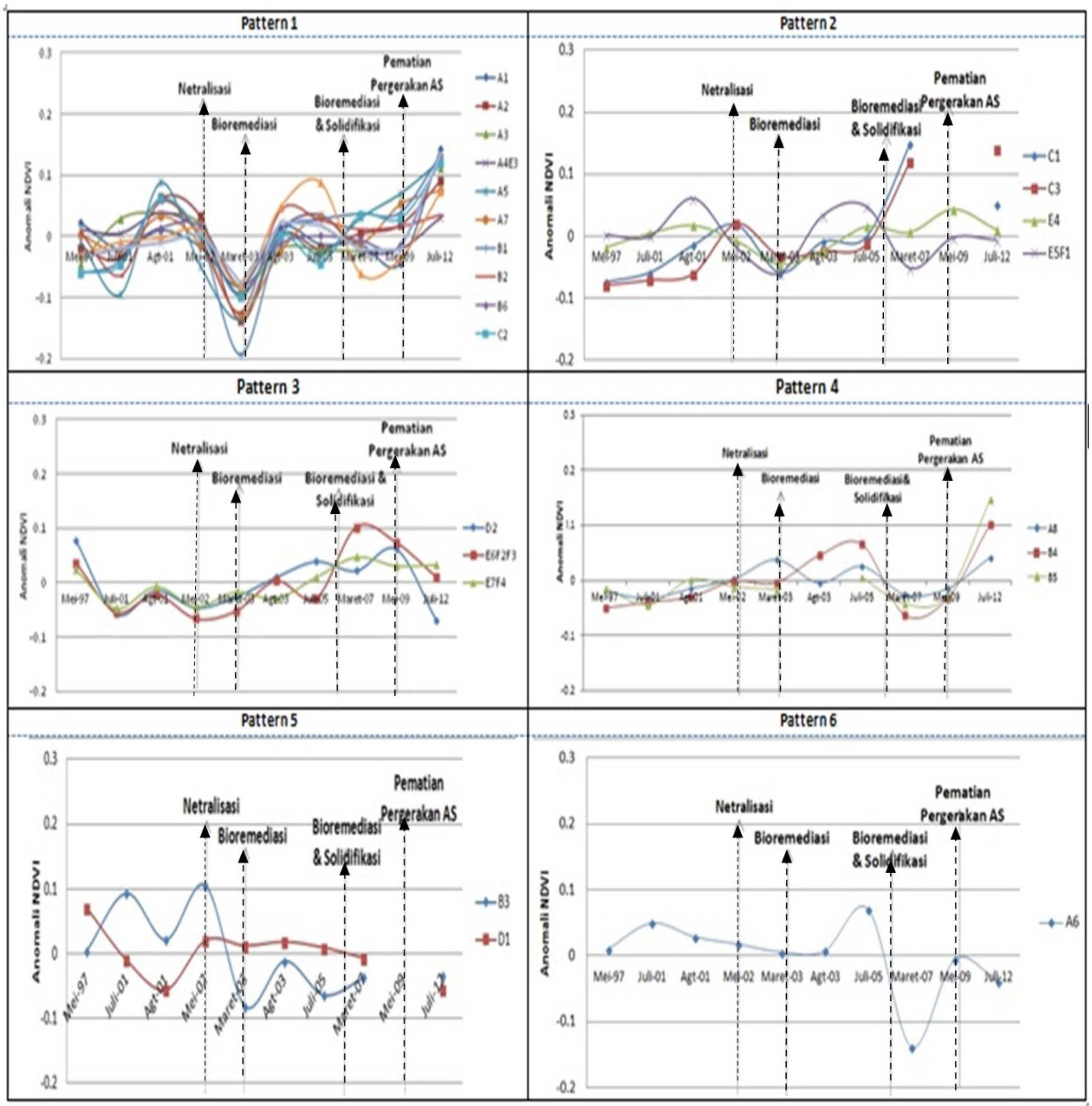

Figure 3-5: NDVI Anomaly graph in dry season

The result of NDVI anomaly analysis pattern 4 in dry season (Figure 3- 5) at 3 location point of A8, B4 and B5 indicates a small increase between 1997 to March 2003, with the value around – 0.049 to 0.019 in May 1997, - 0.016 to 0.038 in March 2003, and increased again to around 0.026 to 0.066 in 2003 to July 2005. NDVI value decreased to around 0.014 to 0.032 in 2005 to 2007, meanwhile it was significantly increased to 0042 to 0.147 in 2007 to 2012.

The result of NDVI anomaly analysis pattern 5 in dry season (Figure 3-5) in 1997 to 2003 was extremely fluctuated, where the value is ranging between 0.106 to – 0.081. Further the NDVI anomaly was less than zero to around – 0.007 to - 0.055 in 2007 to 2012. The result of anomaly analysis pattern 6 in dry season from 1997 to 2003 shows a flat graph at around 0.01 to 0.007, while in 2005 increased up to 0.07 and reversal down trending to – 0.139. The NDVI anomaly increased again to – 0.006 in 2009 and turning down in 2012 to - 0.04.

NDVI Anomaly in wet season

The result of anomaly analysis in wet season at location point A2, A3, A5, A7, B1, B2, B4 and D1 (Figure 3-6) indicates an environment recovery effort in May 2002 through neutralization, and bioremediation in March 2003. Further, a bioremediation and solidification was conducted in 2007. NDVI Anomaly in wet season patern 1 was fluctuated (Figure 3-6). Partial decrease was experienced in 1995 to 2002 and 2003, and further increasing from 2003 to 2004, meanwhile most part are decreased in 2004 to 2006 and reversal increased in 2006 to 2007. NDVI Anomaly in wet season pattern 2 was fluctuated with the value is around – 0.1 to less than 0.1, where it increased from 1995 to 2002 and further decreased in 2003. Reversal up trending was occurred in 2004. In 2005 slightly decreased and return up in 2006 along with a bioremediation and solidification. The value decreased to a below zero level in 2007.

The result of NDVI anomaly pattern 3 in wet season (Figure 3-6) in 1995 to 2007 was significantly increased, where it consistently increased from 1995 to 2004 along with the environment recovery effort in 2002 and 2003 through neutralization and bioremediation subsequently, while it decreased in November to December 2005. Further, it increased in December 2005 to 2007 along with the environment recovery effort through bioremediation and solidification in 2006.

The NDVI anomaly pattern 4 in wet season (Figure 3-6) shows a descending trend in late 2007. The anomaly increased in 1995 to 2002, and reversal down trend from 2002 to 2003 and 2004. It increased from 2004 to November 2005. The value of anomaly significantly decreased from November 2005 to November 2006, while an environment recovery effort through bioremediation and solidification took place in the middle of 2006 which the value increased afterward.

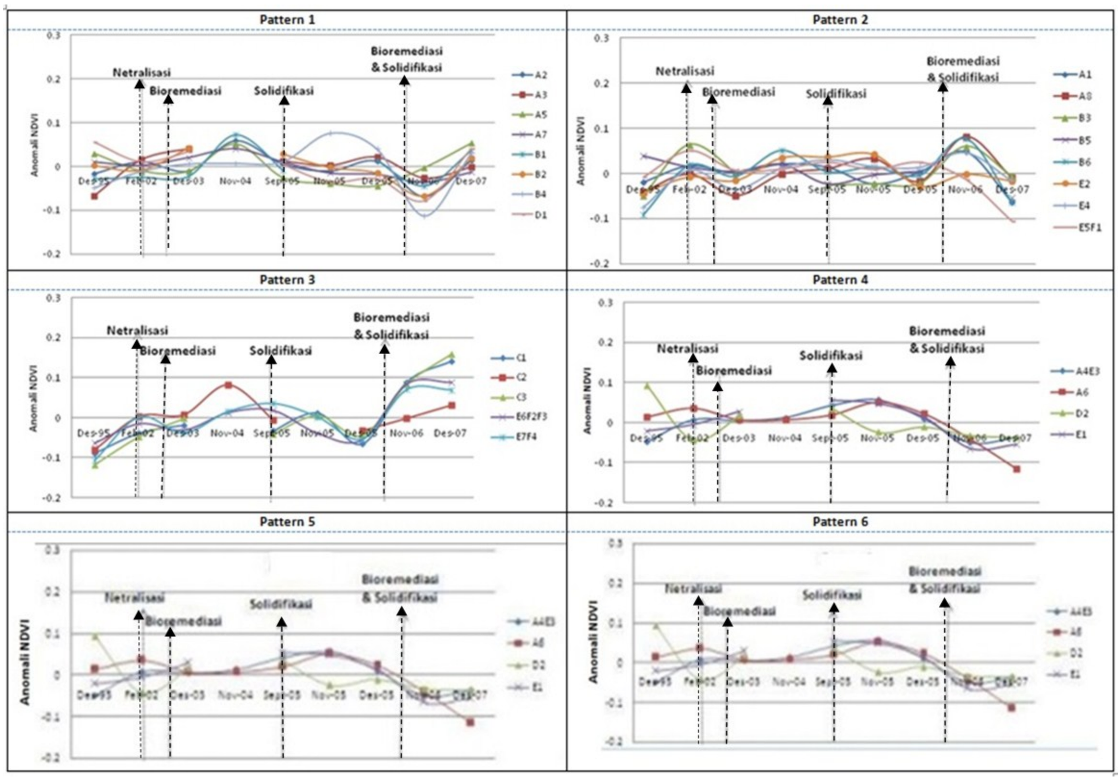

Figure 3-6: NDVI Anomaly graph in wet season

4 CONCLUSION

Based on the analysis in the dry season, it is concluded that there is a significant relationship between NDVI, as wellas NDVI anomaly pattern with the executed remedial process, where after the recovery, the NDVI value and anomaly NDVI trends to increase. The low values of NDVI in study area indicative of the persistence of the pollution, characterized by stress and spare vegetation. While the high values of NDVI and NDVI anomaly indicate a land improvement or recovery, characterized by the better growth of vegetation.

Based on the analysis in wet season, the relationship between NDVI and NDVI anomaly growth pattern with remedial process is not clear. It is possible the existence of water-logging or inundation on the land affects the measurement of NDVI and NDVI anomaly.

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