Method Article

Integration of Sentinel-2A Imagery and Laboratory Measurements for Estuarine Pb and TSS Concentration Monitoring in Suwung, Denpasar City, Indonesia

ABSTRACT

Research has been carried out on integrating the results of Sentinel-2A and laboratory image data measurements in the form of a mathematical model that can be used to estimate the concentration and spatial distribution of Pb and Total Suspended Solid (TSS) of the Suwung estuary, Denpasar city, Bali, Indonesia. Integration is carried out using the regression method and correlation of the pixel value measurement results of the Sentinel-2A and laboratory images. Pixel values in Sentinel-2A image data which represent TSS concentrations are obtained by applying the TSS algorithm and Pb pixel values through Sentinel-2A band matching. The number of samples tested was 30 which were taken and measured at predetermined coordinate points. There are differences in the results of concentration measurements, both Pb and TSS obtained from laboratory measurements with Sentinel-2A pixel values. The integration results obtained in the form of a mathematical model in this research are for Pb, it is p=33.757q – 1.1345 and for TSS it is y=1.0213x – 0.2921. The variables p and y are the results of laboratory measurements, while the variables q and x are the results of measuring the Sentinel-2A pixel values. The spatial distribution of Pb detected was mostly on the west side and a small part on the east and north. For TSS, most of it is upstream in the north, while a small part is in the south and east.

Keywords: Total suspended solid (TSS), PotensialPb, Suwung Estuaries, Sentinel-2A

1. INTRODUCTION

Total Suspended Solid (TSS) and heavy metal concentrations of Plumbum (Pb) can be used as indicators of the level of sedimentation and pollution which is often the main problem for reservoirs (river estuaries) in Indonesia in providing clean water [1],[2]. The estuary of the Suwung Bali, apart from being the mouth of the Badung river, is also known as a provider of clean water for the southern Bali area. As it is known that, most of the southern part of Bali is a tourist area and new settlements, so it is very important to pay attention to the condition or quality of the water on a regular and sustainable basis. For this

reason, we need a technology that can provide data and information related to monitoring water conditions on a regular and continuous basis.

Researches related to monitoring to provide an assessment of water quality through physical parameters such as TSS, temperature or turbidity in various regions in Indonesia outside Bali using remote sensing satellite technology image data (SPOT, Landsat 8, Sentinel, Wordview 3) has been widely carried out ([1],[2],[3],[4],[6],[8],[11],[12]. Although most of the results of these studies discuss the prediction of the distribution and concentration of TSS parameters, they do not reach the point of reviewing and conducting periodic assessments. An effective routine and continuous monitoring method can be carried out with an approach, namely building a mathematical model related to water quality assessment. This mathematical modeling can be derived from remote sensing technology data which is correlated with in-situ data.

Predictive modeling such as the spatial distribution of TSS concentration and the potential presence of heavy metal Pb, extracted from the response spectral reflectance of remote sensing image data, such as Sentinel-2 in the Bottom of Atmosphere (BOA) through an algorithm. The spectral reflectance response of the object surface involves radiometric and atmospheric corrections determined by the Dark Object Subtraction (DOS) method [9].

The aim of this research is (a) to integrate the results of Sentinel-2A and laboratory measurements into a mathematical model to estimate TSS and Pb concentrations in the Suwung estuary, Denpasar City, Bali, Indonesia, and (b) to monitor the spatial distribution of TSS, Pb in the area.

2. METHODOLOGY

The image data used in this research is Sentinel-2A obtained from USGS and the study area of the Suwung estuary is located in the South Denpasar sub-district, Denpasar city which is astronomically located at 8° 43' 26" – 8° 44' 04" South Latitude and 115° 11' 16" – 115° 11' 22" East Longitude [13].

Research activities started from surveys, collecting primary (water samples) and secondary data (Sentinel-2A image data). The location of water sampling in the study area was carried out at random geographical coordinates, then the TSS concentration and Pb potential were measured in the laboratory. Sentinel-2A image processing using software TerrSet 18.21 with the stages in outline are as follows:

1) Convert raw image pixel data to reflectance value on BOA (Bottom of Atmosphere)
2) Geometric, radiometric, atmospheric correction DOS (Dark Object Subtraction)
3) Cropping the image that covers the research area
4) Application of TSS algorithm Equation : and band matching for Pb

$$TSS\left(\frac{mg}{l}\right) = 31.42\,\frac{(Log\,(R_{RS}\ Blue))}{(Log\,(R_{RS}\ Red))} - 12.719 \qquad (1)$$

Where :

R_{RS} Blue is a blue band of reflectance remote sensing

R_{RS} Red is a red band of reflectance remote sensing

5) Determination of Pb in the image using band matching

Statistical and descriptive analysis were carried out through correlation analysis and validity of TSS and Pb in situ data as the dependent variable with Sentinel-2A data as independent variables. The strength of the correlation and the validity of the mathematical model obtained were tested using the regression method and the validation test with RMSE (Root Mean Square Error) [5].Detailed research activities are presented in a flow chart as shown in Figure 1.

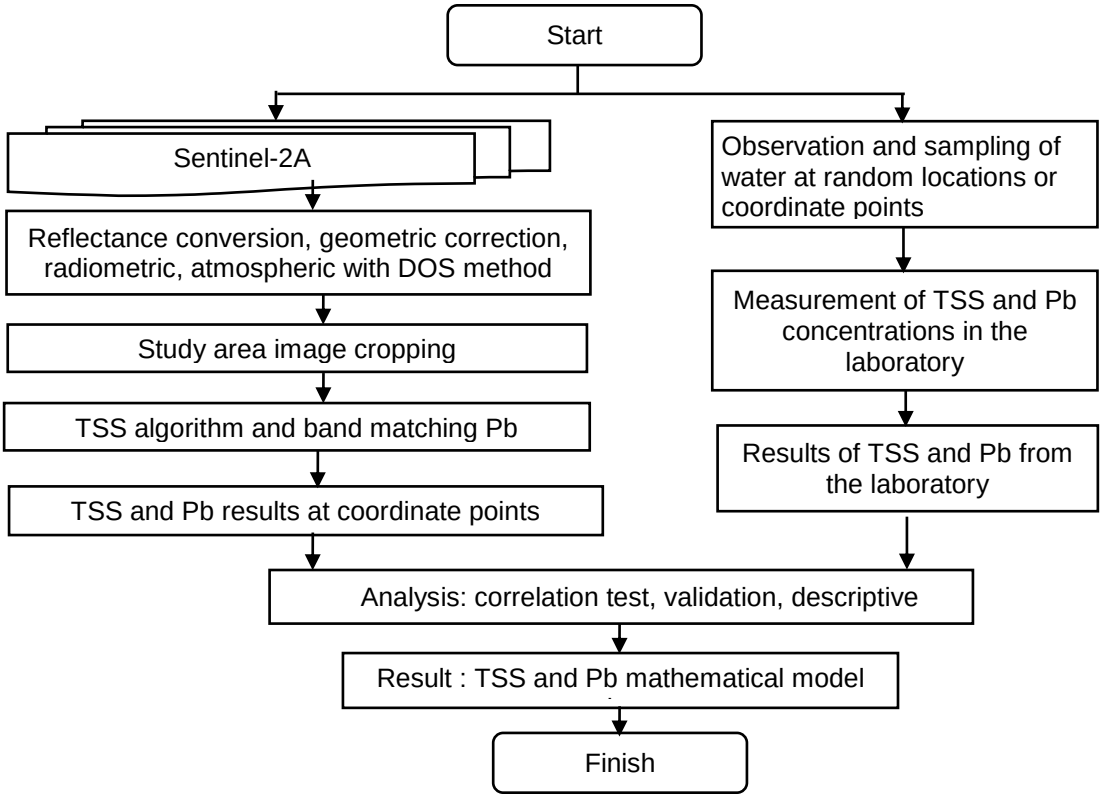

Figure 1. Research flow chart

3. RESULTS AND DISCUSSION

The number of water samples taken in the Suwung estuary is 30 and taken at the selected coordinate points. The concentration of TSS and Pb of this water sample was measured in the laboratory (In-situ). The results of measurements of TSS and Pb concentrations from the laboratory at a wavelength of 510 nm and from pixels in Sentinel-2A images that have been applied to the Equation 1 algorithm for TSS and band matching for Pb concentrations, namely band 3 with a wavelength of 560 nm are presented in Table 1. Spatial information generated and represented in the form of a map of the distribution of TSS concentrations is presented in Figure 2a, while the distribution of potential Pb concentrationsis presented in Figure 2b.

Table 1. Results of measurements of TSS and Pb from In-situ and Sentinel-2A

No.	Coordinates (m)		TSS (mg/L)		Concentration of Pb (mg/L)	
	Latitude	Longitude	In-situ	Sentinel-2A	In-situ	Sentinel-2A
1	300605.65	9034626.56	15.50	15.85	.037	.037
2	300631.85	9034464.69	16.00	15.91	.089	.038
3	300858.86	9034622.19	16.20	15.98	.123	.039
4	300610.02	9034700.94	16.25	16.10	.223	.039
5	300950.54	9034315.94	16.35	16.26	.248	.040
6	300592.56	9034674.69	16.35	16.27	.263	.041
7	300601.29	9034661.56	16.37	16.32	.287	.041

8	300675.52	9034276.56	16.40	16.30	.293	.042
9	300588.19	9034919.69	16.65	16.73	.332	.042
10	300837.03	9034193.44	16.75	16.69	.378	.042
11	300749.72	9034805.94	16.75	16.68	.390	.044
12	300688.61	9034884.69	16.80	16.76	.438	.047
13	300579.46	9034683.44	16.85	16.74	.454	.047
14	300596.92	9035239.06	16,90	16.79	.480	.048
15	300810.84	9034140.94	17.00	16.85	.487	.048
16	300610.02	9034814.69	17.00	16.92	.519	.049
17	300684.24	9034919.69	17.15	17.08	.528	.050
18	300701.69	9034989.69	17.45	17.31	.528	.051
19	300732.26	9034932.81	17.50	17.42	.530	.051
20	300579.46	9035116.56	17.50	17.49	.592	.051
21	300719.16	9034976.56	17.60	17.57	.601	.052
22	300692.97	9035029.06	17.65	17.50	.613	.053
23	300714.79	9034994.06	17.70	17.63	.627	.053
24	300666.77	9035155.94	17.90	17.84	.635	.055
25	300662.41	9035120.94	18.00	17.92	.639	.055
26	300671.14	9035169.06	18.15	18.06	.707	.055
27	300671.14	9035195.31	18.25	18.17	.793	.056
28	300575.09	9035309.06	18.35	18.19	.810	.057
29	300557.63	9035379.06	18.55	18.45	.924	.058
30	300610.02	9035357.19	18.90	18.84	.936	.059

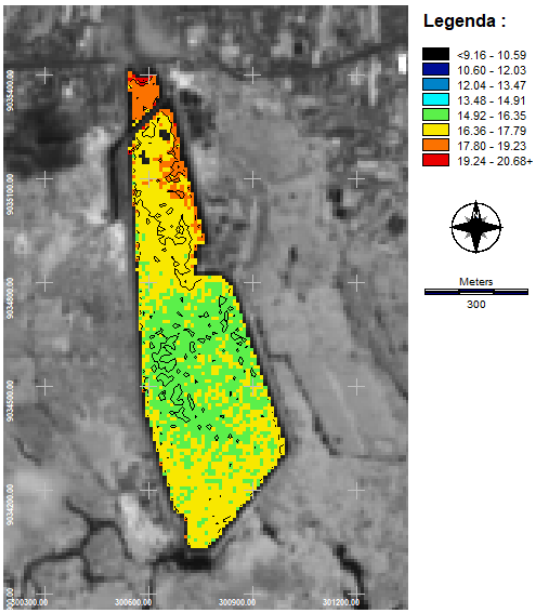

Fig 2a. Distribution of TSS concentration

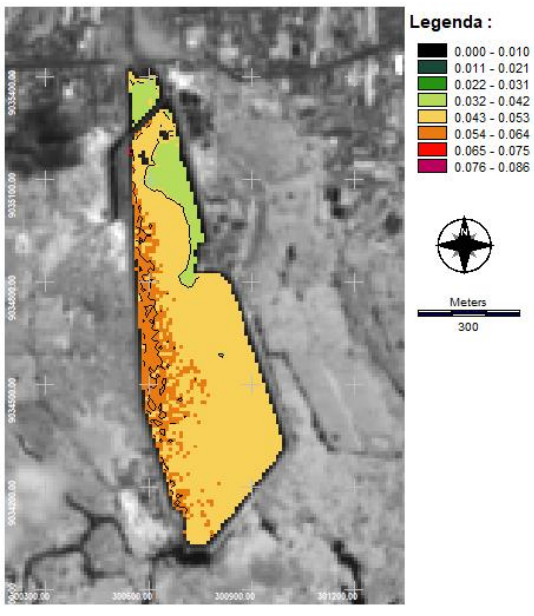

Fig 2b. Distribution of Pb concentration

Test and data analysis to obtain a mathematical model of the correlation between TSS measurement results and the potential distribution of Pb from the Laboratory with Sentinel-2A image data was carried out by statistical regression analysis. The results of this regression analysis will also show the correlation between Sentinel-2A image data and laboratory data obtained from the field and the extent to which the proximity or goodness of the image data used in determining the regression equation model is obtained. From the data in Table 1, a graph of the correlation between TSS and Pb can be made from the results of the Lab measurements with the pixel measurements of the Sentinel-2A image as presented in Figures 3a and 3b.

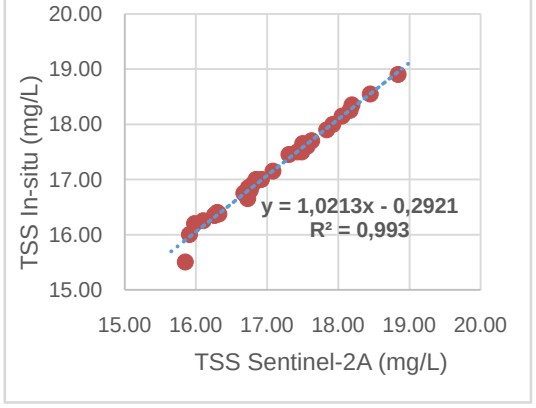

Fig 3a. The TSS correlation graph

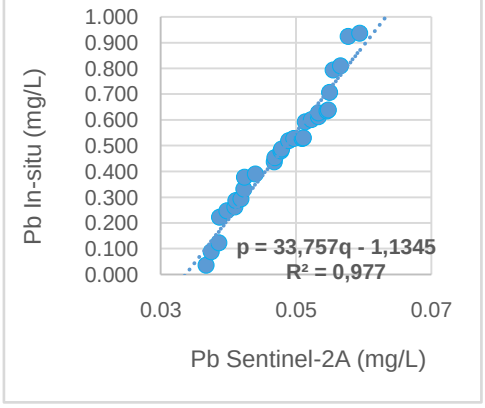

Fig 3b. The Pb correlation graph

In Figure 3a you can see that the resulting regression equation which represents the mathematical model for TSS is y=1.0213x – 0.2921. In this case, the y variable which represents the TSS concentration is the result of laboratory measurements, while the x variable represents the TSS concentration measured in the Sentinel-2A image pixels as a result of applying the algorithm. The resulting coefficient of determination (R^2) was 0.993, which means that 99.3% of the Sentinel-2A measurement data was able to explain the laboratory measurement results. The correlation coefficient for TSS is R of 0.996. This explains that there is a correlation of 99.6% between the TSS measurement results from Sentinel-2A data and the laboratory data measurement results.

In Figure 3b it can be seen that the resulting regression equation which represents the mathematical model for Pb is p=33.757q – 1.1345. In this case, the variable p represents the potential Pb concentration resulting from laboratory measurements, while the variable q represents the potential Pb concentration measured in the pixels of the Sentinel-2A image processed by band adjustment. The resulting coefficient of determination (R^2) was 0.977, which means that 97.7% of the Sentinel-2A measurement data was able to explain the laboratory measurement results.The correlation coefficient for Pb is R of 0.988. This explains that there is a correlation of 98.8% between the Pb concentration measurement results from Sentinel-2A data and the laboratory data measurement results.

Based on the large R values for TSS and Pb, it can be concluded that the two correlations are in the very strong category. The integration of Sentinel-2A and laboratory measurement results produced in this research can be said to be very representative and the 2 mathematical models resulting from regression analysis are very suitable for use in estimating Pb and TSS concentrations.

From Figure 2a it can be explained that the spatial distribution of TSS concentrations is spread randomly with varying values. The concentration value interval that falls into the large category is 19.24 to 20.68 mg/L which is spread in the upstream part of the Suwung estuary or in the northern part. For the small concentration value category, it ranges from 9.16 to

10.59 mg/L which is distributed slightly to the north and on the edge of the Suwung estuary. The waste filtering site and equipment are located a few meters south of the upstream estuary. The large TSS value in the upstream section is more because the trash or dirt carried by the water has not been filtered. When heading south, after passing the waste filtering site, the water conditions are relatively cleaner or the TSS concentration value begins to decrease. From Figure 2b, it can be seen that the Pb concentration detected was relatively very small. The largest category value is in the interval 0.076 to 0.086 mg/L which is distributed in the western estuary.

4. CONCLUSION

Conclusions obtained in this research: (a) Integration of Sentinel-2A and laboratory data in the form of a mathematical model for estimating Pb concentration, namely p=33.757q – 1.1345 and for TSS, y=1.0213x – 0.2921. (b) The spatial distribution of Pb detected was mostly on the west side and a small part on the east and north. For TSS, most of it is upstream in the north, while a small part is in the south and east.

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