The 3rd International Conference on Materials Chemistry and Environmental Engineering
DOI: 10.54254/2755-2721/3/20230484

Amazon River Delta Suspended Sediment Analysis

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Abstract. This study focuses on the variation of suspended sediment concentrations in the Amazon River basin near Macapa, Brazil for each season between 2016 and 2020. The suspended sediment concentrations were calculated by spectral analysis of satellite images obtained by Landsat 8-9 OLI/TIRS in the study area. The effects of seasonality, discharge, and precipitation on suspended sediment concentrations in the Amazon Delta were also investigated in conjunction with discharge and precipitation data in the Amazon River basin near Macapa. Findings showed that precipitation was a strong driver of SSC increase, but high SSC lasts longer after high precipitation in autumn. Precipitation, discharge, and SSC were positively correlated with each other, but there was a lag period between their changes.

Keywords: Suspended Sediments, Landsat8-9 OLI/TIRS, Amazon River.

1. Introduction

This study investigates the suspended sediment dynamics in the Amazon River delta. Suspended sediment includes organic and inorganic particles floating near the surface of the water. Suspended sediment dynamics are important because they affect ecological health and water quality. The suspended sediment can block out sunlight for plants deeper in the river. These plants produce oxygen which other river organisms rely on. Unfortunately, suspended sediment can also block fish gills and create cloudy water [1]. Therefore, the concentration of suspended sediment affects the environmental health of this river and the surrounding area to some extent. I chose the Amazon River basin near the city of Macapa, Brazil, as shown on figure 1, which is in the Amazon Delta region and has complete discharge and precipitation data, as my study site. I have selected one satellite image obtained by Landsat 8-9 OLI/TIRS for each season in this time frame for processing and analysis. This research will build upon a study that measured SSC in the nearby Orinoco River in Venezuela. They derived an algorithm to measure empirical SSC amounts which will be used here in the Amazon River delta study site [2]. I have three major research questions to answer, first, how does seasonality affect the SSCs and river discharge in the Amazon River near Macapa, Brazil? Second, how do changes in discharge affect river SSC in the Amazon River near Macapa, Brazil? Third, how do changes in precipitation affect river discharge and SSC in the Amazon River near Macapa, Brazil? For these three research questions, I have proposed my hypothesis, as seasons change, the precipitation in Macapa. Brazil would change accordingly. As precipitation increases, the discharge and SSC increase as well. Thus, seasonality, precipitation, discharge, and SSC would have a positive relationship between each other.

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Figure 1. Study Site short Map.

To analyse and interpret the research questions, I used one Landsat 8-9 OLI/TIRS Level 2 image from each season from December 2015 to December 2020 obtained from USGS Earth Explorer. With 20 images, these images will allow me to analyse the change of suspended sediment by season and by year in the Macapa basin Amazon during the five-year period as well as give us insight as to what may have caused these changes and their effects. Table 1 is a list of the details of the images.

Table 1. Images.

Date	Season	Path & Row
01/23/2016	Summer	225, 060
12/08/2016		
01/12/2018		
12/30/2018		
12/01/2019		
05/14/2016	Fall	225, 060
04/15/2017		
05/20/2018		
04/21/2019		
05/25/2020		
08/02/2016	Winter	225, 060
08/05/2017		
06/05/2018		
08/27/2019		
07/28/2020		
09/19/2016	Spring	225, 060
09/22/2017		
09/25/2018		
09/12/2019		
09/30/2020		

In addition, to process and analyse the satellite images, I created vector data. The first one is the Crop shapefile, used to crop each image to the same extent to reduce the computing pressure. The other one is the Study site shapefile, which is the polygon of part of the channel near Macapa, used to extract the SSC data of each image and calculate the average value. After obtaining the results, I also used ancillary data to assist in analysing and interpreting the obtained results. The historical precipitation data for the

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city of Macapa, obtained from weatherspark, and the historical discharge data for the Macapa basin of the Amazon River, obtained from the National Water and Sanitation Agency of Brazil, were used.

2. Method

2.1. Pre-Processing

Due to the huge area covered by the acquired 20 Landsat 8-9 OLI/TIRS Level 2 images, the direct processing of the 20 original-size raster images would result in a significant amount of computational effort and time wasted. Therefore, the original images are first cropped to the extent of the study site using RStudio and the created Crop shapefile. The NDVI (Normalized Difference Vegetation Index) values of individual images were then calculated in RStudio using cropped images, and since the water body absorbs the NIR (Near-Infrared) band and has relatively stronger reflectance on the red band, the NDVI of the water body is usually below -0.2. Since clouds have similar reflectance to both the NIR and red bands, the NDVI of clouds is generally around 0. After the calculation, all NDVI raster images were imported into QGIS, and the histogram of each image was generated. By analysing the histograms, it was found that the NDVI values of the Amazon River showed significant differences from those of the land and the cloud cover, with the NDVI values of the land being generally greater than 0.9, while the NDVI values of cloud cover are between -0.1 and 0.1, and the NDVI values of water bodies are generally less than -0.2, therefore I chose -0.2 as the threshold to make the mask shapefile of land and cloud cover. The 20 mask shapefiles generated in this step are then used to remove the land and cloud cover by masking the corresponding cropped images one by one in RStudio, and these pre-processed images can then be used for the SSC calculation.

$$NDVI = (NIR - RED)/(NIR + RED)$$

2.2. SSC Calculation

The algorithm for calculating SSC values calculated from real data collected from field measurements generally provides the most accurate reflection of the SSC of a water body, yet due to the lack of access to field measurements, the calculation of SSC values in this study would be done using an algorithm derived from a study that measured SSC in the nearby Orinoco River in Venezuela [4]. Though the Orinoco River inlet in Venezuela is at a distance from the Amazon River delta, both share similar properties, are in a tropical rainforest region, and both have a similar climate in South America. Although the use of the Venezuelan algorithm does not reflect the most accurate SSC values for the Amazon Delta, it is still possible to calculate the monthly and annual relative differences in SSC for the Amazon Delta. Therefore, I used this algorithm to calculate twenty pre-processed satellite images using RStudio to obtain SSC raster images for each season from 2016 to 2020 for the Macapa basin in the Amazon Delta.

$$SSC = \frac{RED * 1000 - 81.662}{0.5144}$$

After obtaining the SSC images, there are a few enormous or extremely small values in the water body that differ greatly from the surrounding area, as a result of some errors in the sensor. In order to avoid these errors, I created a study site shapefile by examining the images to narrow the analysis area and minimize the impact of the errors on the results. The study site shapefile was then used in Rstudio to extract the SSC values within the study site and to calculate the average SSC values for each time point.

3. Results

3.1. SSC Visualization

I obtained a total of 20 SSC maps for the Amazon River waters near Macapa, Brazil. Figures 2,3,4, and 5 are the SSC maps we selected as most representative of summer, fall, winter, and spring, respectively. The analysis of these maps revealed that the SSC in spring was relatively low among these four seasons.

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Then there is a more moderate rise in SSC from spring to summer. This was followed by an increase in SSC in the fall compared to the summer. Then, the SSC peaked in winter. Subsequently, there was a very sharp decrease in SSC during the transition from winter to spring.

In general, the Amazon River basin near Macapa shows a relative change in suspended sediment concentrations with the seasons. The general trend is that SSC values are lowest in spring, then gradually increase, peaking in winter, and finally dropping sharply to a minimum in spring.

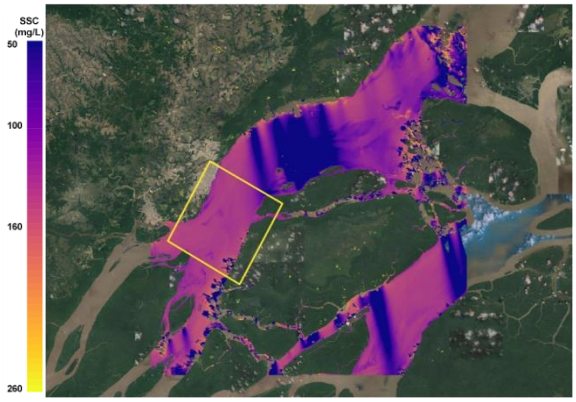


Figure 2. Summer SSC.

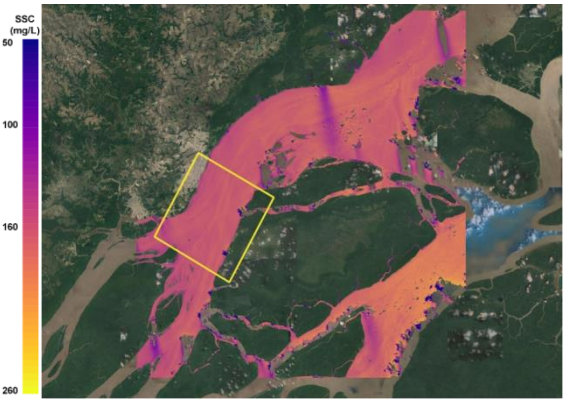


Figure 3. Fall SSC.

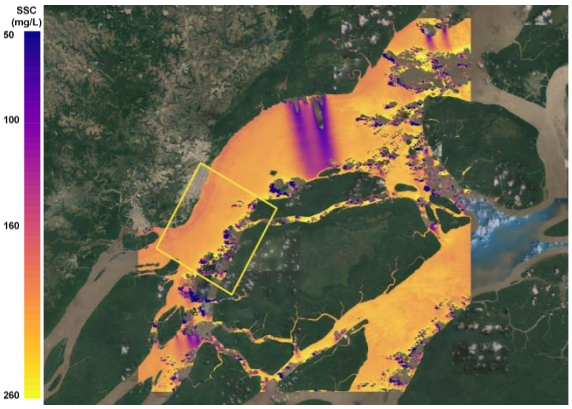


Figure 4. Winter SSC.

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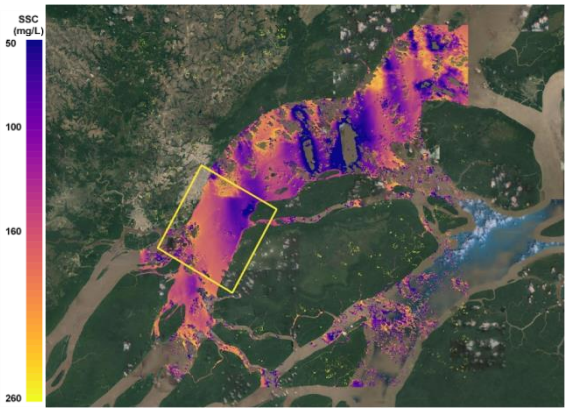


Figure 5. Spring SSC.

3.2. SSC, Discharge, Precipitation Comparisons

Finally, I obtained the monthly average SSC plot and the monthly average discharge of the waters around Macapa, which are shown on figure 6 and 7 respectively [3], as well as the monthly average precipitation plot for this area of Macapa, as shown on figure 8 [4]. Comparing plot 1 with the four maps presented above, we can see that the trend shown by plot 1 is the same as that shown by the maps. In each year, the SSC is lowest in the spring, then gradually increases until the winter, and then suddenly decreases again in the spring.

Comparing the precipitation plot and the discharge plot, we can find that. They show similar trends, but the discharge is lowest in winter, then gradually rises to a peak in autumn, and then gradually decreases until it reaches a minimum in winter. And the precipitation is lowest in spring, then gradually rises to the peak in autumn, then gradually decreases to the lowest point in spring. there is a certain lag between the discharge reaching the lowest point and the precipitation.

Comparing the SSC plot with the precipitation plot and the discharge plot, we can see that SSC and precipitation show relatively similar trends, and they both reach their lowest point in the spring. However, the difference is that SSC decreases more than precipitation from winter to spring, while precipitation changes more smoothly. In addition, SSC peaks in both fall and winter and remains for a relatively longer period, while precipitation peaks only in fall and then starts to decline. In general, SSC has a certain lag and a longer retention time compared to precipitation. However, in general, the effect of precipitation on SSC is considerable, and discharge has a relatively small effect on SSC variability.

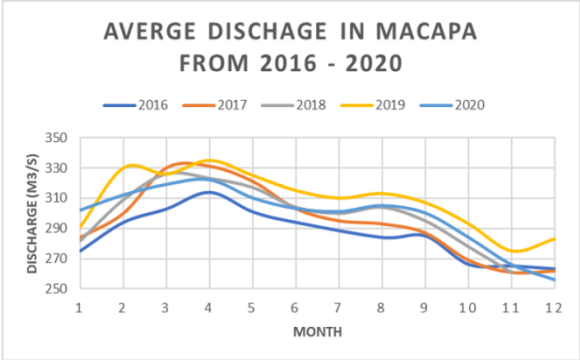


Figure 6. Average Discharge Plot.

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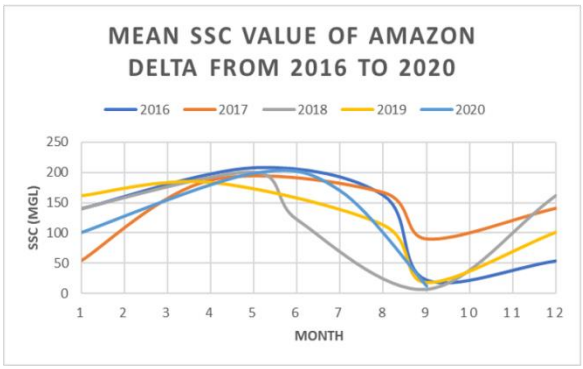


Figure 7. Average SSC Plot.

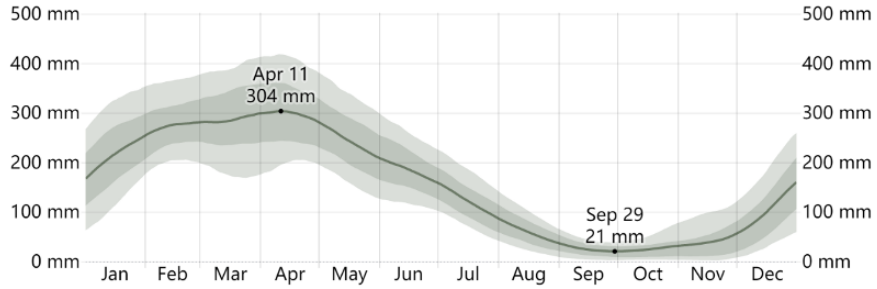


Figure 8. Average Precipitation Plot.

3.3. Conclusion

Based on the results, we can conclude that in the Amazon delta, precipitation is a strong drive of the increase of SSC, but high SSC lasts longer after high precipitation in fall. Moreover, a steep decline as precipitation decreases to the low point in spring. The seasonal trends of SSC levels, discharge, and precipitation follow what we predicted in our hypothesis where high levels of precipitation lead to higher SSC values.

Discharge was at its highest during the months of March and April of the fall season and lowest during the months of October, November, and December of the spring season and beginning of the summer season. Precipitation was at its highest in the Month of April in the Fall season and lowest in the month of September in the Spring season. Mean SSC values were highest in May and June at the end of the fall season and the beginning of the winter season. Values were at their lowest in September and October of the spring season.

SSC values peak a little later in May and June compared to the peak in discharge and precipitation which is in March and April. This hysteresis is the resultant amount of time it takes for the sediments to accumulate due to the increase in precipitation and discharge. Precipitation, discharge, and SSC have positive relationships with each other, but there is a lag time between their changes.

4. Challenges/Gaps and Future Direction

In this study, many Landsat 8-9 OLI/TIRS satellite images have large areas of cloud cover, which, although unavoidable, does affect the calculation and analysis of the actual data to some extent. Not only that, almost every image has substantial shadows and solar reflections on the water surface as well as sensor errors that make the results inaccurate. Also, the algorithm used to calculate the SSC was not particularly suitable for calculating the SSC of the Amazon River, I used the SSC algorithm of the Orinoco River in Venezuela, which resulted in not being able to obtain the most accurate SSC values only the relative variation of the SSC values. This is due to my lack of in situ data and thus my inability to develop the most appropriate algorithm myself.

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References

[1] US Department of Commerce, N. O. and A. A. (n.d.). Nonpoint Source Pollution, NOS Education Offering. Retrieved May 23, 2022, from https://oceanservice.noaa.gov/education/tutorial_pollution/011sediments.html#:~:text=Soil%20in%20the%20water%2C %20called,extended%20periods%2C%20they%20will%20di

[2] Yepez S, Laraque A, Martinez J.-M, De Sa J, Carrera J. M , Castellanos B, Gallay M, and Lopez J. L 2018 Retrieval of suspended sediment concentrations using landsat-8 OLI satellite images in the Orinoco River (Venezuela). Comptes Rendus Geoscience vol 350 pp 20–30. https://doi.org/10.1016/j.crte.2017.08.004

[3] ANA 2022 Discharge Data of Macapa. HIDROWEB. Retrieved May 2022, from https://www.snirh.gov.br/hidroweb/serieshistoricas

[4] Weatherspark.com 2022 Precipitation of Macapa. Macapá Climate, Weather By Month, Average Temperature (Brazil) - WeatherSpark. Retrieved May 24, 2022, from https://weatherspark.com/y/29785/Average-Weather-in-Macap%C3%A1-Brazil-Year-Round