Utilization of Sentinel-2A imagery For Mapping The dynamics of Total Suspended Sediment at The River Mouth of The Padang City

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***Abstract* - Total Suspended Sediment (TSS) is one of the factors to determine water quality. The large number of TSS indicated the turbid water. Highly turbid water can affect water biophysics. Therefore, mapping TSS distribution is important for managing and preserving coastal areas. Sentinel-2A image uses to create multitemporal TSS from January 2017 to May 2018. This study goals are testing Sentinel-2A image to create TSS map and making TSS temporal map. Image transformations that used were Normalized Difference Suspended Sediment Index (NDSSI), Normalized Suspended Material Index (NSMI) and Band Ratio using green, red, and blue band channels. The best image transformation that analysis with Stepwise Regression is Band Ratio image. The results of laboratory tests showed minimum TSS content of 0.98 mg/L and maximum content of 4.56 mg/L. The accuracy value from TSS mapping with a band ratio image reach 80.51%, indicates that the use of band ratios (b3/b4) is representative to TSS mapping. TSS distribution is dynamic, indicated by TSS temporal map. Dynamic content of TSS influenced by the season. TSS content in wet seasons (October-April) is higher than in dry season (April-October).**

Keyword* - *band ratio, NDSSI, NSMI, Sentinel 2A, Total Suspended Sediment

I. INTRODUCTION

The coastal area is interface area between land and sea, heading to the land is still influenced by the nature of the oceans such as tides, sea winds, and water permeation, while towards the ocean is still influenced by natural processes that occur on land such as sedimentation, fresh water flow and due to human activities such as deforestation and pollution [1]. The coastal area has many functions, like tourism and fisheries that have ecologic and economic values. From those facts, sustainability of coastal areas need attention. Efforts to manage and maintain the sustainability of coastal areas, one of which is to maintain the quality of coastal waters.

Total Suspended Soil (TSS) is a type of suspension sediment (sediment that floats on water). The large intensity of TSS can accelerate the sediment deposition process. TSS is one of the problems in the coastal area of Padang City. Batang Arau River, Banjir Kanal Barat River, and Batang Kuranji River are main rivers in Padang city that contribute TSS in Padang coastal area. TSS is one of the factors that influence the brightness level of the waters. The more turbid waters, indicated the more TSS content. Water brightness affects the ease of phytoplankton photosynthesis because it is easier for sunlight to penetrate the water. On the other hand, turbid waters can block the penetration of sunlight. Mapping TSS concentration is an important thing to determine the level of water quality.

Remote sensing images can be used to estimate TSS content. Sentinel-2A with 10 meters spatial resolution and 4 multispectral bands can use for TSS studies [2]. This research aims to assess the best spectral transformation to mapping the TSS content at estuary of the Batang Arau River, Banjir Kanal Barat River, and Batang Kuranji River in Padang City. Multitemporal TSS modeling from January 2017 to May 2018 use to know TSS dynamic condition in a

Water quality depends on the influence of various parameter such as physical and chemical anorganic condition. Remote sensing has a sensor with wavelength that can be used for measure water quality parameter. Remote sensing measure based on spectral characteristics reflected by water. Contained material in water can affect changes in the spectral characteristic of the water. Water quality parameters can affect directly and indirectly. One of the parameters that can affect water quality is total suspended solid (TSS).

Reflection and emission measurement of water electromagnetic energy carried out with various

transformation to represent TSS distribution. Transformation carried out include NDSSI, NSMI, Band Ratio (Green/Blue), and Band Ratio (Red/Blue). Stepwise test is performed for each transformation result to get the best transformation. Sequentially the transformation is Band Ratio (Green/Blue), Band Ratio (Red/Blue), NDSSI, and then NSMI. the best indeks transformation indeks based on the test is Band Ratio (Green/Blue).

TSS in the water can affect spectral characteristic. Pure water is high in blue and decreases consistenly when the wavelength increases. Water that contain TSS has higher reflection than pure water, the greater the influence, the higher the spectral value. From the result of the extraction of reflected values it can be seen that refection value in blue band range from 0.08 until 0.11, green band 0.06 until 0.08, red band 0.02 until 0.4, and green/blue transformation 0.63 until 0.83, and red/blue transformatin 0,30 until 0,49. From the result of reflected value for each band it can be seen that clue band reflection is more higher than the other bands, so water in that location tends to be clear. TSS can be known by using transformation or band ratio. The result or band ratio shows that green band has bigher influence than red band.

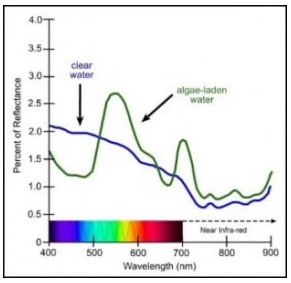

Fig. 1 Percent reflectance of clear (blue) and algae-laden (green) water [3]

According to [3] when the green spectral reflection is greater than red spectral reflection it is indicated that there is an effect in the form of algae pigmen or fitoplankton containing clorophyll. Color of water of the sea found to have a green spectral effect greater than blue is indicated only by phytoplankton. But in coastal regions, the optical properties of seawater are more complex because they are influenced by inputs from rivers, regional winds, and ocean currents.

Band Ratio Green / Blue is the best metod result in representing suspended solids content in coastal areas because it does not use red bands in image transformation such as in Band Ratio (Red / Blue) and NSMI. This is based on the influence of red spectral objects not too large. Whereas the NDSSI is also not good, even though it does not use a red band because the index transformation method uses infrared bands. Infrared band is a band that is used for correction of sunglint. So this band when used for transformation is not corrected for sunglint, while this Sentinel-2A image is a high resolution image so the effect of sunglint must be minimized.

II. METHODOLOGIES

a. Images Correction

Sentinel-2A images have download in C1 level correction so image have geometric correction and radiometric correction. We just change the projection to UTM. Pixel value should to changes become float format number. The formula that use to changes format number show in bellow.

b" = float(b1/10000), …… (1)
b" = band with new pixel value in surface reflectance
b1 = band target

Transformation index use for process Sentinel 2A image for total suspended solid. Transformation index that use in this study are NDSSI (Normalized Difference Suspended Sediment Index), NSMI (Normalized Suspended Material Index), and Band Ratio.

1. NDSSI (Normalized Difference Suspended Sediment Index)
   Range of NDSSI transformation values is between 1 to -1. The value close to 1 indicates that the water is getting turbid (higher TSS) while close to -1 indicates that the water getting clearer (lower TSS) [4].

$$NDSSI = \left(\frac{blue\ band - infrared\ band}{lue\ band + infrared\ band} \right) \ldots\ldots\ldots (2)$$

2. NSMI (Normalized Suspended Material Index)
   Range of NSMI transformation values is between 1 to -1. In NSMI, the value close to 1 indicates that the water is getting clearer (lower TSS) and the value to with -1 getting turbid (higher TSS) [5].

$$NSMI = \left(\frac{red\ band + green\ band - blue\ band}{red\ band + green\ band + blue\ band} \right) \ldots\ldots\ldots.. (3)$$

3. Band Ratio
   This index transformation used 2 band [6], green band and blue band. This method is different from the two previous methods, range of values produces is infinite.

$$Band\ ratio\ 1 = \left(\frac{green\ band}{lue\ band} \right) \ldots\ldots\ldots\ldots\ldots (4)$$

b. Sampling design

NDSSI, NSMI, and Band Ratio image compare with visual interpretation and pixel value variation for determine sample distribution. Each image digital number classified to 5 range, then image that have higher color variation and higher pixel value variation is use for determine sample. From this analysis, band ratio image is use for determine sample. Transect sampling model is used to distribute sample. Distribution of sample show in Figure 2.

Fig. 2 Sample Distribution Map

Field measurement take time at April 10th 2018. Field measurement synchronized to image acquired at 9th April 2018. There is 46 bottles of water sample collected from field work. Sample water was carried out at Water Laboratory of Universitas Andalas.

c. Post-field Data Processing

Post-field data processing consists of laboratory test, regression analysis, and accuracy test. Laboratory test were conducted to find out the concentration of suspended solids in units of mg/liter based on 1liter water sample. Stepwise regression method combines the forward and backward methods to get the best model. Each parameter of the transformation index and field data is carried out by correlation test using SPSS 2.3 software. Accuracy test is carried out to find out the accuracy of the new models that have been developed through spectral reflection values result from transformation index. Accuracy test compare the value between suspended solids by models with suspended solids on the field. The validation samples are used for the accuracy test are no more than the model samples. Accuracy test results are standard errors, following the standard error formula:

$$SEE = \sqrt{\frac{(y'-y)^2}{n-2}} \quad \text{..... (6)}$$

Note:
SEE = Standard Error of Estimation
y = Concentration TSS on field
y' = Concentration TSS by model estimation
n = Amount of data

d. Research Diagram Method

TSS research method show in diagram that describe in Figure 3. This method diagram consists of image correction, sampling design, field measurement, laboratory test, stepwise regression analysis, TSS modelling, and TSS mapping.

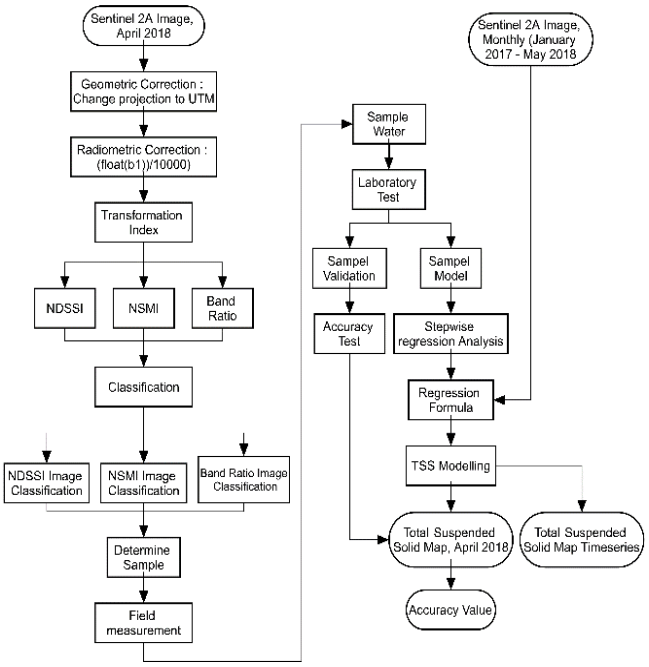

Fig. 3 Research Diagram Method

III. Results and Discussion

TSS actual value from laboratory test in range 0.98 – 4.56 mg/L. Highest value of TSS sample found in Batang Arau estuary. the region that close to estuary has higher TSS value than the next region. The TSS value from laboratory show bellow.

TABLE I. Laboratory Test Result

No	X	Y	TSS (mg/L)	Band Ratio (B3/B2)	NDSSI	NSMI
1	648411.5	9892845.29	0.98	0.673891	0.148622	0.026981
2	648620.12	9896170.2	1.12	0.676789	0.236234	-0.005227
3	646800.64	9900695.89	1.34	0.639186	0.288651	0.000852
4	647239.63	9894588.72	1.35	0.647618	0.210949	0.007339
5	647279.86	9901321.37	1.36	0.661885	0.234795	0.017802
6	649156.87	9896164.25	1.38	0.662096	0.271174	0.000049
7	649492.69	9896293.59	1.4	0.684479	0.301319	0.0363
8	648476.26	9899221.62	1.53	0.6734	0.201616	0.085099
9	647473.1	9900498.18	1.6	0.637152	0.433423	0.025948
10	649226.31	9892993.89	1.62	0.754024	0.16148	0.048586
11	649735.84	9896238.87	1.63	0.692325	0.265783	0.035095
12	648800.77	9899189.43	1.64	0.665909	0.213892	0.074879
13	648291.62	9901332.73	1.67	0.672532	0.125748	0.068767
14	648221.1	9894326.65	1.69	0.644264	0.110443	-0.022257
15	648261.1	9897643.34	1.79	0.640461	0.132143	0.140486
16	648046.01	9892821.88	1.86	0.653221	0.126846	0.021775
17	649148.72	9901451.27	1.91	0.755556	0.176764	0.044115
18	649626.99	9899147.22	2.14	0.77759	0.35563	0.035798
19	649319.47	9899109.19	2.15	0.74528	0.406768	0.049488
20	649781.36	9893117.17	2.15	0.805975	0.140867	0.081397
21	648648.89	9900165.96	2.18	0.718549	0.24323	0.013685
22	649325.26	9897330.93	2.21	0.672638	-0.096125	0.061685
23	649330.22	9894047.27	2.21	0.730386	0.101022	0.053809
24	650223.88	9896325.81	2.26	0.774728	0.197378	0.026432
25	650328.05	9893762.85	2.28	0.730034	0.027343	0.065519
26	649613.68	9897226.45	2.84	0.656068	0.089051	0.062576
27	649304.36	9900071.74	2.9	0.833037	0.317851	0.015944
28	650054.02	9897118.16	2.91	0.753704	0.123607	0.043479
29	649262.45	9901402.25	3.66	0.766128	0.139221	0.078933
30	649134.43	9900109.18	4.56	0.788227	0.354321	0.013077

Statistical test result based Table 2 show that band ratio transformation is the most influential variable. The correlation value which is 0.622 with R square value 0,387. The significance value 0.01 is smaller than a value (a = 0.05), so this variable passes the statistical test. The resulting formula is seen from the coefficient B, so it generates a regression formula.

$$y = (-3{,}889 * (B3/B2)) + (8{,}354) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

There is only one variable that passes, band ratio (B3/B2). Band ratio become the passed variable because significance of other variables for the dependent variable is greater than a value (a=0.05), that is NDSSI = 0.487, NSMI = 0.503. Beside that, variable correlation value for the dependent variable is very small, that is NDSSI = -0.135, NSMI = 0.13.

TABLE II. STEPWISE REGRESSION RESULT

Coefficients[a]

Model	Unstadardized Coefficients		Stadardized Coefficients	t	Sig.	95.0 % Confidence Interval for B	
	B	Std. Error				Lower Bound	Upper Bound
1 (constant)	-3.889	1.408		-2.763	.010	-6.6773	-1.006
Band_ratio	8.354	1.987	.622	4.204	.000	4.284	12.425

a. Dependent Variable: TSS

ANOVA[a]

Model	Sum of Square	df	Mean Square	F	Sig.
1 Regression	6.531	1	6.531	17.677	.000[b]
Residual	10.345	28	.369	.130	
Total	16.876	29			

a. Dependent Variable: TSS

b. Predictors: (Constant), band_rasio

Excluded Variables[a]

Model	Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
					Tolerance
1 ndssi	-.106[b]	-.706	.487	-.135	.981
nsmi	-.102[b]	.679	.503	.130	.994

a. Dependent Variable: TSS

b. Predictors: (Constant), band_rasio

TSS best model result based on the results of the stepwise regression, tested for accuracy using the Standard Error of Estimate (SE). Calculation of accuracy of the TSS estimation model with significance level of 95% calculated using the upper range, lower range, maximum error, and minimum error. TSS accuracy test using average data of estimation model as input at the validation and standard deviation sample points. The average estimation model results at the validation sample point is 1.94 mg/L and the standard deviation is 0,46. The Standard Error of Estimate (SEE) value indicates the accuracy of the TSS estimate. The smaller the SE value indicates that the estimation results will be more accurate. Based on the Table 3, the resulting SE value is 0.42 which indicates that the TSS estimation using the band ratio is quite accurate, because the resulting SE value is too small. In addition, a high level of accuracy is also supported by the maximal accuracy value of 80.51% which indicates that the accuracy of TSS estimates is quite good and accurate.

TABLE III. ACCURACY TEST WITH SEE

Sum	2.49
SE	0.42
Mean	1.94
Stdev	0.46
CL95%	0.23
Upper range	2.16
Lower rang	1.71
Maximum Error	24.68
Minimum Error	19.49
Maximum Accuracy	80.51
Minimum Accuracy	75.32

Monitoring of total suspended solids is carried out by modeling Sentinel-2A images monthly based on modeling results in April 2018, except August, September, and December 2017 because they are covered by clouds. In January 2017, the distribution of the most extensive total suspended solids was 2.3680 to 3.5230 mg/l. The distribution of TSS in the river estuary of the Batang Arau and the river estuary of the Batang Kuranji has almost same spatial distribution, while the river estuary of the Banjir Kanal is the smallest. In February 2017 there was no significant difference with the previous month. In March 2017 the TSS content was reduced as indicated by the highest TSS value of 2.3680 to 3.6230 mg/L. The distribution is not too different from the previous month. In April 2017, the TSS concentration increased compared to March but not greater than in January. In May 2017 TSS's concentration is highest than in March 2017 but not widespread. In June and July 2017, TSS is spread in the north around the mouth of the river estuary of Batang Kuranji but the highest consentration in the around the estuary of Batang Arau. In October 2017, scattered in the north around the mouth of the river estuary of Batang Kuranji. In December 2017, TSS distribution not widespread than previous month. January, February, and March 2018 TSS content increases with the widest distribution in the Batang Arau River and Batang Kuranji River which are almost the same. In April 2018 the concentration of TSS was reduced compared to the previous month with a value of 1.2120 to 2.3670 mg/L. In May 2018, the TSS concentration increased was shown to be increasingly widespread compared to the distribution in April 2018.

Based on temporal map in Figure 4, TSS concentration changes dynamically every month. These changes include the content and location of spatial distribution. The river estuary of the Batang Arau river has highest TSS concentration and its distribution is broad compared to other river estuaries in almost every month. This is caused by the influence of geographical conditions from upstream to downstream and climatological conditions such as rainfall, direction and magnitude of current.

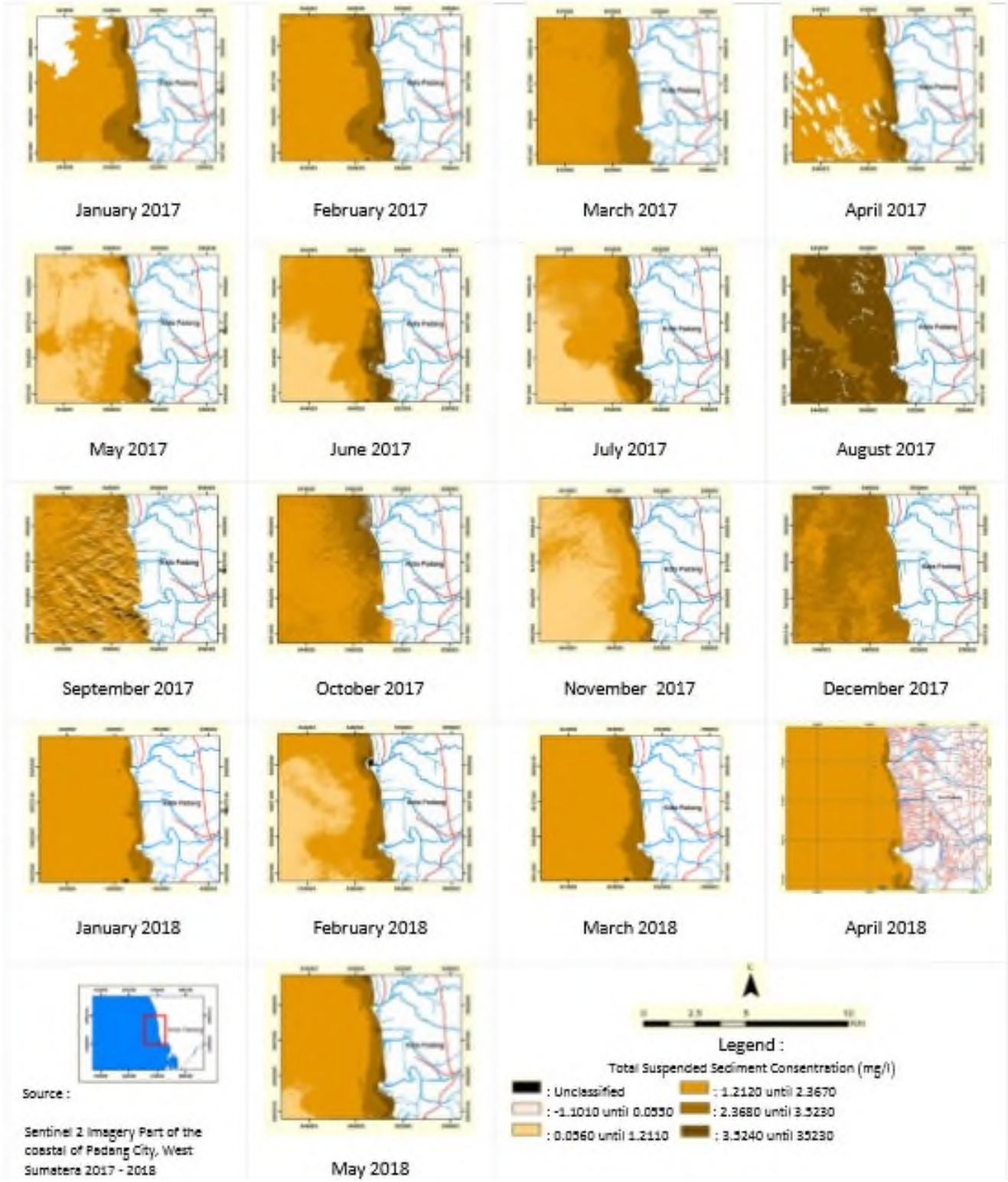

Fig. 4. Multitemporal Map of The Dynamics Total Suspended Sediment at Padang City

IV. Conclussion

1. Sentinel-2A image can use to mapping Total Suspended Sediment (TSS) in Padang City with 80.51% accuracy and use band ratio image transformation.
2. Total Suspended Sediment (TSS) content at the estuary of Batang Arau River, Banjir Kanal Barat River and Batang Kuranji River in Padang City is wet season has higher TSS content than in dry seasons.

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