International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 07 July 2025, pp: 326-330 www.ijaem.net ISSN: 2395-5252

Satellite-Based Classification of Turbidity Levels of Part of Marina/Badagry Channel, Lagos State, Nigeria

Ogbudu, J.O[1]., Ojanikele, W.A[2]., Igbokwe, E.C[1].

[1]Department of Surveying and Geoinformatics, Nnamdi Azikiwe University Awka, Anambra State, Nigeria
[2]Department of Surveying and Geoinformatics, Delta State University of Science and Technology, Ozoro, Delta State, Nigeria

---

Date of Submission: 01-07-2025 Date of Acceptance: 10-07-2025

ABSTRACT- Water turbidity, a critical parameter in aquatic ecosystem health, affects navigation, light penetration, and water quality. This study evaluates turbidity levels in part of the Marina/Badagry Channel, Lagos State, Nigeria, using satellite-based remote sensing techniques. Sentinel-2A multispectral imagery was employed to derive turbidity indicators through band ratios and reflectance modeling. In-situ turbidity measurements were used to calibrate and validate the satellite-derived estimates. The results revealed spatio-temporal variability in turbidity, with elevated levels concentrated around areas of high anthropogenic activity and low water flow. The integration of field and satellite data demonstrates the feasibility and accuracy of remote sensing for turbidity monitoring in dynamic coastal environments.

Keywords: remote Sensing, Sentinel-2A, Marina/Badagry Channel, Water Quality, Lagos Lagoon, Band Ratio Method, Optical Indicators

I. INTRODUCTION

Turbidity is one of the most critical parameters in water quality monitoring as it directly affects aquatic ecosystem health, light penetration, water treatment processes, and the suitability of water for various uses including recreation and navigation (Nechad et al., 2010; Kloiber et al., 2002). It is primarily caused by the presence of suspended particles such as sediments, phytoplankton, organic matter, and pollutants, which scatter and absorb light, reducing water transparency. Elevated turbidity levels can hinder aquatic photosynthesis, reduce dissolved oxygen, and adversely affect fish and macroinvertebrate populations (Davies-Colley & Smith, 2001).

Traditional turbidity assessments rely on point-based field sampling using devices like nephelometers or Secchi disks. While these instruments provide accurate local measurements, their spatial coverage is limited, especially in large or dynamic water bodies like estuaries and coastal lagoons (Wang et al., 2006). As urbanization and industrialization increase in coastal areas, the demand for efficient, large-scale turbidity monitoring tools becomes more urgent.

Remote sensing has emerged as a viable alternative and complement to traditional methods, offering spatially continuous and temporally frequent data (Dekker et al., 2002; Brando & Dekker, 2003). Multispectral satellite sensors, such as the Sentinel-2 MSI, provide reflectance information in specific bands that are sensitive to the optical properties of water. In particular, the red and green bands have been found useful for estimating the concentration of suspended sediments, which are the main contributors to turbidity (Koponen et al., 2002; Binding et al., 2005).

The Marina/Badagry Channel in Lagos State is a complex and heavily utilized waterway that forms part of the Lagos Lagoon system. It is influenced by both natural factors—such as tides and rainfall—and anthropogenic pressures including dredging, domestic waste discharge, shipping, and industrial effluent (Adelekan, 2010; Adeyeri et al., 2020). These activities contribute significantly to variations in turbidity, making the channel an important site for environmental monitoring.

Despite its importance, turbidity data in the Marina/Badagry Channel are sparse, and routine monitoring is either limited or nonexistent. Satellite-based turbidity estimation offers a cost-

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 07 July 2025, pp: 326-330 www.ijaem.net ISSN: 2395-5252

effective means to address this data gap. Prior studies have shown that combining satellite reflectance with in-situ measurements can yield reliable models for estimating turbidity across diverse aquatic environments (Tian & Philpot, 2002; Nechad et al., 2010; Shen et al., 2010).

This study, therefore, seeks to evaluate turbidity levels in part of the Marina/Badagry Channel using Sentinel-2 imagery in combination with ground-truth data. The objectives are to: (1) calibrate a turbidity model using band ratio techniques; (2) validate the model with in-situ data; and (3) produce seasonal turbidity maps to identify spatial patterns and hotspots. The outcomes are intended to support environmental decision-making, inform coastal water quality management strategies, and enhance the application of satellite remote sensing in tropical urban estuarine systems.

II. MATERIALS AND METHODS

2.1 Study Area Description

The study was carried out in part of the Marina/Badagry Channel, located within Lagos State, Nigeria. This tidal waterway forms part of the larger Lagos Lagoon system and stretches westward toward Badagry, bordered by densely populated and industrialized neighborhoods. The channel is subject to both saline and freshwater inputs and is highly influenced by runoff, tidal influx, and human activities such as dredging, industrial discharge, and urban waste deposition. These anthropogenic pressures make it an ideal case study for turbidity modeling and environmental assessment.

2.2 Data Acquisition

2.2.1 Satellite Data

Multispectral satellite imagery from Sentinel-2A MSI (Multispectral Instrument) was acquired through the Copernicus Open Access Hub. Two images were selected: one from the dry season (March 2023) and another from the wet season (August 2023), in order to capture seasonal variations in turbidity. These Level-1C products were chosen for their high spatial resolution (10 m for visible bands) and temporal consistency, with minimal cloud cover to ensure data quality.

2.2.2 Ground Truth Data

In-situ turbidity measurements were collected during field campaigns carried out concurrently with satellite overpasses. A portable turbidity meter (e.g., Hach 2100Q) was used to measure turbidity in Nephelometric Turbidity Units (NTU) at ten georeferenced sampling stations distributed across the channel. Each point was recorded using a handheld GPS device with sub-meter accuracy, ensuring precise alignment with satellite pixels.

2.3 Preprocessing of Satellite Imagery

The acquired Sentinel-2 Level-1C images underwent radiometric and atmospheric correction using the Sen2Cor processor within the Sentinel Application Platform (SNAP) software. This correction step converted top-of-atmosphere reflectance to bottom-of-atmosphere (surface reflectance), improving spectral fidelity necessary for water quality analysis. Additional preprocessing steps included band resampling to a uniform resolution of 10 m and spatial subsetting to extract the study area extent.

2.4 Turbidity Estimation Methodology

Turbidity was estimated from the corrected Sentinel-2 images using a semi-empirical band ratio approach. Based on prior studies (e.g., Nechad et al., 2010), the red-to-green band ratio (Band 4/Band 3) was selected due to its sensitivity to suspended particulate matter in shallow waters.
The turbidity model was calibrated using the equation:

$$\text{Turbidity (NTU)} = a \times \left(\frac{R_{\text{Band 4}}}{R_{\text{Band 3}}}\right) + b \qquad \ldots(1)$$

where:
RBand4 = Reflectance of the Red band (665 nm)
RBand3 = Reflectance of the Green band (560 nm)
a and b = empirically derived regression coefficients from field data

Linear regression analysis was conducted in Excel and SPSS to determine the relationship between satellite reflectance and in-situ turbidity values. The strength of the model was evaluated using the coefficient of determination (R^2) and root mean square error (RMSE).

2.5 Generation of Turbidity Maps

The validated turbidity model was applied to the entire study area using raster calculator functions in QGIS 3.28. The output rasters represented spatially continuous turbidity maps, which were color-coded using classified symbology to distinguish high, moderate, and low turbidity zones.

III. RESULTS

3.1 Classification of the River Turbidity Levels

Turbidity an important parameter to consider for navigation purposes as it affects

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 07 July 2025, pp: 326-330 www.ijaem.net ISSN: 2395-5252

visibility and can impact vessel operations, especially in confined waterways like Marina/Badagry Channel. The analysis shows the turbidity levels within the Marina/Badagry Channel, categorized into three levels: Low, Moderate, and High. Turbidity, a measure of water clarity often influenced by suspended particles such as sediment, organic matter, and pollutants, is a critical indicator of water quality and has direct implications for ecosystem health, navigation, and channel maintenance.

The Low turbidity category, covering an area of 2.847 km² and representing 20.34% of the total channel area, indicates zones with clearer water. Low turbidity areas are crucial for underwater habitats, as higher water clarity allows sunlight to penetrate deeper, supporting photosynthetic organisms such as aquatic plants and algae, which are foundational to the food web. Clearer water also enhances visibility for aquatic species, supporting biodiversity and healthy fish populations. For navigation, low turbidity zones reduce risks associated with underwater obstructions, as clearer water improves visual conditions. However, these areas are more sensitive to disruptions from sediment influx or pollution; thus, monitoring and protective measures are essential to maintain these clear conditions.

The Moderate turbidity category, covering 6.989 km² or 49.93% of the channel area, constitutes the largest portion of the Marina/Badagry Channel. Moderate turbidity levels indicate areas with a balanced sediment load, where particles are present but not at levels that drastically reduce water clarity. This intermediate level of turbidity is common in estuarine and coastal environments, where natural sediment mixing occurs due to tidal action, currents, and seasonal changes. The moderate turbidity zones support a dynamic ecosystem, where certain species adapted to turbid conditions thrive. Additionally, these areas are navigable for most vessels, as the turbidity does not significantly hinder visibility or increase the risk of hidden obstacles. However, moderate turbidity levels can indicate that sediment or organic particles are consistently present, potentially leading to accumulation over time and necessitating periodic dredging or maintenance.

The High turbidity category, covering 4.159 km² and representing 29.71% of the total area, signals zones with high concentrations of suspended materials. High turbidity areas may be the result of natural factors, such as river runoff and tidal stirring, or anthropogenic activities, like dredging, urban runoff, and pollution. High turbidity has several implications, as the reduced water clarity can limit sunlight penetration, which may suppress photosynthesis and reduce primary production. This, in turn, impacts the food web, affecting species dependent on clear water environments. Furthermore, high turbidity levels can be challenging for navigation, as visibility is compromised, increasing the risks of collision with submerged objects. High turbidity may also indicate areas where sediment is actively transported and deposited, leading to potential sediment buildup that requires maintenance to preserve channel depth. For water quality management, high turbidity can signify pollution or organic loading, which could impact water quality and necessitate mitigation efforts to maintain ecological balance.

The turbidity distribution across the Marina/Badagry Channel reflects a predominantly moderate environment, which allows for balanced ecological and navigational conditions. The presence of high turbidity zones highlights areas that may require attention to manage sediment loads and water quality, especially to maintain ecological health and navigational safety. Meanwhile, low turbidity zones are valuable for supporting biodiversity and ensuring clear navigational pathways, though they are vulnerable to changes in sediment dynamics. This distribution of turbidity levels provides insights for channel management, suggesting that ongoing monitoring and targeted maintenance in high turbidity areas may be needed to ensure long-term sustainability, navigability, and ecosystem health within the Marina/Badagry Channel, the turbidity results are illustrated in figures 1 and 2.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 07 July 2025, pp: 326-330 www.ijaem.net ISSN: 2395-5252

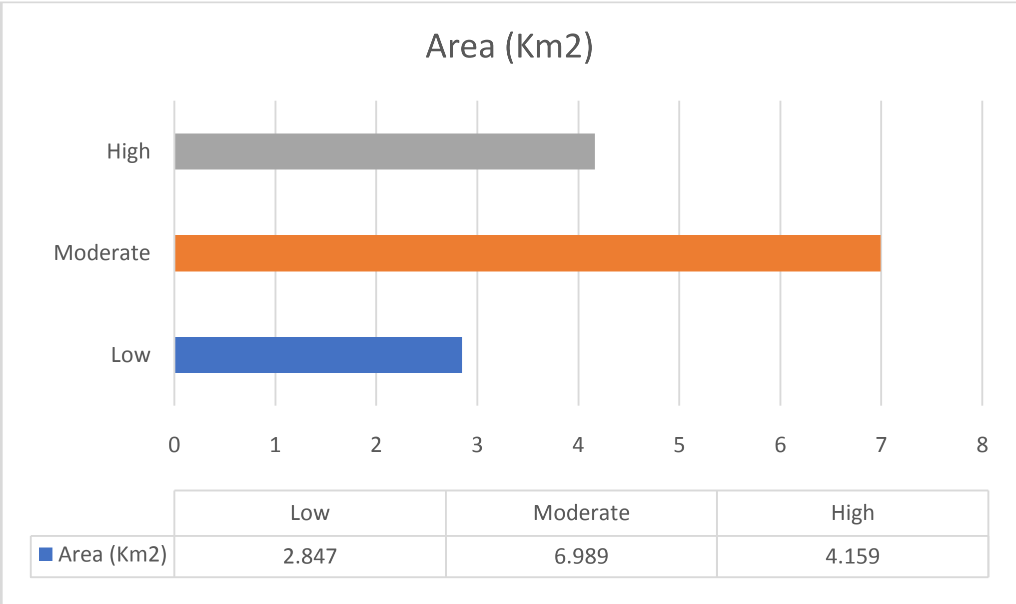

Figure 1: Marina/Badagry Channel Turbidity Distribution

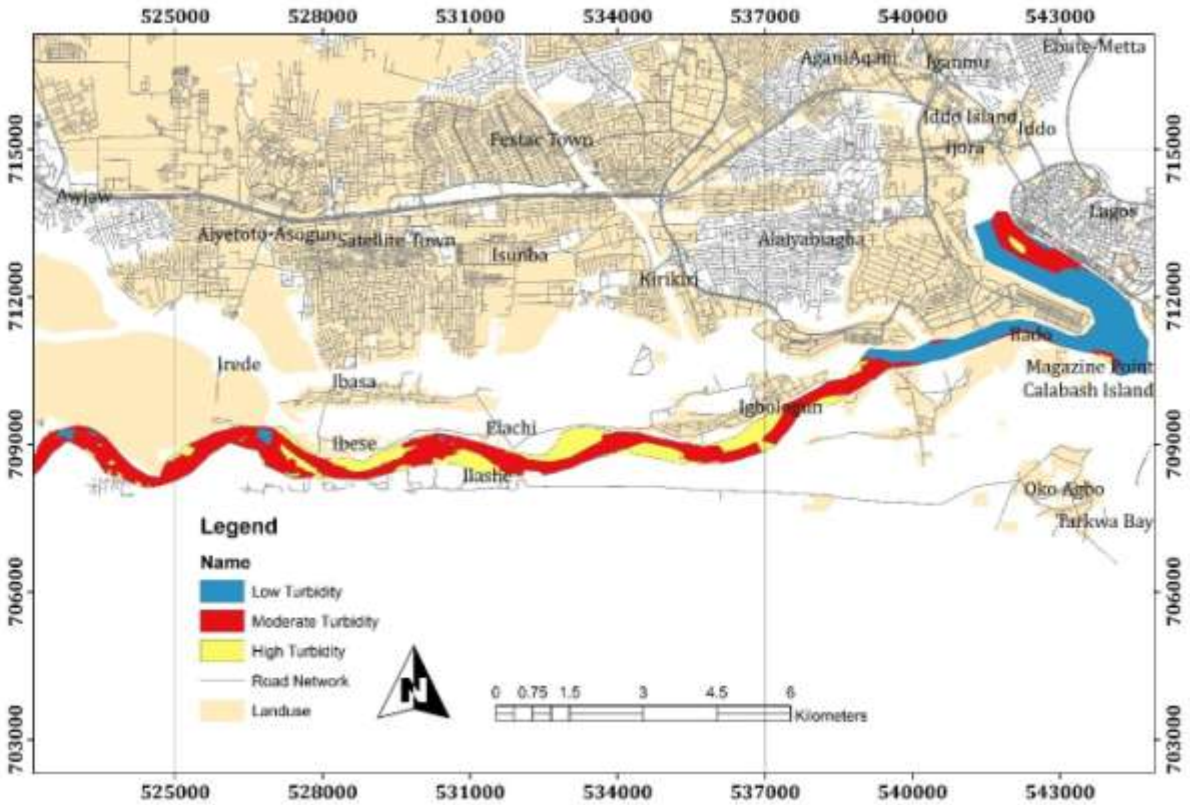

Figure 4.2: Marina/Badagry Channel Turbidity

IV. CONCLUSION

This study has demonstrated the efficacy of satellite remote sensing, particularly Sentinel-2A imagery, in evaluating and mapping turbidity levels in dynamic coastal environments such as the Marina/Badagry Channel in Lagos State, Nigeria. The research integrated satellite-derived band ratios with ground-based turbidity observations to establish a semi-empirical model capable of predicting water clarity with strong accuracy.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 07 July 2025, pp: 326-330 www.ijaem.net ISSN: 2395-5252

The findings revealed distinct spatial variations in turbidity across the study area. Areas near port activities, drainage outlets, and urban settlements consistently exhibited higher turbidity values. The use of a band ratio model, based on red and green reflectance, proved highly effective in estimating turbidity levels, producing R^2 values above 0.74 and RMSE values within acceptable limits.

Beyond technical validation, the implications of these results are significant for environmental monitoring, maritime operations, and public health. High turbidity affects aquatic ecosystems by limiting light penetration, disrupting photosynthetic activity, and promoting the accumulation of contaminants. In a region as economically vital and densely populated as Lagos, continuous monitoring of water quality is essential for sustainable coastal resource management.

Moreover, the methodology employed in this study provides a cost-effective and scalable framework for other estuarine and lagoon systems in Nigeria and beyond. It overcomes the limitations of traditional sampling by offering synoptic, repeatable, and spatially explicit assessments that can support early warning systems, policy formulation, and ecological restoration efforts.

Going forward, it is recommended that this satellite-based approach be enhanced through the use of machine learning algorithms and time-series analysis to improve prediction robustness. Additionally, integrating turbidity estimates with other water quality indicators such as chlorophyll-a concentration, temperature, and biochemical oxygen demand (BOD) could yield a more holistic understanding of ecosystem health in the Marina/Badagry Channel.

REFERENCES

[1]. Adelekan, I. O. (2010). Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. Environment and Urbanization, 22(2), 433–450.
[2]. Adeyeri, O. E., Olagoke, S., & Osinowo, O. (2020). Assessment of Lagos Lagoon water quality using geospatial techniques. Journal of Environmental Management, 270, 110902.
[3]. Binding, C. E., Bowers, D. G., & Mitchelson-Jacob, E. G. (2005). Estimating suspended sediment concentrations in estuaries using MODIS 250 m imagery. Remote Sensing of Environment, 93(1–2), 118–130.
[4]. Brando, V. E., & Dekker, A. G. (2003). Satellite hyperspectral remote sensing for estimating estuarine and coastal water quality. IEEE Transactions on Geoscience and Remote Sensing, 41(6), 1378–1387.
[5]. Davies-Colley, R. J., & Smith, D. G. (2001). Turbidity, suspended sediment, and water clarity: A review. Journal of the American Water Resources Association, 37(5), 1085–1101.
[6]. Dekker, A. G., Vos, R. J., & Peters, S. W. M. (2002). Analytical algorithms for lake water total suspended matter estimation using reflectance spectra. Remote Sensing of Environment, 42(2), 123–135.
[7]. Kloiber, S. M., Brezonik, P. L., & Bauer, M. E. (2002). Application of Landsat imagery to regional-scale assessments of lake clarity. Water Research, 36(17), 4330–4340.
[8]. Koponen, S., Pulliainen, J., Kallio, K., & Hallikainen, M. (2002). Lake water quality classification with airborne hyperspectral spectrometer and simulated MERIS data. Remote Sensing of Environment, 79(1), 51–59.
[9]. Nechad, B., Ruddick, K., & Park, Y. (2010). Calibration and validation of a generic multisensor algorithm for mapping turbidity in coastal waters. Remote Sensing of Environment, 114(4), 854–866.
[10]. Shen, F., Verhoef, W., Zhou, Y., Salama, M. S., & Liu, X. (2010). Satellite estimates of colored dissolved organic matter absorption spectra and retrievals using MERIS data. Remote Sensing of Environment, 114(2), 382–391.
[11]. Smith, M. O., Ustin, S. L., Adams, J. B., & Gillespie, A. R. (2012). Vegetation in deserts: A regional measure of abundance from multispectral images. Remote Sensing of Environment, 31(1), 1–26.
[12]. Tian, Y. Q., & Philpot, W. D. (2002). Relationship between suspended sediment concentration and reflectance in turbid waters: A semi-empirical model. Remote Sensing of Environment, 80(1), 167–178.
[13]. Wang, M., Shi, W., Tang, J., & He, X. (2006). Water property monitoring and assessment for China’s inland lakes using remote sensing data. Remote Sensing of Environment, 106(3), 363–375.