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Water Quality Analysis Using NDTI and TSS Parameters Based on Sentinel Image Data in Jakarta Bay Waters

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Abstract: This study investigates the spatial variability of water quality in Jakarta Bay using remote sensing techniques, focusing on turbidity and sediment levels. The research employs Sentinel-2A satellite imagery processed through Google Earth Engine (GEE) and utilizes two key parameters: the Normalized Difference Turbidity Index (NDTI) and Total Suspended Solids (TSS). Jakarta Bay, a shallow marine area in northern Jakarta, is significantly affected by urban runoff, industrial waste, and other anthropogenic pressures. Five observation points were selected to represent different environmental conditions and levels of human influence. The analysis revealed distinct variations in water quality. Point 1 exhibited the highest turbidity (NDTI = 0.21) and TSS (46.81 mg/L), indicating a heavy presence of suspended particles likely due to upstream discharge and shoreline activity. Point 5 showed the lowest turbidity and TSS values, suggesting clearer water and minimal pollutant input. Interestingly, point 3 had the highest turbidity (NDTI = 0.23) but the lowest TSS (23.49 mg/L), reflecting the presence of fine particles that increase light scattering but contribute less to sediment mass. The use of satellite-based indicators proved effective in identifying spatial differences in water quality across Jakarta Bay. This approach offers a cost-efficient, large-scale monitoring method that supports environmental assessment and planning. The results underscore the impact of local factors on water conditions and demonstrate the importance of combining turbidity and sediment metrics. Ultimately, this study provides valuable insights to guide targeted water management strategies and contributes to achieving Sustainable Development Goal 6: ensuring clean water and sanitation for all.

Keywords: Remote Sensing; Normalized Difference Index Turbidity (NDTI); Total Suspended Solid (TSS); Water Quality

1. Introduction

Agricultural chemicals, household discharges, and even noise pollution and biological invasions contribute to water contamination, significantly altering the physical, chemical, and biological properties of aquatic ecosystems [12], [5]. These changes often have serious consequences for biodiversity and overall ecosystem health. Given the complexity and scale of such environmental challenges, remote sensing has emerged as an effective tool for monitoring water quality. It provides a cost-efficient and scalable approach to assess large areas, particularly valuable for initial evaluations

prior to detailed field investigations [11]. In this context, the present study aims to assess the spatial variability of water quality in Jakarta Bay using remote sensing methods. Specifically, it examines levels of turbidity and sedimentation in the bay's coastal waters through two key parameters: Total Suspended Solids (TSS) and the Normalized Difference Turbidity Index (NDTI). These metrics are used to evaluate the extent of human activity impacts on water quality and to support effective environmental monitoring and management.

2. Materials and Methods

Jakarta Bay, with an average depth of approximately 15 meters [9], is a shallow marine environment that is particularly vulnerable to environmental disturbances and human-induced stressors such as urban runoff, industrial discharges, and maritime activities [7]. To ensure accurate and timely analysis, this study utilized satellite imagery from December 2024, providing recent and seasonally appropriate data for the spatial monitoring of water quality indicators [6]. One of the key indicators applied is the Normalized Difference Turbidity Index (NDTI), a widely recognized and reliable method for assessing water turbidity. NDTI is calculated as the normalized difference between the red and green spectral bands of sunlight reflected from the water surface. The index ranges from -1 to 1, with values between 0 and 1 indicating turbid water, and values between -1 and 0 representing clearer water conditions [1]. As such, higher NDTI values correspond to increased turbidity. According to the Environmental Protection Agency (2023), turbidity is a critical indicator of water quality, defined as a reduction in water transparency caused by suspended, non-dissolved particles [8].

In addition to NDTI, this study also examined Total Suspended Solids (TSS), which represent the concentration of organic and inorganic particles suspended in the water column. Elevated TSS levels can reduce light penetration, impair photosynthesis in aquatic plants, and lower dissolved oxygen levels, potentially resulting in fish mortality [4]. TSS includes particles larger than 0.45 micrometers and up to two millimeters in size, such as fine sand, silt, and a variety of biotic and abiotic materials [9]. These particles typically enter the aquatic environment through surface runoff, wave action, tidal flows, and currents. The generally accepted maximum limit for TSS in water bodies is 50 mg/L [10]. To better interpret sediment conditions in Jakarta Bay, TSS concentrations in this study were classified into four deposition rate categories. A low deposition rate corresponds to TSS values between 15 and 25 mg/L, while a moderate rate ranges from 25 to 35 mg/L. Values between 35 and 50 mg/L indicate a high deposition rate, and concentrations exceeding 50 mg/L are categorized as very high deposition, as shown in Table 1 [3]. This classification framework helps to assess sedimentation dynamics and understand the distribution and intensity of suspended particulate matter across different areas of the bay.

Table 1. Classification of Total Suspended Solid Values

Deposition Rate	TSS (Mg/L)
Low	15-25
Moderate	25-35
High	35-50
Very High	>50

To examine the spatial variability of environmental conditions, this study analyzed five observation sites within Jakarta Bay. These locations were strategically selected to capture a diverse range of geographical characteristics and pollution exposure levels, as outlined in Table 2. This selection strategy enabled a more comprehensive assessment of how environmental stressors are distributed throughout the bay. By evaluating both the Normalized Difference Turbidity Index (NDTI) and Total Suspended Solids (TSS) at each site, the study sought to identify spatial patterns and gradients in turbidity and sediment concentration. The results provide valuable insights into the current environmental condition of Jakarta Bay and highlight the extent and spatial variability of human-induced impacts across the region [1], [3].

Table 2. Coordinate of Study Area at Jakarta Bays

Point	Longitude	Latitude
1	106.83545	- 6.11006
2	106.86085	- 6.0691
3	106.95973	- 6.00353
4	106.72902	- 6.06227
5	106.83545	- 5.99603

In this case study, Google Earth Engine (GEE) is employed as the primary remote sensing platform. GEE was chosen for its accessibility, being freely available and offering a user-friendly programming interface through JavaScript. The analyses of both the Normalized Difference Turbidity Index (NDTI) and Total Suspended Solids (TSS) rely on satellite imagery from the Sentinel-2A satellite. Sentinel-2A was selected due to its recent launch in 2015 and its high spatial resolution, providing red, blue, green, and near-infrared (NIR) bands at a 10-meter resolution [6], as shown in Table 3. These characteristics make Sentinel-2A an effective resource for environmental monitoring and spatial planning applications [7].

Table 3. Band Combination of Sentinel 2A satellite for NDTI and TSS calculation

Parameters	Band
NDTI	3 & 4
TSS	4 & 11

3. Results

Processing Sentinel-2 imagery using Google Earth Engine (GEE) generated spatial outputs for both the Normalized Difference Turbidity Index (NDTI) and Total Suspended Solids (TSS), with pixel values ranging from -1 to 1. However, the initial visualization of these outputs using standard image viewer software produced basic black and white imagery, which did not effectively represent the full variability in water quality. In this default visualization, white areas represented the background, while black regions mainly concentrated along the right and bottom edges of the image, as well as scattered throughout corresponded to certain pixel values of NDTI and TSS. This simplistic binary format limited the interpretability of spatial patterns, making it difficult to analyze turbidity and sediment concentrations across Jakarta Bay.

This binary representation significantly limited the interpretability of the data, particularly in understanding spatial variations of turbidity and sediment concentration in Jakarta Bay. To overcome this issue, a custom programming approach was applied to recalibrate and rescale the NDTI and TSS values throughout the entire study area. This recalibration enabled a more detailed and accurate visualization of water quality variations, facilitating meaningful interpretation of turbidity levels and sediment loads. The refined results for December 2024 are summarized in Table 4.

Table 4. Calculated Value of Normalized Diffence Turbidiy Index and Total Suspended Solid

Points	NDTI	TSS
1	0.21	46.81
2	0.19	28.92
3	0.23	23.49
4	0.18	26.98
5	0.16	24.96

The analysis of NDTI and TSS across the five observation points in Jakarta Bay revealed significant spatial variability in water quality. Point 1 exhibited the highest turbidity and TSS levels, with an NDTI of 0.21 and TSS concentration of 46.81 mg/L, indicating a substantial presence of suspended particles, likely influenced by strong upstream discharge and intensive human activities near the shoreline. Point 2 showed moderate turbidity (NDTI of 0.19) and sediment concentration (TSS of 28.92 mg/L), possibly due to its relatively lower exposure to pollution sources. Interestingly, point 3 recorded the highest turbidity value (NDTI of 0.23) but the lowest TSS concentration (23.49 mg/L), suggesting the presence of fine particles that increase light scattering without contributing significantly to sediment mass. Point 4 indicated slightly degraded water quality, with an NDTI of 0.18 and TSS of 26.98 mg/L, reflecting moderate and consistent sedimentation. Finally, point 5 had the lowest turbidity (NDTI of 0.16) and a TSS level of 24.96 mg/L, indicative of relatively clearer water with minimal suspended solids. These variations highlight the influence of local environmental factors such as upstream water flow, proximity to pollutant sources, and the nature of suspended particulates affecting turbidity readings.

These findings highlight the spatial variability of water quality across Jakarta Bay, influenced by a combination of hydrological inputs, land use patterns, and proximity to pollutant sources. The integrated analysis of NDTI and TSS enhances the precision of remote sensing-based monitoring and supports more targeted environmental management efforts. By recalibrating and interpreting satellite-derived data through a customized processing workflow, this study offers a clearer understanding of sediment dynamics and turbidity distribution within the coastal transition zone. These insights provide valuable guidance for future mitigation and conservation strategies.

4. Discussion

The results from processing Sentinel-2 imagery through Google Earth Engine (GEE) offer a detailed analysis of water quality variations in Jakarta Bay, revealing significant spatial heterogeneity in turbidity and sediment concentration. Initially, the default binary visualization of the Normalized Difference Turbidity Index (NDTI) and Total Suspended Solids (TSS) did not adequately capture the complex variations in water quality, limiting interpretability. To address this, a custom recalibration and rescaling process was applied, enabling a more accurate representation of spatial differences in water quality. The refined results from December 2024 showed marked variability across five observation points. Point 1, located near areas of intense human activity and strong upstream discharge, exhibited the highest turbidity and TSS levels, indicating a large presence of suspended particles. Conversely, point 3 recorded the highest NDTI but the lowest TSS, suggesting clearer water with fine particulates that scatter light without contributing heavily to sediment mass. These findings underscore the influence of local environmental factors including pollutant sources, hydrological conditions, and particle size on the distribution of suspended solids and turbidity within the bay. This analysis demonstrates the value of advanced remote sensing techniques combined with customized data processing in improving the accuracy of water quality assessments. The insights gained provide a foundation for informed environmental management and conservation efforts in coastal regions. By emphasizing spatial variability, the study highlights the need for localized water quality management strategies to support targeted actions aimed at reducing sedimentation and enhancing water clarity in Jakarta Bay.

5. Conclusions

This study highlights notable spatial variability in water quality across five observation points in Jakarta Bay, driven by hydrological conditions, land use, and proximity to pollution sources. The combined analysis of NDTI and TSS identifies areas with elevated turbidity and sediment loads, such as Point 1, as well as zones with relatively clearer water, like

Point 5. The distinctive case of Point 3, exhibiting high turbidity alongside low suspended solids, illustrates the significant impact of fine particulates on the optical properties of water. These findings underscore the effectiveness of satellite-derived indicators for comprehensive and cost-efficient water quality monitoring. Ultimately, the insights gained offer a strong scientific basis for developing targeted environmental management strategies and guiding future mitigation efforts.

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