# Study of Total Suspended Solids (TSS) Distribution and Salinity of Coastal Area Using Satellite Imagery for Pond Development in Pond Irrigation Areas (DIT) Sei Teras

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**ABSTRACT**
The Sei Teras Pond Irrigation Area (DIT) is an aquaculture zone on the coast of Central Kalimantan Province. TSS and salinity are water parameters that affect the development of aquaculture. Water quality studies and their distribution are needed to support aquaculture enhancement. This study aims to investigate the distribution of TSS and salinity in the coastal waters of Sei Teras as a source of fish pond water and fish pond development potential for the Sei Teras. This study utilized Sentinel-2 imagery which the visible spectrum was extracted based on water quality parameters using the Liu et al. algorithm. The study results show that the distribution of TSS has values between 163.27 to 326.68 mg/l, and salinity exists in the range of 21.92 to 23.94 ppt. Calibration of the analysis results with in situ measurement data shows different values indicated by the RMSE value. The RMSE values are between 9.12 to 60.57 for TSS and 0.34 to 1.70 for salinity. The difference between result estimation and data in situ is caused by the dissimilarity of sampling time of image and image quality used. TSS and Salinity conditions support the development and improvement of DIT Sei Teras from extensive traditional to semi-intensive.

***Keywords:*** *Sentinel-2, Remote Sensing, TSS, Salinity*

## 1. INTRODUCTION

The Sei Teras Pond Irrigation Area (DIT) is an aquaculture zone on the coast of Central Kalimantan Province. The technology used for cultivation is extensive traditional. Extensive traditional is a fish pond system highly dependent on natural conditions [1]. Fish pond cultivation has been developed since 2006. In 2009-2010, the Ministry of PUPR developed DIT Sei Teras by building canals for salt water sources. The commodities developed are mostly shrimp and crab and a small portion of milkfish [2].

Studies on water quality and distribution are needed to support aquaculture enhancement. Water quality affects the quality of life of the developed biota. Good water quality will support fish's growth, development, and survival [3]. This study aims to investigate the distribution of TSS and salinity in the coastal waters of Sei Teras as a source of fish pond water and fish pond development potential for the Sei Teras.

Total Suspended Solid (TSS) is one of the physical parameters of water quality. TSS affects river morphology due to sediment and erosion, resulting in bed sediment washout, sandbar moves, mudflat, or silting-up. Other influences are changes in light attenuation and primary production, oxygen saturation, and modification of nutrient pathways [4]. High TSS levels can decrease photosynthesis activity and increase the surface temperature of the water, thus reducing the oxygen released by the aquatic plants and causing the death of fish and other freshwater animals [5].

Salinity is the total concentration of ions in the waters [6], while according to Kordi (2010), Salinity is the concentration of salt obtained in seawater. Salinity is related to the water's osmotic pressure condition, where a high salinity concentration will result in a sizeable osmotic pressure. The condition of high osmotic pressure causes an adaptation of fauna behavior to the conditions of osmotic pressure in their environment.


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Generally, remote sensing is an optical remote sensor from various radiation on the water surface. The images provide information about water parameters such as physical properties (brightness, TSS), organic properties (TOC, TICs), and microbiological properties [7,8]. Previous research has used remote sensing to investigate and monitor aquaculture ponds. Fuchs et al. (1998) used the Landsat Thermatic Mapper (TM) Pur I'Observation de la Terre (SPOT) satellite and airborne hyper-spectral data to classify land cover, including aquaculture ponds. Jaelani [9] used Landsat-8 imagery to study the distribution of chlorophyll-A in the waters of Lake Matano and Lake Towuti, South Sulawesi.

## 2. MATERIAL AND METHOD

### *2.1. Study Area*

The research location is Sei Teras villages in Kuala Kapuas District, Kapuas Regency, Central Kalimantan Province. Geographically, the Sei Teras aquaculture area is located at the coordinates of 3°23'47,20"S-3°27'32,50"S and 114°19'32,82"E -114°20'24,99"E.

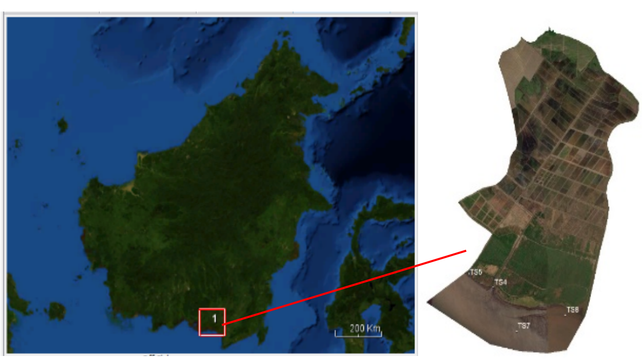


**Figure 1** Research Locations of DIT Sei Teras (Source: Google Earth)

### *2.2. Data and Instrument*

This study used Sentinel-2 imagery data recorded on March 21, 2022 (source:https://rus-copernicus.eu/portal) and in situ data on March 14, 2022. The image data analysis was processed by SNAP Toolboxes v.8.0.0 and ArcGIS 10.0 software.

Sentinel-2 imagery has a spatial resolution of 10 meters for 4 bands, 20 meters for 6 bands, and 60 meters for 3 bands as shown in Table 1.

**Table 1.** Spectrum characteristics of Sentinel-2

| Band | Spectrum | Wave Length µm | Spacial Resolution m |
|---|---|---|---|
| 1 | Coastal Aerosol | 0.433 - 0.453 | 60 |
| 2 | Blue | 0.458 - 0.523 | 10 |
| 3 | Green | 0.543 - 0.578 | 10 |
| 4 | Red | 0.650 -0.680 | 10 |
| 5 | Vegetation Red Edge 1 | 0.698 - 0.713 | 20 |
| 6 | Vegetation Red Edge 2 | 0.733 - 0.748 | 20 |
| 7 | Vegetation Red Edge 3 | 0.765 - 0.785 | 20 |
| 8 | NIR | 0.785 - 0.900 | 10 |
| 8a | Vegetation Red Edge 4 | 0.855 - 0.875 | 20 |
| 9 | Water Vapour | 0.855 - 0.875 | 60 |
| 10 | SWIR-Cirus | 1.365 - 1.385 | 60 |
| 11 | SWIR1 | 1.565 - 1.655 | 20 |
| 12 | SWIR2 | 2.100 - 2.280 | 20 |

(source : ESA, 2015)[10]

### *2.3. Data Processing*

The first step in data processing was optical resampling. The purpose of optical resampling is to uniform the spatial resolution of the image. Then, the resampling results were offset in the research area.

After resampling the image data, the data was extracted to obtain the NDTI and NDWI values. Data extraction is performed for the display of water suspension. The calculation of NDTI and NDWI is obtained by Xu [11] algorithm.

$$NDTI = (B4 - B3) / (B4 - B3) \quad (1)$$

$$NDWI = (B3 - B11) / (B3 + B11) \quad (2)$$

Where,
NDWI = *Normalized Difference Water Index*
NDTI = *Normalized Difference Turbidity*
B3 = Green
B4 = Red
B11 = SWIR1

Furthermore, to determine the TSS value, the NDWI data was extracted using Liu et al., algorithm [12].

$$TSS = 2950 \times B71.357 \quad (3)$$

where,
TSS = Total Suspended Solid
B7 = VRE2

TSS value was used in estimating the salinity value with an algebraic equation below:

$$Salinity = 0.0097TSS + 20.715 \quad (4)$$

Based on the TSS and salinity values of the two methods, the accuracy of the estimated and in situ data was tested using the RMSE (Root Mean Square Error).

$$\text{RMSE} = \sqrt{\frac{\Sigma(yi-y'i)^2}{n}} \quad (5)$$

where,
RMSE = Root Mean Square Error
y = insitu value
y' = estimated value
i = order of the data base
n = amount of data

## 3. RESULTS AND DISCUSSION

### *3.1. TSS (Total Suspended Solid)*

The spectral values in the Sentinel-2 satellite imagery which are divided into 13 bands was extracted by NDTI (Normalized Difference Turbidity) and NDWI (Normalized Difference Water Index) as shown in Figure 2.

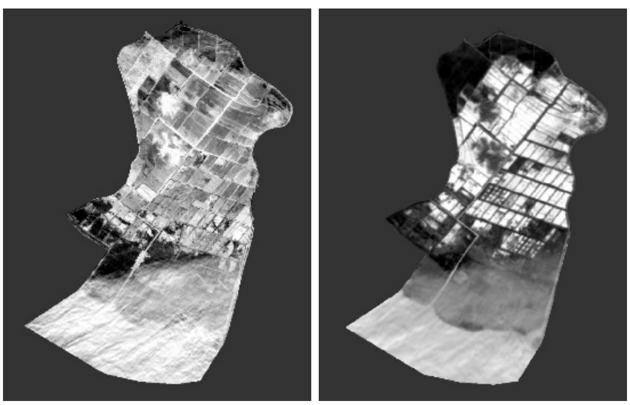

**Figure 2** (a) NDTI (b) NDWI
(source: SNAP Toolboxes analysis v.8.0.0).

The NDTI value indicates the level of object turbidity. The greater the NDTI value indicates higher turbidity of water [13]. While NDWI is an index that describes an object's water body [14]. After decomposing the image based on NDTI and NDWI, the TSS is obtained as shown in Figure 3.

**Figure 3** shows that the distribution of TSS in the study area ranges from 163.27 to 326.68 mg/l. The distribution of TSS is various, where the distribution of TSS is highly concentrated in the coastal area and lowers towards the sea. This condition indicates a build-up of sediment in the estuary coming from upstream. The displacement of coastal sediments can be caused by many factors such as river flows, waves, tides, and winds [15].

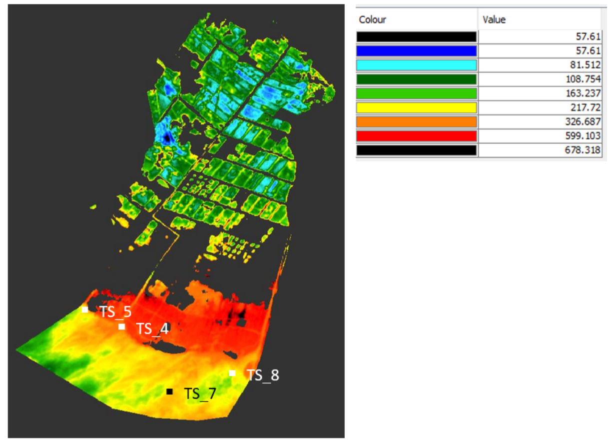


**Figure 3** TSS Distribution
(source: SNAP Analysis Toolboxes v.8.0.0)

**Table 2.** TSS Value Estimated with SNAP Analysis and In Situ Measurement

| Location | | | TSS | | RMSE |
|---|---|---|---|---|---|
| Code | Coordinate | | Estimation | In situ | |
| TS_4 | -3.452068° | 114.318750° | 291.15 | 170 | 60.575 |
| TS_5 | -3.448984° | 114.312727° | 189.76 | 121 | 34.38 |
| TS_7 | -3.461847° | 114.324507° | 206.88 | 97.33 | 54.775 |
| TS_8 | -3.458326° | 114.336431° | 218.91 | 200.67 | 9.12 |

The TSS values of the analysis result are relatively different from the data and in situ measurement. The results of the analysis tend to provide a higher TSS than in situ data. Based on Table 2. TSS values of the analysis results for TS_4, TS_5, TS_7 and TS_8 are 291.15 mg/l, 189.76 mg/l, 206.88 mg/l and 218.91 mg/l. Meanwhile, the in situ measurement data for TS_4, TS_5, TS_7 and TS_8 are 170 mg/l, 121 mg/l, 97.33 mg/l and 200.67 mg/l. After being calibrated with the RMSE method, RMSE values TS_4, TS_5 and TS_7 and TS_8 are 60.58, 34.38, 54.78, and 9.12. The RMSE values mean that in TS_4, the TS_5 and TS_7 TSS estimations do not provide an overview representing field measurement data. Meanwhile, at the TS_8 point, the estimation result is close to the actual conditions in the field. The mean RMSE value is 39.71. The reason for the different values can be caused by the dissimilarity in the timing of in situ measurement with the sampling time of the image. Prominent time intervals allow for the dynamics of water conditions, such as floods and rains. In addition, the quality of the imagery used affects the spectral values recorded in the waters. Brighter image data and less interference will improve the accuracy of the analysis results. The presence of cloud-shaped interference in the image can reduce the accuracy of image data [16].

The difference between the measured data and the estimated may be reduced by multiplying the estimated data with a coeeficient of 0.65. The mean RMSE value decrease to 14.64. The result shown in Table 3.

**Table 3.** TSS Value Estimated with SNAP by Multiplying 0.65 and In Situ Measurement

| Location | | | TSS | | RMSE |
|---|---|---|---|---|---|
| Code | Coordinate | | Estimation | In situ | |
| TS_4 | -3.452068° | 114.318750° | 189.2475 | 170 | 9.62375 |
| TS_5 | -3.448984° | 114.312727° | 123.344 | 121 | 1.172 |
| TS_7 | -3.461847° | 114.324507° | 134.472 | 97.33 | 18.571 |
| TS_8 | -3.458326° | 114.336431° | 142.2915 | 200.67 | 29.18925 |

## 3.2. Salinity

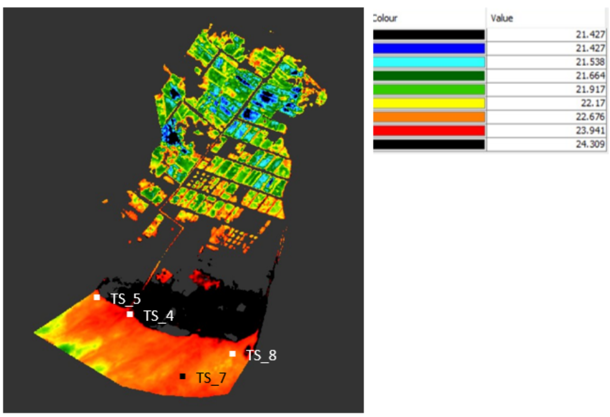


**Figure 4** Salinity Distribution
(source: SNAP Analysis Toolboxes v.8.0.0)

Figure 4 shows the salinity values are 21.92 to 23.94 ppt. The salinity distribution has stable values and relatively uniform conditions in the coastal area.

**Table 4.** Salinity Values Estimated with SNAP Analysis and In Situ Measurement

| Location | | | TSS | | RMSE |
|---|---|---|---|---|---|
| Code | Coordinate | | Estimation | In situ | |
| TS_4 | -3.452068° | 114.318750° | 23.61 | 20.2 | 1.705 |
| TS_5 | -3.448984° | 114.312727° | 22.97 | 24.1 | 0.565 |
| TS_7 | -3.461847° | 114.324507° | 22.77 | 24.02 | 0.625 |
| TS_8 | -3.458326° | 114.336431° | 22.96 | 23.64 | 0.34 |

**Table 4.** shows the salinity values of the analysis results and in situ measurements. The salinity values of the analysis results at the point of TS_4, TS_5, TS_7, and TS_8 are 23.61 ppt, 22.97 ppt, 22.77 ppt, and 22.96 ppt. Meanwhile, the salinity values of in situ measurement results in the field at the point of TS_4, TS_5, TS_7, and TS_8 are 20.2 ppt, 24.1 ppt, 24.02 ppt, and 23.64 ppt. It can be seen that the results of the analysis are relatively equal to the value of the field measurement results. The RMSE test also showed almost small values where the RMSE at the TS_4, TS_5, TS_7, and TS_8 points of 1.705, 0.56, 0.62, and 0.34. The mean RMSE value is 0.81. Unlike the TSS, the insignificant difference between the estimated and the measured salinity is due to minimal variation of water salinity caused by natural events.

## 3.3. Development Potential

The development of technology and knowledge provides an opportunity for the improvement of a method of cultivation. There are 4 (four) fish pond systems i.e. extensive traditional, semi-intensive, intensive and super-intensive [17]. Table 5. provides water quality parameters for fish pond development.

**Table 5.** Water Quality Parameters

| No | Water Parameters | Unit | Level of Technology | | | |
|---|---|---|---|---|---|---|
| | | | Traditional Exstensive | Semi-Intensive | Intensive | Super Intensive |
| 1 | Temperature | °C | 28-32 | 28-30 | 28-30 | 28-30 |
| 2 | Salinity | ppt | 5-40 | 10-55 | 26-32 | 26-32 |
| 3 | pH | | 7.5-8.5 | 7.5-8.5 | 7.5-8.5 | 7.5-8.5 |
| 4 | DO | mg/l | >3.0 | >3.0 | >4.0 | >4.0 |
| 5 | Alkalinity | mg/l | 100-250 | 80-150 | 100-150 | 100-150 |
| 6 | BOD | mg/l | 55 | 55 | ≤ 90 | ≤ 90 |
| 7 | Ammonia max | mg/l | < 0.01 | < 0.01 | < 0.1 | < 0.1 |
| 8 | Nitrit, max | mg/l | < 0.01 | < 0.01 | < 1 | < 1 |
| 9 | Nitrat, max | mg/l | 0.5 | 0.5 | 0.5 | 0.5 |
| 10 | Phosfat, max | mg/l | 0.1 | 0.1 | 0.1-5 | 0.1-5 |
| 11 | Turbidity | cm | 30-45 | 30-45 | 30-50 | 30-50 |
| 12 | TSS | mg/l | | 150-200 | | |
| 13 | Heavy Metal | | | | | |
| | - pB | mg/l | 0.03 | 0.03 | 0.03 | 0.03 |
| | - Cd | mg/l | 0.01 | 0.01 | 0.01 | 0.01 |
| | - Hg | mg/l | 0.002 | 0.002 | 0.002 | 0.002 |
| 14 | Hidrogen Sulfida | mg/l | | | ≤ 0.01 | ≤ 0.01 |
| 15 | Total Vibrio | CFU | | | ≤ 1x103 | ≤ 1x103 |

source: Ministry of Marine Affairs and Fisherses [18]

**Table 6.** Water Quality Measurement and Semi-IntensiveCriteria

| No | Parametres | Unit | Insitu | Semi Intensif |
|---|---|---|---|---|
| 1 | TSS | mg/l | 71 - 200.67 | 150 - 200 |
| 2 | Salinity | ppt | 20.2 - 24.1 | 10 - 35 |
| 3 | pH | | 6.92 - 7.01 | 7.5 - 8.5 |
| 4 | Temperature | °C | 28.6 - 31.5 | 28 - 30 |

(Source: measurement data)

Semi-intensive technology can increase productivity and be more profitable [19]. Semi-intensive aquaculture is aquaculture that has begun to use technology and human management [17]. Semi-intensive technology includes reservoir/pond processing, water preparation, fry stocking, feeding, water management, pest and disease control, and harvest management. The development of technology and knowledge provides opportunities for improvement by an appropriate method.

## 4. CONCLUSIONS AND SUGGESTIONS

### *4.1. Conclusions*

1. The distribution of TSS in the study area ranges from 163.27 to 326.68 mg/liter, concentrated mainly in the estuary area. The value difference between the analysis results and in situ measurement in the field. TSS values in situ measurement are 71 to 200.67 mg/l. The difference between result estimation and data in situ is caused by the dissimilarity of sampling time of image and image quality used. A coefficient of 0.65 reduces the difference between estimated and measurement data and decreases the mean RMSE value from 39.71 to 14.64.
2. The salinity distribution at the study site showed that the salinity values were at 21.92 to 23.94 ppt. The analysis results provide almost the same results as In situ data obtained were 20.2 to 24.1 ppt. The mean RMSE value is 0.81.
3. The distribution of TSS and salinity in the study area provide development possibilities from extensive traditional to semi-intensive.

### *4.2. Suggestions*

1. Although the satellite image analysis resulted in acceptable values of TSS and Salinity data, another set of measurements is required at almost the same time to assure the calibration value's reliability.
2. Research with more varied algorithms will provide a more suitable description of field conditions.
3. It is necessary to increase the time history data to get a more comprehensive illustration of the study area.

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