JOURNAL OF APPLIED GEOSPATIAL INFORMATION

Vol 7 No 2 2021

http://jurnal.polibatam.ac.id/index.php/JAGI
ISSN Online: 2579-3608

TSS (Total Suspended Soil) Analysis Using GEE (Google Earth Engine) Cloud Technology In Sibolga Waters

Mardame Pangihutan Sinaga[1]*,Jono Barita Sianipar[2] Ady Frenly Simanullang[3], Goldberd Harmuda Duva Sinaga[4], Mila Susanty Sianipar[5]

[1,3] University of HKBP Nommensen Pematangsiantar / Water Resource Management / research / Sangnawaluh Street #4, Siopat Suhu Village, Siantar Timur District. Province of North Sumatra. Area Code: 21139. [2] Lab Data Spatial.
[4] University of HKBP Nommensen Medan. Province of North Sumatra. [5] Student of University of HKBP Nommensen Pematangsiantar.
*Corresponding author e-mail: m.pangihutan@gmail.com

Received: July 12, 2023
Accepted: August 21 , 2023
Published: August 21, 2023

Abstract

The TSS research using GEE Cloud Technology in Sibolga Waters was carried out from February to April 2021, Mey to July 2021, August to October 2021, and October to December 2021. The analysis was carried out using the Sentinel-2 Satellite. TSS results showed that the highest amount was 60-120 mg/liter and the lowest was 0-60 mg/l. The content of TSS is spread evenly around the edge of the Sibolga coast to the Middle of Sibolga Waters and has passed the quality standard limit according to the Minister of Environment of the Republic of Indonesia which means the Sibolga Water area is polluted and improper for drinking water as well as for fish cultivation. The result has been seasonal influence can determine the direction of the TSS distribution pattern, both tidal factors and weather conditions such as rain anddry season. The side effect on the TSS distribution pattern in Sibolga Waters causes the TSS value at high tide to be higher than at low tide. Sentinel-2 TOA Reflectance Data imagery can be used to map the TSS distribution pattern in the Sibolga Waters area.

Keywords: TSS, Sentinel-2 Satellite, Sibolga Waters.

1. Introduction

Sub Introduction

Sibolga is a city in North Sumatra Province, Indonesia. The city is located on the west coast of Sumatera Island, stretching along the coast from North to South, and is in the Tapian Nauli Bay area. The distance is about 350 km from Medan City, or about 8 hours drive. The city of Sibolga only has an area of 10.77 km^2 and based on data from the Central Bureau of Statistics for the city of Sibolga 2023, this city has a population of 90,366 people, with a population density of 8,391 people/km^2. During the Dutch East Indies era, this city was the capital of the Tapanuli Regency. After the independence period until 1998, Sibolga became the municipality of Sibolga.

Sibolga City is located on the west coast of North Sumatra Province. The location is south of Lake Toba. The area of Sibolga City is divided into coastal plains, slopes, and mountains. Located at an altitude ranging from 0-150 meters above sea level (below sea level), with the slope of this city area varying from 0-2% to more than 40%.

The climate of the city of Sibolga is quite hot with a maximum temperature of 32 ºC and a minimum of 21,6 ºC. Meanwhile, rainfall in Sibolga tends to be irregular throughout the year. The highest rainfall occurs in November with a total of 798 mm, while the most rain occurs in December, namely 26 days. The islands included in the Sibolga City area are Poncan Gadang Island, Poncan Ketek Island, Sarudik Island, and Panjang Island. Its boundaries are east, south, north to Central Tapanuli Regency, and west to the Indian Ocean. While the rivers that flow in the city are Aek Doras, Sihopo-hopo, Aek Muara Baiyon, and Aek Horsik.

Sibolga City is an area that has great tourism potential with a variety of beaches in it. Sibolga Waters is an area that is naturally a beach that I overgrown with shady trees in the form of cypress and pines. Sibolga waters are also a supporter of the economy and tourism for some people close to the coast. In addition to tourism, the Sibolga waters are also a place to live and a habitat for coral reefs and various living creatures such as reef fish that form ecosystems on the coast.

Sibolga Waters, which is located in the coastal area of Sibolga City, is a busy area, as there are fishing companies, fishermen, and the disposal of garbage and sewage from the community that flows into Sibolga Waters, so they are affected by busy activities that are not environmentally friendly. This is the cause of these coastal waters becoming turbid and getting a lot of sediment input due to dredging.

Total Suspended Soil (TSS) are suspended substances or materials with a maximum size of 2 m consisting of mud, fine sand, and other particulate matter such as biotic or abiotic components. These components come from land, sea, and atmosphere that are carried to water bodies through various factors such as wind, rainfall, waves, currents, and tides that can affect TSS concentrations in natural waters (Effendi, 2003). Waters with a high TSS value will affect the brightness so that light penetration is inhibited into the water and disrupt photosynthesis and the survival of marine life for a long period will result in siltation or sedimentation.

Total Suspended Solid (TSS) is an indicator that can assess the quality of water (Wang, *et al*., 2017 in Qanita, *et al*., 2019). Suspended materials in the form of solid particles enter the waters and cause adverse effects on water quality and reduce the penetration of light into the water column.

Total suspended solids (TSS) are suspended substances or materials with a maximum size of 2 µm consisting of silt, fine sand, and other particulate matter such as biotic or abiotic components. These components come from land, sea, and atmosphere which are carried into the water bodies through various factors such as wind, rainfall, waves, currents, and tides which can affect the concentration of TSS in natural waters (Effendi, 2003). Waters with a high TSS value will affect brightness so that light penetration is hampered from entering the water and resulting in disruption of photosynthesis and the survival of marine biota and over a long period will result in silting or sedimentation.

Suspended solid material or TSS is where heterogeneous reactions take place which form the initial precipitate so that it can hinder the production of organic matter in the waters (Tarigan dan Edward, 2003 in Jiyah, *et al*., 2016). High concentrations of TSS in the waters will have an impact on the process of photosynthesis and reduce oxygen from plants which causes fish to die. So it is necessary to conduct a more in-depth study using satellite imagery to determine its distribution in the waters.

The concentration of TSS can also be influenced by rainfall where rainwater is a medium for the transportation of pollutants from the surface such as bacteria and other microorganisms. A high level of rainfall will cause a higher TSS concentration than a low rainfall level (Bae, 2013).

Remote sensing technology is one of the sources of information in collecting marine data effectively and efficiently and remote sensing covers a wide area of study, the accuracy is relatively high, and the process requires less time and costs and is shorter than field surveys. Several products from satellite imagery provide information about an image of water including several types of satellite imagery, namely Landsat, SPOT, Quick Bird, Worldview-2, and Sentinel images. The satellite image used to determine the distribution and concentration level of TSS in Belawan Waters is Sentinel-2 with a spatial resolution of 10 meters.

The purpose of this study was to analyze the content TSS (Total Suspended Soil) using sentinel-2 in the Belawan Waters and it is surrounding at the time before and after rainfall, to expand rainfall to TSS the wide waters, the phenomena of TSS descent around the estuary and need to study discharge. Rainfall on TSS, which is basic information for other researchers in further research to determine the effect of TSS in living tissue, as a reference source in the management of the Belawan Harbor Waters area which is more environmentally sound, and as information for the local government and residents which in the Belawan Harbor Waters.

2. Methodology

This research was conducted from February to April 2021, Mey to July 2021, August to October 2021, and October to December 2021. The period includes data collection, data analysis, and processing, as well as the preparation around Sibolga Waters, North Sumatera Province. As shown in the location map in Figure 1, data processing and analysis were carried out at the GIS Laboratory at the Study Program of Waters Resources Management.

Methods and Tools

Data

Sentinel-2 satellite image data source obtained from NASA downloaded via the website: https://earthengine.google.com/.

Equipment

The tools and materials used in this study are tabulated in Table 1.

Table 1. Tools and Materials used during data processing.

Materials	Function
Data in situ TSS	Secondary Data (9 stations)
Citra Satelit Sentinel-2	Primary Data
Rainfall	Secondary Data
Data Analysis Tool	Function
Laptop	Data Analysis
Ms. Excel 2016	Data processing and calculation
ArcGis 10.5	Map Visualization

Methods

Sentinel 2 images processing in the analysis of total suspended solids TSS using GEE (Google Earth Engine) Cloud is divided into several processes, namely taking the Collection Snippet, Resampling (Geometric Correction), masking (Separating land and sea), TSS calculation based on the algorithm from (Liu *et al*., 2017), then export maps to Google Drive

1. Take *Collection Snippets*

Collection snippet retrieval is the initial stage in image processing. The Collection snippet process starts with: ee.ImageCollection("COPERNICUS/S2_SR") into the script in: https://code.earthengine.google.com/.

2. *Filtering*

Filtering the data to be obtained. There are 2 ways to filter the google earth engine, namely:

a. Date
b. Observation

To obtain data, the dates and observations to be studied must be entered, namely:

```
TSS PERAIRAN SIBOLGA *   Get Link   Save   Run   Reset   Apps
Imports (1 entry)
var roi: Polygon, 4 vertices
var dataset = ee.ImageCollection("users/mpangihutan/Sibolga");

function maskS2clouds(image) {
  var qa = image.select('QA60');

  // Bits 10 and 11 are clouds and cirrus, respectively.
  var cloudBitMask = 1 << 10;
  var cirrusBitMask = 1 << 11;

  // Both flags should be set to zero, indicating clear conditions.
  var mask = qa.bitwiseAnd(cloudBitMask).eq(0)
      .and(qa.bitwiseAnd(cirrusBitMask).eq(0));

  return image.updateMask(mask).divide(10000);
}

// Load Sentinel-2 TOA reflectance data.
var dataset = ee.ImageCollection('COPERNICUS/S2_SR')
                  .filterDate('2021-10-01', '2021-12-31')
                  .filter(ee.Filter.lt('CLOUDY_PIXEL_PERCENTAGE', 30))
                  .map(maskS2clouds)
                  .filter(ee.Filter.bounds(roi));

var rgbVis = {
  min: 0.0,
  max: 0.3,
  bands: ['B4', 'B3', 'B2'],
};
```

3. Retrieval of selected data and the median value of the set.

```
TSS PERAIRAN SIBOLGA *   Get Link   Save   Run   Reset   Apps
// Proses Sentinel - 2
var image = dataset.median();
var clipped = image.clip(roi)

var ndwi = clipped.normalizedDifference(['B3', 'B11']).rename(['ndwi']);

var tss = clipped.expression(
        "(ndwi > 0.1) ? 2950 * pow(VNIR,1.357)"+
        ": 0",{
          'ndwi' : ndwi,
          'VNIR': image.select('B7')
}).rename('tss');


var palete = ['blue','yellow','red','brown']

var maxTSS = tss.reduceRegion({
      reducer: ee.Reducer.max(),
      geometry: roi,
      scale : 120
      })

//print(maxTSS)
```

```
TSS PERAIRAN SIBOLGA *   Get Link   Save   Run   Reset   Apps
var vizTSS = {
  min: 1,
  max: 120,
  palette: palete
}

function createColorBar(titleText, palette, min, max) {
  // Legend Title
  var title = ui.Label({
    value: titleText,
    style: {fontWeight: 'bold', textAlign: 'center', stretch: 'horizontal'}

  // Colorbar
  var legend = ui.Thumbnail({
    image: ee.Image.pixelLonLat().select(0),
    params: {
      bbox: [0, 0, 1, 0.1],
      dimensions: '200x20',
      format: 'png',
      min: 0, max: 1,
      palette: palette},
    style: {stretch: 'horizontal', margin: '8px 8px', maxHeight: '40px'},
  });
```

4. Image Analysis

Image analysis to determine TSS using an algorithm developed (Liu, dkk., 2017) with Modell:

$$C_{SPM} = 2950\ x\ B7^{1.357}$$

```
  // Legend Labels
  var labels = ui.Panel({
    widgets: [
      ui.Label(min, {margin: '4px 10px',textAlign: 'left', stretch: 'horiz
      ui.Label((min+max)/2, {margin: '4px 20px', textAlign: 'center', stre
      ui.Label(max, {margin: '4px 10px',textAlign: 'right', stretch: 'hori
    layout: ui.Panel.Layout.flow('horizontal')});

  // Create a panel with all 3 widgets
  var legendPanel = ui.Panel({
    widgets: [title, legend, labels],
    style: {position: 'bottom-left', padding: '8px 15px'}
  })
  return legendPanel
}
// Call the function to create a colorbar legend
var colorBar = createColorBar('Total Suspended Soil / TSS - mg/liter', pal
```

CSPM is suspended particular matter, while the exponent value is 2950 which is the coefficient and B7 is the Band 7 channel in the Sentinel-2 image. Band 7 was used because the MAPE (mean absolute percentage error) value was 16,58%, RMSE (Root Mean Square Error) was 16,50% mg/l, and F (test score) was better than the scores in the other bands.

5. *Masking*

Masking can be said to be a technique of separating land and sea. Masking is done as an effort to improve image quality in terms of visuals and available information. The masking results are expected to reduce the error of intercepting information in a deeper analysis. Formula value in masking (land and sea separator) is:

```
// Tayang peta2
Map.centerObject(roi, 13);
Map.addLayer(clipped, rgbVis, 'RGB');
//Map.addLayer(ndti, {}, 'NDTI');
//Map.addLayer(ndwi, {}, 'NDWI');
var tssMasked = tss.updateMask(tss.gt(0));
Map.addLayer(tssMasked, vizTSS, 'TSS masked');
Map.add(colorBar)
```

6. Export Maps to Google Drive

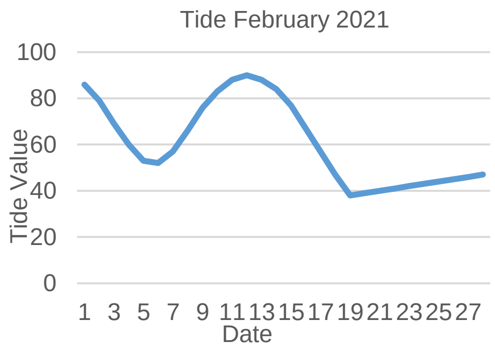
Transferring data results in the form of maps by exporting maps to Google Drive. Then, the exported map (*.tiff) is transferred to ArcGIS to view the resulting TSS data.

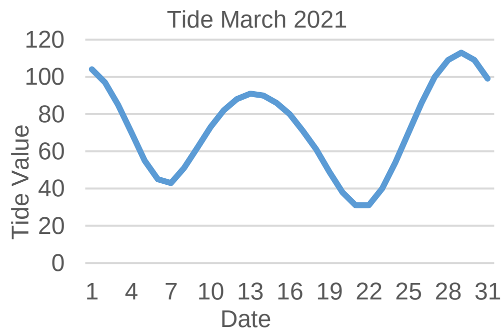
```
    Export.image.toDrive({
  image: tssMasked,
  description: "tss",
  scale: 30,
  region: roi
})
```

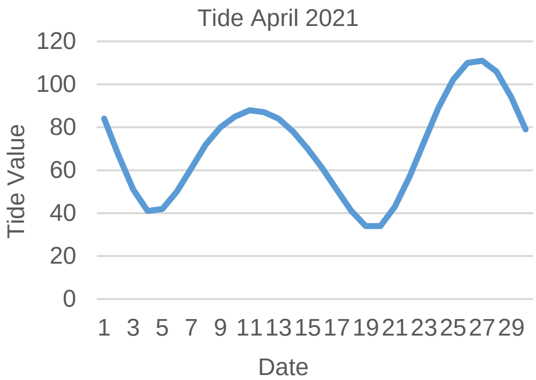
Results and Discussion

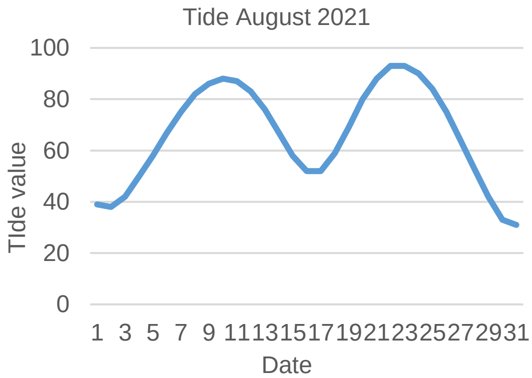
Tide

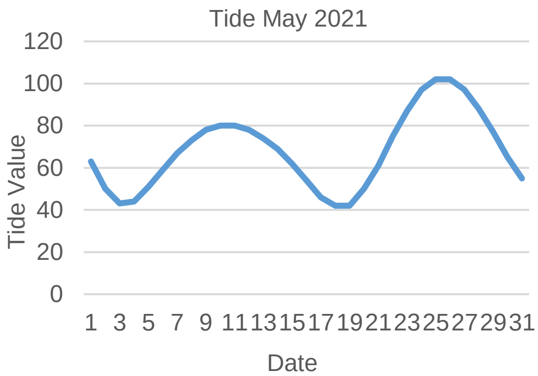
The tidal phenomenon is a process that occurs in the sea continuously. This natural process occurs due to the gravitational force of the sun, moon, and celestial bodies that attract each other so that the parts of the earth that are close to celestial bodies will experience tides, while in other parts of the earth, there will be receding. Salinity, temperature, pH, DO, and brightness.

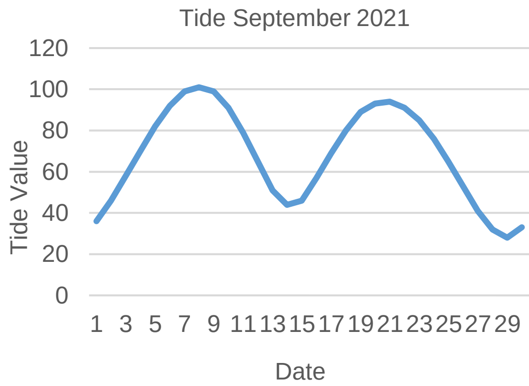


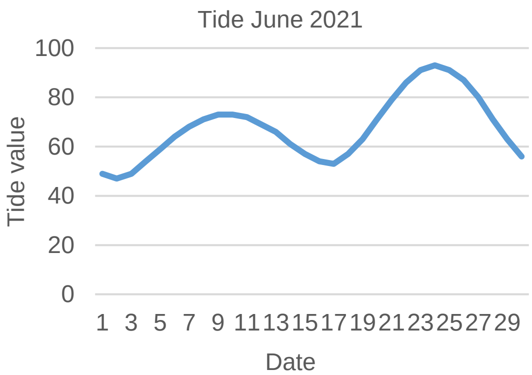


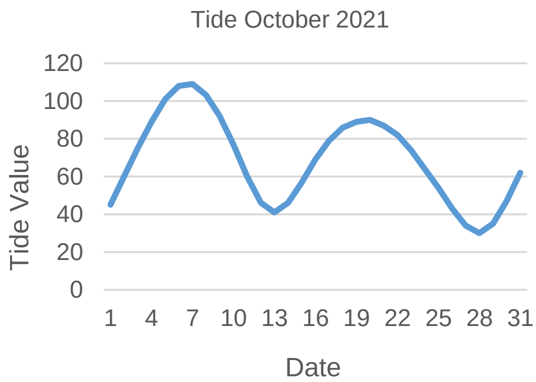

Tide April 2021
Tide Value
120
100
80
60
40
20
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Date

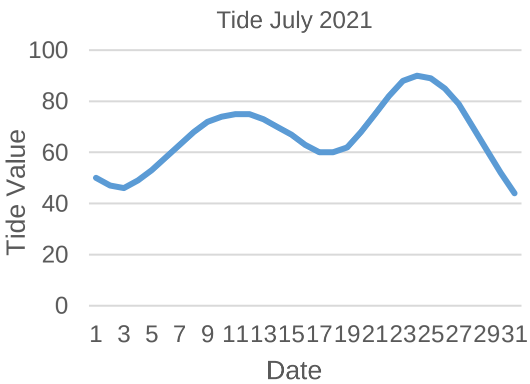

Tide August 2021
TIde value
100
80
60
40
20
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Date

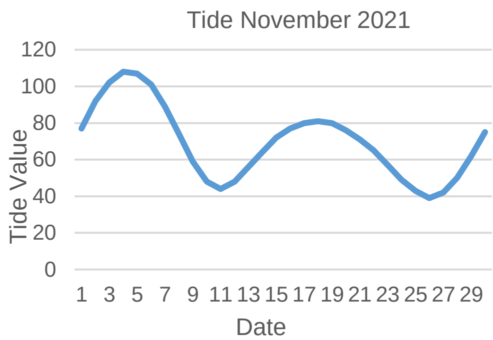

Tide May 2021
Tide Value
120
100
80
60
40
20
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Date


Tide September 2021
Tide Value
120
100
80
60
40
20
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Date


Tide June 2021
Tide value
100
80
60
40
20
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Date


Tide October 2021
Tide Value
120
100
80
60
40
20
0
1 4 7 10 13 16 19 22 25 28 31
Date


Tide July 2021
Tide Value
100
80
60
40
20
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Date


Tide November 2021
Tide Value
120
100
80
60
40
20
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Date

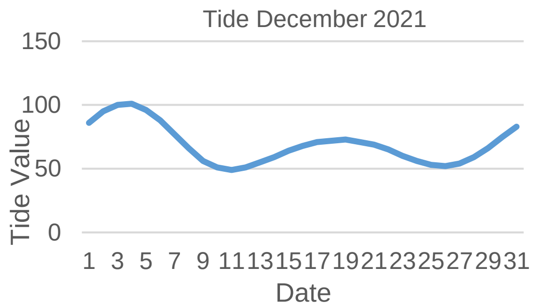


Figure 1. Real-Time Tide Prediction in February, March, April, May, June, July, August, October, September, November, and December 2021.

Rainfall

Precipitation is water released from clouds as rain, snow, or hail. Precipitation begins after water vapor condensing in the atmosphere becomes too heavy to remain in the atmospheric air currents and falls.

The stages of the rain process:

1. Evaporation

Evaporation is the process of changing liquid water into gaseous water (evaporation). This allows the gas to rise above the Earth's atmosphere. The higher the sun's heat, the more amount of water becomes water vapor and rises to the earth's atmosphere.

2. Transpiration

The other stage is the evaporation of water. Evaporation of water does not only occur in the soil but also takes place in the tissues of living things. The working principle of transpiration with evaporation is almost the same. Both turn water into water vapor which rises to the top of the atmosphere.

Transpiration is the process of evaporation in plants when they breathe. However, the amount of water that becomes vapor through transpiration is generally much less than the amount of water vapor produced by evaporation.

3. Condensation.

Furthermore, water vapor undergoes condensation or condensation in the form of ice particles. Changes in form occur due to the influence of very low air temperature at that altitude.

The ice particles are then formed into saturated clouds which will then be the beginning of the process of rain.

4. Precipitation (Rain)

This stage is the stage of the occurrence of rain. The reason is, at this stage the saturated clouds containing water droplets in the atmosphere get colder. This makes the clouds heavier, until finally the water droplets they contain fall to the earth's surface.

The fall of water droplets from the atmosphere to the earth's surface is called rain. If the ambient temperature is less than 0 ^{0}C, snow or ice is likely to occur.

Rainwater has fallen to the ground, some will seep into the ground as groundwater. Some of flows into lakes or rivers which then flow into the sea.

The phenomenon of rainfall that occurred in Belawan Waters for 9 months can be seen in Figure 2-4. This natural process occurs due to too much water vapor being stored so that the clouds can't accommodate the water vapor and fall to the earth.

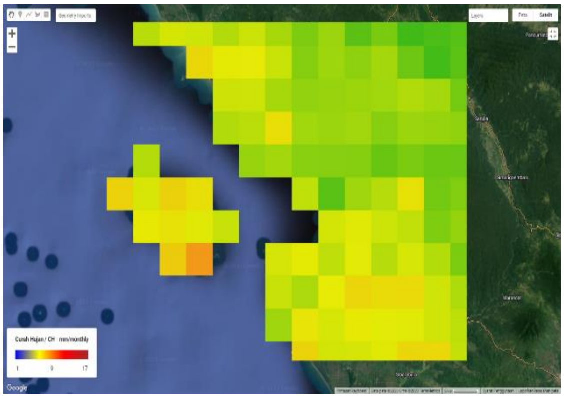


Figure 2. Rainfall for February 1st-April 30th 2021 in Sibolga Waters and Surrounding Areas.

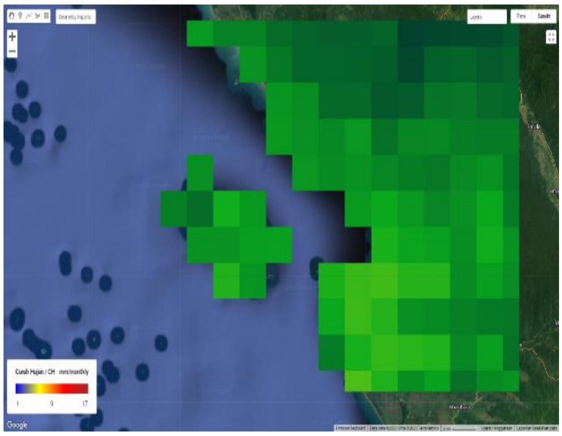


Figure 3. Rainfall for Mey 1st-July 31st 2021 in Sibolga Waters and Surrounding Areas.

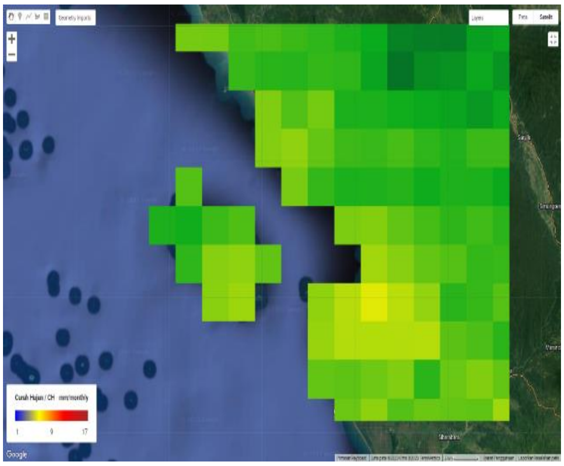


Figure 4. Rainfall for August 1st-October 31st 2021 in Sibolga Waters and Surrounding Areas.

TSS (Total Suspended Soil) Analysis using GEE Cloud

The analysis of the Sentinel-2 satellite image using the GEE Cloud can be seen in Figures 5, 6, 7, dan 8.

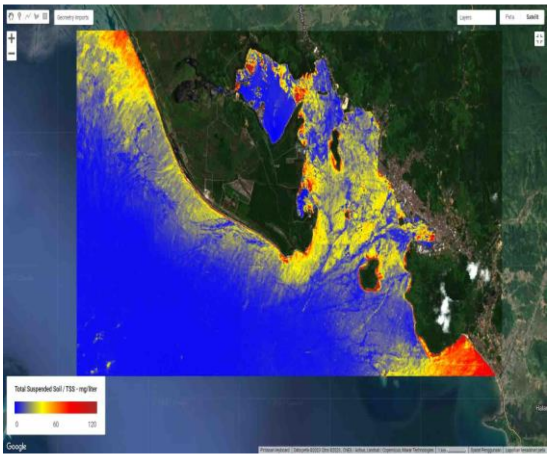


Figure 5. TSS Analysis February 1st-April 30th 2021.

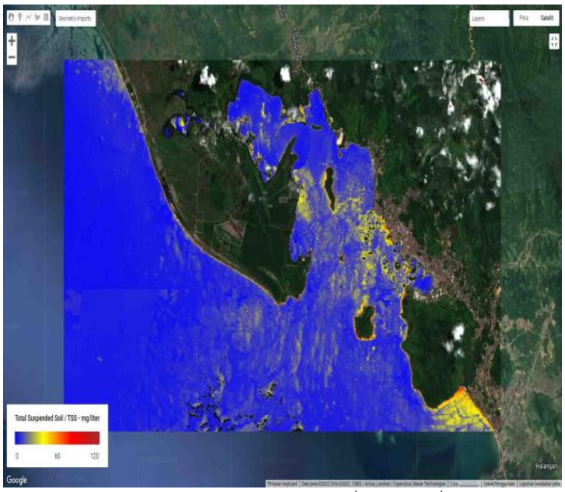


Figure 6. TSS Analysis Mey 1st-July 31st 2021.

Sentinel-2 image analysis doesn't require radiometric correction because the value of the image is already a reflectance value. Geometric analysis is also not needed because this study only focuses on the reflectance value of the image. The image used is the Sentinel-2 image with the recording date during the dry and rainy seasons in 2021.

The map of the TSS distribution on February 1st – April 30th, 2021 (Figure 5) and image recording shows that at high tide and high rainy season, the highest TSS value is 114-124 mg/l, and the lowest, TSS values spread evenly throughout Sibolga waters and around Murshala Island of 0-60 mg/l, and the highest TSS if found around the coast of Sibolga waters of 60-120 mg/l.

The TSS distribution map on May 1st-July 31st 2021 (Figure 6), and image recording show the position of high tide with a low rainy season and has the highest TSS values of 60-120 mg/l around the port and the coast of Sibolga water while the lowest values of 0-60 mg/l spreads evenly and far from the coast and harbors.

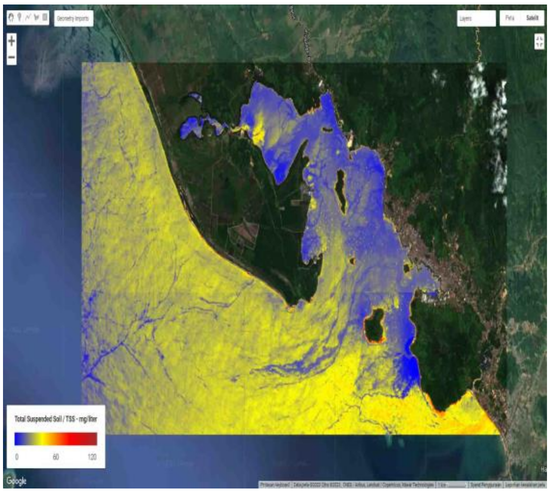


Figure 7. TSS Analysis August 1st-October 31st 2021.

The TSS distribution map on August 1st – October 31 st 2021 (Figure 7) with the highest TSS values of 60-120 mg/l found around ports and beaches while the lowest TSS values of 0-60 mg/l spread evenly far and some close to the coast as well as port. This TSS spreads as a whole around the edge of the Sibolga coastal waters and the port.

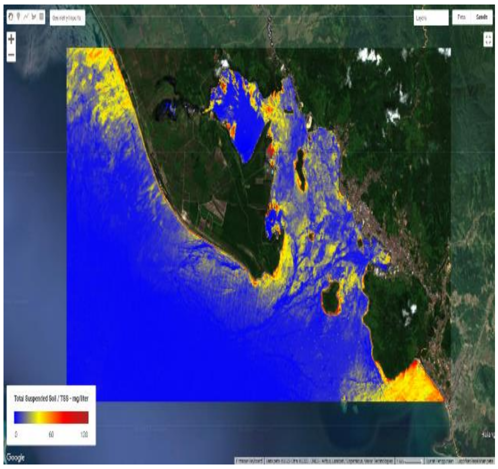


Figure 8. TSS Analysis October 1st-December 31st 2021.

The TSS distribution map on October 1st-December 31st, 2021 (Figure 8) and image recording show that high tide position and high rainy season have the lowest TSS values of 0-60 mg/l found in the area around the coast, Sibolga coastal area, while the highest TSS value is 60-120 mg/l occurring in parts of the Sibolga coastal area.

Discussion

Based on the analysis at the location of Sibolga Waters, North Sumatera Province, it was found that the tidal patterns that occurred at the research location were mixed, inclined, and double daily types. The Sentinel-2 image used will show the time at which the image was recorded which, if adjusted for the tides, will result in the position of the waters at high or low tide.

The tide analysis was carried out, and in February 2021 it was found the water level reached 0,90 m higher than MSL and the lowest water level reached 0,38 m indicating the position of the high tide towards ebb, in April 2021 it showed the highest water level rise with a height of 0,111 m higher than MSL and lowest water level rise at a height of 0,34 m. The results of TSS recording in surrounding Sibolga Waters for February 1st-April 30th 2021, namely 0-60 mg/l were more dominant, while the highest TSS values occurred around the Sibolga coast and ports of 60-120 mg/l.

In May 2021, a water level rise of 0,102 m and the lowest water level of 0,42 m indicates the highest tide and lowest ebb, the highest water level rise for June is 0,93 m, and the lowest water level is 0,47 m while for July it is 0,90 m and the lowest water level is 0,44 m. The TSS recording results obtained in Sibolga waters from May 1 to July 31 2021 were very small around Sibolga coastal waters and most were in several near the coast including Sibolga waters, namely 0-60 mg/l, for the highest TSS values spread slightly on the outskirts of the surrounding Sibolga coast, which is equal to 60-120 mg/l.

The tidal analysis was carried out, and in August 2021 it was found that the water level reached 0,93 m higher than MSL and the lowest water level reached 0,31 m indicating a high tide position towards low tide. September-October 2021 shows the highest water level rise with a height of 0,101-0,109 m higher than MSL and the lowest water level rise at an altitude of 0,28-0,30 m. The results of TSS recording in Sibolga Waters for August 1 to October 31, 2021, that is, the lowest value it spreads fluctuating around the waters, the Sibolga coast is 0-60 mg/l and the highest TSS value spreads evenly on the outskirts of the beach is 60-120 m/l.

For the tidal analysis conducted, in October-December 2021, the water level reached 0,100-0,109 m higher than MSL and the lowest water level reached 0,30-0,51 m indicating a high tide position. TSS recording results in Sibolga waters for October 1 to December 31, 2021, namely the lowest of 0-60 mg/l occurred around the Sibolga coastal waters, and the highest of 60-120 mg/l was found around the Sibolga coast.

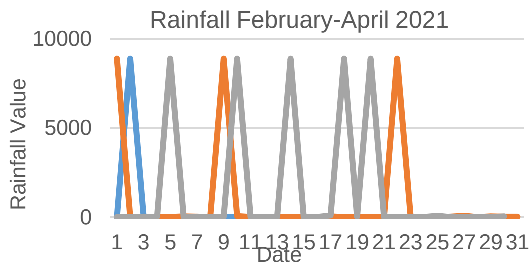


Figure 9. Rainfall from February 1st to April 30th, 2021.

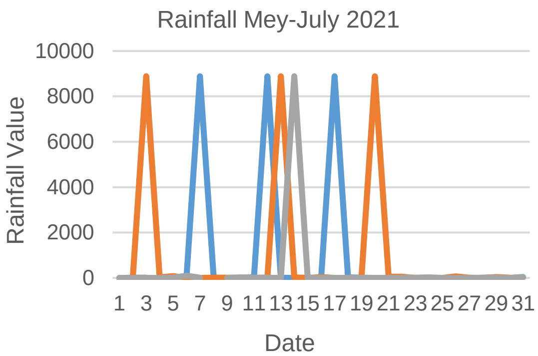


Figure 10. Rainfall from Mey 1st to July 31st, 2021.

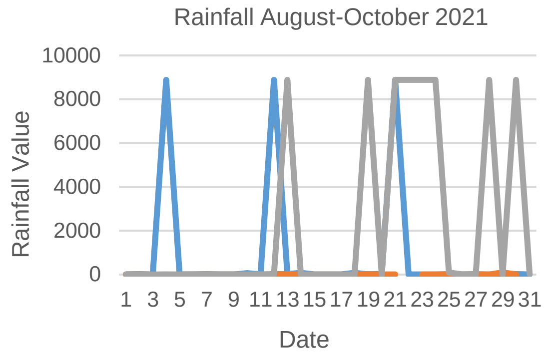


Figure 11. Rainfall from August 1st to October 31st, 2021.

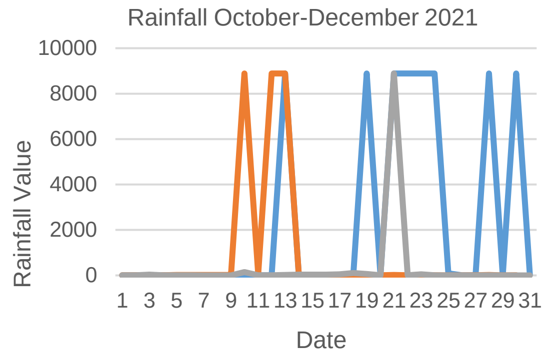


Figure 12. Rainfall from October 1st to December 31st, 2021.

The seasonal forecast based on BMKG data for Figure 9-12 above shows that from February 1 to April 30, 2021, from the dry season to the rainy season, that is, with a value of 0,3-95,4 mm^3. May 1 to July 31, 2021, are the low level of the rainy season towards the dry season, with a value of 0,5-84,8 mm^3. August 1 to October 31, 2021, is the high rainy season, with a value of 0,4-98 mm^3. October 1 to December 31, 2021, is a very high rainy season, with a value of 0,6-100,9 mm^3. The results of the analysis of the tides in the season show that the dry season occurs on May 1 to Juli 31, 2021, indicating the waters are in a low tide position, and in the rainy season the waters are in a very high tide position, namely October 1 to December 31, 2021.

Figure 5 shows that the TSS results obtained for February 1st - April 30th, 2021 are evenly distributed and dominate from Murshala Island to Sibolga Waters. This is different from the results of the TSS for May 1 to July 31, 2021, namely only a small amount of TSS around Sibolga beach. TSS results for August 1-October 31, 2021, which are evenly distributed to all Sibolga coasts and ports. And the TSS results for October 1 to December 31, 2021 (Figure 8) show that TSS is spread evenly for parts of the Sibolga coast.

The TSS value is higher in the rainy season compared to the dry season due to the flow of rivers entering Sibolga Waters with more water intensity and the tides affect the distribution pattern of TSS where during high tide the distribution pattern will be inclined towards the estuary due to input from around Sibolga Waters and at low tide in the deep waters by the bay.

CONCLUSION

Based on the results of the analysis of the TSS study using the Sentinel-2 TOA Reflectance imagery, the analysis shows that the TSS value in 2021 during the dry season has a lower value compared to the rainy season. So, the influence of the season can determine the direction of the TSS distribution pattern, both tidal factors and weather conditions such as rain and dry season. The effect of tides on the distribution pattern of TSS in Sibolga Waters causes the TSS value at high tide to be higher than at low tide. Sentinel-2 TOA Reflectance Data imagery can be used to map TSS distribution patterns in the Sibolga Waters area.

REFRENCES

Bae, H. K. 2013. Changes in the river's water quality responded to rainfall events. *Environment and Ecology Research*, 1(1), pp. 21–25.

Chen, J., W. Zhu, Y. Q. Tian, Y. Zheng & L. Huang. 2017. Remote estimation of colored dissolved organic matter and chlorophyll-a in Lake Huron using Sentinel-2 measurements. Journal of Applied Remote Sensing 11(3): 036007-1-036007–036015.

Effendi, H. 2003. Review of water quality, for management of aquatic resources and environment. Kanisius.

ESA. 2015. *Microbial Adaptation*, *Sentinel-2 User Handbook*. European Space Agency. doi:10.1021/ie51400a018.

Gu, Y. G., & Y. P. Gao. 2019. An unconstrained ordination- and GIS-based approach for identifying anthropogenic sources of heavy metal pollution in marine sediments. Marine Pollution Bulletin 146: 100–105.

Hua, A. K. 2017. Identifying the source of pollutants in the Malacca River using the GIS approach. Applied Ecology and Environmental Research 15(4): 571–588.

Jiya., Sudarsono, B., Sukmono, A. 2017. Study of the Distribution of Total Suspended Solid (TSS) in the Coastal Waters of Demak Regency Using Landsat Imagery. Journal of Geodesy UNDIP. January 2017. 1-7 p.

Juliasih, N. L. G. R., D. Hidayat, M. P. Ersa, & Rinawati. 2017. Determination of Nitrite and Nitrate Levels in Lampung Bay Waters as an Indicator of Water Environmental Quality. Analytical and Environmental Chemistry 2(2): 47–56.

Kamal, A. N., N. S. Muhammad, & J, Abdullah. 2020. Scenario-based pollution discharge simulations and mapping using integrated QUAL2K-GIS. Environmental Pollution 259 (113909): 1-10.

Kamara, S. M. 2019. Integration of GIS in the Development of an Environmental Cadastre Administrative System for the Environment Protection Agency Sierra Leone. Journal of Geographic Information System 11: 411–428.

Khairul. 2017. Study of Aquatic Physicochemical Factors on Aquatic Biota in the Belawan River Ecosystem. Proceedings of the Multidisciplinary National Seminar on Science UNA 2017:1132–1140.

Liu, H., Li, Q., Shi, T., Hu, S., Wu, G., Zhou, Q. 2017. Application of Sentinel 2 MSI Images to Retrieve Suspended Particulate Matter Concentrations in Poyang Lake', *Remote Sensing*, 9(7), p. 761. doi 10.3390/rs9070761.

Mir, A., J. Piri & O. Kisi. 2017. Spatial monitoring and zoning water quality of Sistan River in the wet and dry years using GIS and geostatistics. Computers and Electronics in Agriculture 135: 38–50.

Nasrabadi, T., H. Ruegner, Z. Z. Sirdari, M. Schwientek & P. Grathwohl. 2016. Using total suspended solids (TSS) and turbidity as proxies for evaluation of metal transport in river water. Applied Geochemistry 68: 1–9.

Qanita, H., S. Subiyanto & H. Hani'ah. 2019. Distribution Analysis of Total Suspended Soil and Chlorophyll-a Content in West Semarang Flood Canal Waters using Landsat 8 and Sentinel-2A Imagery. UNDIP Geodetic Journal 8(1) : 435–445.

Saberioon, M., J. Brom, V. Nedbal, P. Souček & P. Císař. 2020. Chlorophyll-a and total suspended solids retrieval and mapping using Sentinel-2A and machine learning for inland waters. Ecological Indicators 113(106236): 1-11.