Variability of Total Suspended Solid Using Medium Resolution Imagery (Landsat 8 OLI) in Coastal Waters of Banyuasin Regency, South Sumatera Province

Andi Agussalim[1], Sigit Heru Murti BS[2], Langgeng Wahyu Santosa[3]

{andiagussalim@gmail.com[1,2], sigit.heru.m@ugm.ac.id[3]*, langgeng.sains@ugm.ac.id[4]}

Geography Doctoral Program, Faculty of Geography, Gadjah Mada University, Yogyakarta, Indonesia[1]
Faculty of Geography, Gadjah Mada University,Yogyakarta, Indonesia[3,4]
Department of Marine Science, FMIPA, University of Sriwijaya, Palembang, Indonesia[2]
*Corresponding author: sigit.heru.m@ugm.ac.id

Abstract. Total suspended solids (TSS) are an important biogeochemical parameter for water quality monitoring and determining potential fishing grounds habitat. Elevated TSS concentrations can inhibit the growth of producer organisms, and are considered harmful to fish. Therefore, the temporal and spatial change of suspended sediment concentration is an important issue in coastal and seawater research. This study aims to analyze and map the spatio-temporal distribution of TSS in coastal water of Banyuasin from Landsat 8 OLI. The remote sensing method was used in this study. The results showed that the distribution of TSS was spatio-temporally different in the study area. TSS in transitional season II is 132.76 mg/l - 446.33 mg/l, in the west season, it ranges from 67.732 mg/l to 375.64 mg/l; in transitional season I, it ranges from 33.41 mg/l to 235.16 mg/l; and in the east season, it ranges from 97.73 mg/l to 297 mg/l.

Keywords: Total suspended solids (TSS), medium resolution imagery, coastal waters.

1 Introduction

The coastal waters of Banyuasin are directly connected to the sea waters of the Bangka Strait. Banyuasin coastal waters include shallow sea waters, which are one of the most important aquatic ecosystems and have provided many benefits, including providing habitat for various kinds of organisms, including fish, which are important resources in the fisheries sector. Hence, these waters have become the center of fishing activities in South Sumatera Province due to their high potential and diversity of fishing resources (1,2). The continued suitability of aquatic habitats for aquatic life depends heavily on the quality of the water (3). Therefore, water quality plays a key role in determining water habitat health, fish species survival, and water productivity. One parameter that can affect water quality is total suspended solids (TSS) (4,5**.** Clear waters are essential, as all photosynthetic organisms require light for growth but can become turbid due to the presence of TSS (6).

SICBAS 2023, November 03, Palembang, Indonesia

DOI 10.4108/eai.3-11-2023.2347972

TSS refers to the mass (mg) or concentration (mg/l) of inorganic and organic material floating in the water column (7). TSS is mostly caused by soil erosion that is carried into water bodies (8,9). High TSS conditions can have a serious impact on aquatic ecosystems. Increased TSS can have significant negative impacts, including decreased water quality or the occurrence of water pollution, reduced penetration of light into waters, damage to aquatic habitats, and a decrease in fisheries resources and biodiversity in aquatic ecosystems (10,11). Suspended particles, both organic and inorganic, and dissolved organic matter play a role in controlling the penetration of light into the water column so that it can inhibit the primary productivity of water (12). The decrease in light reaching the underwater layer can, in turn, inhibit the growth of phytoplankton, which is the primary food source for various organisms in the aquatic food chain. It can affect the abundance and variation of fish species distribution and environmental conditions around fishing grounds. Moreover, suspensive particles in the waters can cause damage to underwater habitats, such as coral reefs and oak fields, which are breeding grounds and shelters for various types of fish.

Considering the vital role of TSS in the water system, it is necessary to monitor its concentration dynamics periodically, both spatially and temporally. Conventional methods through direct field measurements (in situ) can only show values at the measurement point, which is limited in terms of spatial coverage and inconsistent temporal data. Although the field observation method produces accurate measurements, it is time-consuming and costly. Therefore, measurements using remote sensing technology are highly needed. This method has been widely used for observing the spatial characteristics of water bodies (13). Remote sensing technology can help overcome some of the limitations of conventional observation, one of which is limited space and time coverage (14). Remote sensing technology is a technology for recording the earth's surface, including waters, that can cover large areas and be performed repeatedly (in real time) (15), thus becoming an effective and efficient tool for monitoring water quality by spasiotemporal. Landsat 8 OLI is a medium-resolution remote sensing satellite. Using the images of Landsat 8 OLI with better spatial resolution provides the potential to obtain more detailed and accurate images for the study of coastal water dynamics. Blue, green, and red bands are bands that can be used and are sensitive to the concentration of suspended solid (16). A number of studies have explored the potential of Landsat 8 remote sensing data in particular for estimating TSS concentrations with a good accuracy rate (17,18,19,20,21). The study aims to analyze and map the spatio-temporal variability of TSS concentrations in Banyuasin coastal waters. Understanding the dynamics of TSS variability is crucial in evaluating its impact on water quality and fisheries. It can provide basic information for designing coastal water management strategies more effectively, restoring ecosystems, and preserving the quality of aquatic habitats, which in turn will support the balance of the aquatic ecosystem and sustainable fisheries productivity.

2 Method of research

The method used in this study is remote sensing method. The use of Landsat 8 images will involve spectral analysis to extract TSS information. This approach allows the identification of patterns of distribution in areas with high and low TSS concentrations in more detail, both spatially and temporarily. The results are compared to the research that has been conducted, especially in the field of study.

2.1 Study area

The research site is situated in the coastal waters of Banyuasin Regency (Figure 1), which has a marine area of 1,765.4 km2 and a coastline that stretches for +274 km (22). Banyuasin Regency's coastal waters are influenced by two distinct water masses: the waters of the South China Sea to the north and the waters of the Java Sea to the east, and the tides have an impact on the dynamics of these waters. A number of major rivers, including the Sembilang, Banyuasin, Musi, Upang, Salek, and Sugihan rivers, as well as smaller ones, supply material suspension from the land to coastal waters and the sea via runoff.

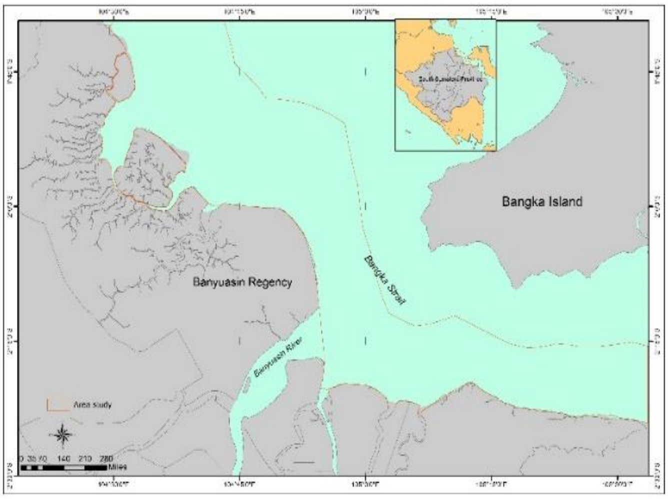

Fig. 1. Map of study area.

2.1 Data analysis

Image correction. The study utilized Landsat OLI images that were obtained on September 19, 2019, December 30, 2019, April 20, 2020, and July 20, 2020. The Landsat 8 OLI data is downloaded from https://earthexplorer.usgs.gov/ website. Image correction, which consists of both geometric and radiometric correction, is done first before any additional image processing. The goal of both types of correction is to enhance the image quality so that the image to be used provides geometrically and radiometrically accurate information, while also improving the spectral quality of the recording results and the accuracy of the object's position. The image geometry correction was done using the Banyuasin Regency RBI map at a scale of 1:50,000, while the radiometric correction is done using a formula contained in the user manual data 8 v-5.0. The digital value of the Landsat 8 image was first converted to the reflectance value (without correcting the sun angle) using the equation 1:

$$\rho'_{\lambda} = M\rho * Q_{cal} + A_{\rho} \qquad (1)$$

where:
$\boldsymbol{\rho'_\lambda}$ = TOA spectral reflectance (W/(m2 * sr * um)).
Mρ=Multiplicative reflectance scale factor of each channel (Reflectanc_Mult_Band_N) from metadata
Qcal = Image pixel value in the form of Digital Number (DN).
Aρ = Additive radiance scale factor of each channel (Radiance_Add_Band_n)

The following calculation is to find the reflectance value of the TOA performed divided by the sun angle according to formula 2:

$$\rho_\lambda = \frac{\rho'_\lambda}{\mathrm{Cos}(\theta_{SZ})} = \frac{\rho'_\lambda}{\sin(\theta_{SE})} \qquad (2)$$

where:
Pλ = TOA spectral reflectance corrected sun angle
$\boldsymbol{\rho'_\lambda}$ = TOA spectral reflectance uncorrected sun angle
θ_{SE} = Sun elevation angle, available in the image metadata
θ_{SZ} = Solar zenith angle; $\theta_{SZ} = 90^{O} - \theta_{SE}$

Atmospheric correction is necessary in satellite remote sensing because at visible wavelengths received by satellites, the reflections are affected by gas particles and aerosols in the atmosphere. The atmospheric correction in this study used ACOLITE (version 20170718.0). ACOLITE software is designed for atmospheric correction in marine and inland waters. Application of ACOLITE processor effectively improves atmospheric correction in highly turbid waters (23), and supports Sentinel 2 and Landsat 8 image correction (24).

Masking. Masking aims to separate land and ocean objects. Only sea waters area that will be processed further. The masking process is done using the NDWI (Normalized Difference Water Index) index, which is an algorithm for separating water and land pixels by creating a water value index that is derived using green and NIR bands (25,26). The NDWI index has been widely used to delineate water objects from satellite images (27). The NDWI index has values ranging from -1 to 1(28). In Landsat 8, the reflectance values of band 3 and band 5 are used to calculate the NDWI using equation (3):

$$\mathrm{NDWI} = \frac{\mathrm{RrsBand\ 3} - \mathrm{RrsBand\ 5}}{\mathrm{RrsBand\ 3} + \mathrm{RrsBand\ 5}} \qquad (3)$$

Determining the concentration of total suspended solids. Budiman's algorithm is the one that was utilized to extract the total suspended solids content. The red band from Landsat 8 OLI are used in this algorithm. Budiman's algorithm equation (29) based on formula (4) as follows:

$$\mathrm{TSS} = (8.1429 * (\mathrm{Exp}^{(23.704*0.94*\mathit{Red\ Band}\ )}) \tag{4}$$

Where:
TSS = Total suspended solids (mg/l)
Red Band = Reflectance value of band 4

3 Results and discussion

Based on the analysis results of Landsat 8 OLI imagery, there are differences in the concentration of TSS in Banyuasin coastal waters in each season, both spatially and temporally.The concentrations of TSS for each consecutive season is as follows: the transitional season II ranges from 132.76 mg/l to 446.33 mg/L, the western season from 67.73 mg/l to 375.62 mg/L, the transitional season I from 33.41 mg/l to 235.16 mg/L, and the eastern season from 97.73 mg/l to 297.17 mg/L. The lowest and highest TSS concentration values for each season are presented in Table 1, while their distribution is presented in Figures 2, 3, 4, and 5, respectively. The color difference indicates the distribution of the range of TSS concentration values. The closer the dark blue color, the lower the distribution of TSS concentration values.

Table 1. The lowest and highest TSS concentration values for each season

Periods	Lowest value of TSS concentration (mg/l)	Highest value of TSS concentration (mg/l)
Transitional season II	132.76	446.33
Western season	67.73	375.62
Transitional season I	33.41	235.16
Eastern season	97.73	297.17

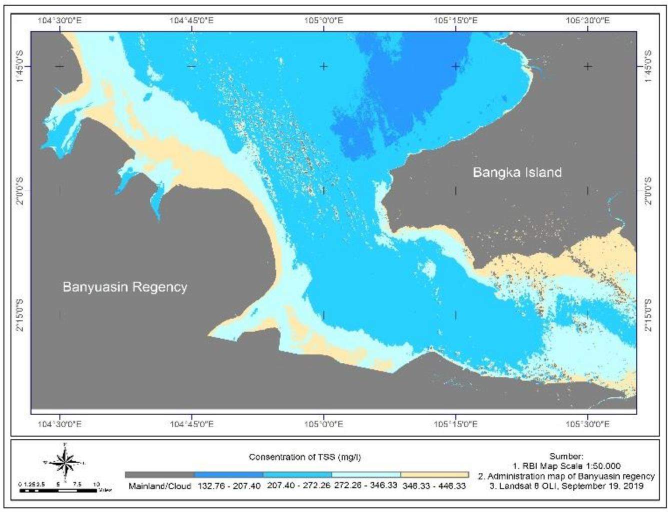

Fig. 2. Distribution pattern of total suspended solid in Banyuasin sea waters in the second transitional season.

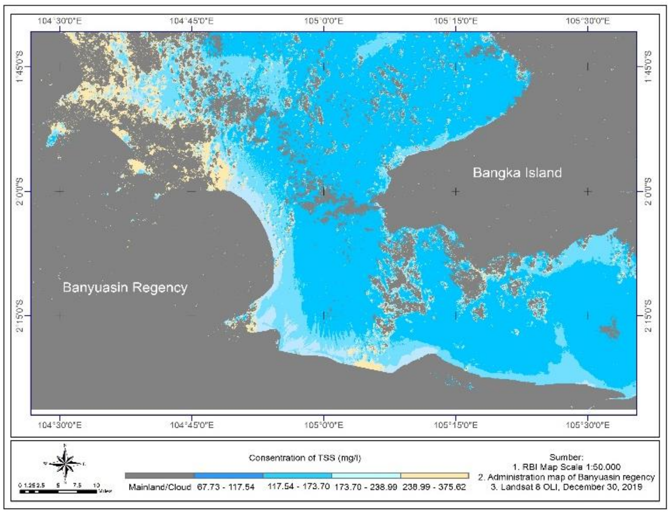

Fig. 3. Distribution pattern of total suspended solid in Banyuasin sea waters in the west season.

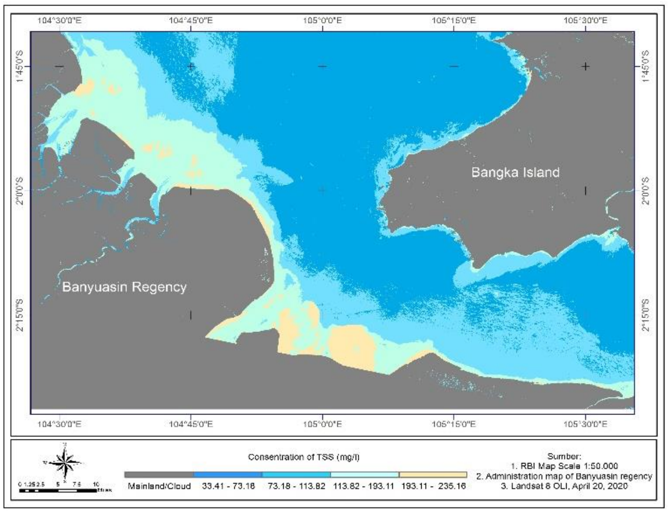

Fig. 4. Distribution pattern of total suspended solid in Banyuasin sea waters in the first transitional season.

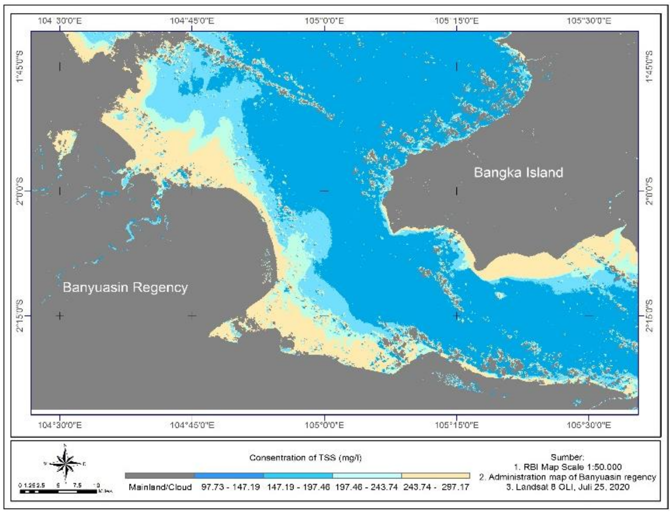

Fig. 5. Distribution pattern of total suspended solid in Banyuasin sea waters in the East season.

Based on the generated map, each season has a different concentration distribution. When compared with TSS concentrations in other seasons, transitional II and west seasons have higher TSS levels compared to transitional I and east seasons. The highest concentrations of TSS were found at 446.33 mg/L (transitional season II) and 375.62 mg/L in the west season. The dominant and smallest TSS spatial distribution is also different for each season. During transitional season II, the dominant TSS spatial spread was in the TSS range of 207.40 mg/l–272.26 mg/l and the range with the lowest spatial spread (132.79 mg/l–207.40 mg/L) (Figure 2). In the west season, the dominant concentration distribution ranged from 67.73 mg/l to 117.54 mg/l, and the smallest distribution from 173.70 mg/l to 238.99 mg/l (Figure 3). Whereas at transition I, the dominant TSS concentration range is in the TSS spread range from 73.18 mg/l to 113.82 mg/L, and the smaller spread is from 193.11 mg/l to 235.16 mg/L (Figure 4). In the eastern season, the prevalence of TSS is 97.73 mg/l to 147.19 mg/l, with the least spread being from 197.48 mg/liter to 243.74 mg/liter (Figure 5).

In general, higher TSS concentrations can be found near the coast, especially near river mouths, and TSS concentrations gradually decrease towards the sea, and this decrease can be seen along the coast of Banyuasin. The high concentration of TSS near the coast (coastal waters) as a result of the high supplay of coming from land through river runoff along the coastal area of the Banyuasin district. Whereas in the second transitional season, the TSS concentration is higher than the other seasons because the second transitional season is the season entering the rainy season, where rainfall is higher, so that it provides a greater input of sediment particles from the land channeled through rivers to estuarine and marine waters. River inflow is a major source of terrigenous material supplied to marine sedimentary basins (30). According to (31) that during the rainy season, the presence of river runoff can carry anthropogenic organic compounds into the waters resulting in TSS concentrations.The eastern season and transitional season I are often identified with the dry season. During this season, TSS concentrations are also lower compared to the transition II and western season (wet season), due to lower rainfall compared to the western season. The distribution of TSS concentration tends to be lower in offshore areas because offshore areas do not get their particle of sediment supply from land. High rainfall can cause large-scale soil erosion which increases the amount of suspended solid matter that enters the river body and discharges it to the rivers, coastal waters and seas. TSS concentration shows significant variation in different seasons, and rainfall variation is one of the causes (32), and its concentration decreases from the coast towards the sea (33). Research by (34) in the coastal waters of Surabaya also found that the TSS distribution pattern in the west season showed high concentrations spread over the coastal area to the offshore, while the TSS distribution pattern in the east season only showed high concentrations in the coastal area, and the distribution pattern was strongly influenced by the season. Various dynamic factors such as river discharge, rainfall, and coastal processes are causative attributes in the distribution of SSC in coastal areas (35). Besides rainfall, according to (36) another factor that can cause differences in water TSS concentrations is that currents and waves are strong enough to cause sediment resuspension.

3 Conclusion

From the results, it can be concluded that Landsat 8 OLI imagery can be used to clearly identify the spatial and temporal distribution of TSS in coastal waters.The distribution of TSS in the coastal waters of banyuasin is higher in the second transitional season and western season compared to the first transitional season and eastern season strongly influenced by the season. The spatial distribution of TSS is higher in the nearshore area and decreases towards the sea.

Acknowledgments. This research was supported by RTA Program of Gadjah Mada University with the Grant Number 5075/UN.1.P.II/Dit.-Lit/PT.01.01/2023.

References

1. Fauziyah, Nurhayati, Bernas SM, Putera A, Suteja Y, Agustiani F. Biodiversity of fish resources in Sungsang Estuaries of South Sumatra. IOP Conf Ser Earth Environ Sci. 2019;278(1):1–12.
2. Fauziyah ., Aprilita AM, Putri WAE, Ningsih EN, Purwiyanto AIS, Agustriani F. Using the hydroacoustic and mini trawl data for estimating fish density in the eastern part of Banyuasin coastal waters, South Sumatra of Indonesia. J Fish. 2022;10(2):1–7.
3. Hamuna B, Tanjung RHR, Suwito S, Maury HK, Alianto A. Assessment of Seawater Quality and Pollution Index Based on Physics-Chemical Parameters in Depapre District Waters, Jayapura. J Ilmu Lingkung. 2018;16(1):35–43.
4. Bright CE, Horton SL, Mager SM. Clarifying the waters : the use of turbidity for suspended sediment monitoring in New Zealand. 2020;59(2):83–99.
5. Masoud AA. On the Retrieval of the Water Quality Parameters from Sentinel-3/2 and Landsat-8 OLI in the Nile Delta's Coastal and Inland Waters. Water (Switzerland). 2022;14(4):2–25.
6. Prior EM, O'donnell FC, Brodbeck C, Donald WN, Runion GB, Shepherd SL. Measuring high levels of total suspended solids and turbidity using small unoccupied aerial systems (Suas) multispectral imagery. Drones. 2020;4(54):1–15.
7. Bilotta GS, Brazier RE. Understanding the influence of suspended solids on water quality and aquatic biota. Water Res. 2008;42(12):2849–2861.
8. Parwati E, Purwanto AD. Time Series Analysis Of Total Suspended Solid (Tss) Using Landsat Data In Berau Coastal Area, Indonesia. Int J Remote Sens Earth Sci. 2017;14(1):61–70.

9. Sutari CAT, Van Der Perk M, Middelkoop H. Estimation of suspended sediment concentrations in the Rhine River using Landsat Satellite Images. IOP Conf Ser Earth Environ Sci. 2020;451(1):1–10.
10. Jiang D, Matsushita B, Pahlevan N, Gurlin D, Lehmann MK, Fichot CG, et al. Remotely estimating total suspended solids concentration in clear to extremely turbid waters using a novel semi-analytical method. Remote Sens Environ. 2021;258:1–18.
11. Chapman PM, Hayward A, Faithful J. Total Suspended Solids Effects on Freshwater Lake Biota Other than Fish. Bull Environ Contam Toxicol. 2017;99(4):423–427.
12. Braga F, Zaggia L, Bella D, Bresciani M, Giardino C, Lorenzetti G, et al. Mapping turbidity patterns in the Po river prodelta using multi-temporal Landsat 8 imagery. Estuar Coast Shelf Sci. 2017;198:555–567.
13. Grendaitė D, Stonevičius E. Machine Learning Algorithms for Biophysical Classification of Lithuanian Lakes Based on Remote Sensing Data. Water (Switzerland). 2022;14(11):1–18.
14. Choo J, Cherukuru N, Lehmann E, Paget M, Mujahid A, Martin P, et al. Spatial and temporal dynamics of suspended sediment concentrations in coastal waters of South China Sea, off Sarawak, Borneo: Ocean colour remote sensing observations and analysis. Biogeosciences Discuss. 2022;19(May):5837–5857.
15. Tu Q, Hao Z. Validation of Sea Surface Temperature Derived from Himawari-8 by JAXA. IEEE J Sel Top Appl Earth Obs Remote Sens. 2020;13:448–459.
16. Yin F, Yang G, Yan M, Xie Q. Application of multispectral remote sensing technology in water quality monitoring. Desalin Water Treat. 2019;149(May):363–369.
17. Wang C, Chen S, Li D, Wang D, Liu W, Yang J. A Landsat-based model for retrieving total suspended solids concentration of estuaries and coasts in China. Geosci Model Dev. 2017;10(12):4347–4365.
18. Emiyati, Manoppo AKS, Budhiman S. Estimation on the concentration of total suspended matter in Lombok Coastal using Landsat 8 OLI , Indonesia. IOP Conf Ser Earth Environ Sci. 2017;54:1-10
19. Nasiha HJ, Shanmugam P, Sundaravadivelu R. Estimation of sediment settling velocity in estuarine and coastal waters using optical remote sensing data. Adv Sp Res. 2019;63(11):3473–3488.
20. Annisa I, Supriatna S. Mapping chlorophyll-a and total suspended solid (TSS) distribution in the waters of Ciletuh Bay. IOP Conf Ser Earth Environ Sci. 2021;623(1):1–6.
21. Sa'ad FNA, Tahir MS, Haniza N, Jemily B, Ahmad A, Rahman A, et al. Applied Sciences Monitoring Total Suspended Sediment Concentration in Spatiotemporal Domain over Teluk Lipat Utilizing Landsat. 2021;11(7082):2–16.
22. Rosalina D. Strategy Analysis of Pelagic Fisheries Development in Banyuasin Regency, South Sumatra Province. J Kebijak Sos Ekon Kelaut dan Perikan. 2011;1(1):63–77.
23. Caballero I, Navarro G. Retrieval of suspended solids from Landsat-8 and Sentinel-2: A tool for coastal monitoring in extremely turbid waters. Int Geosci Remote Sens Symp. 2018;2018(July):7874–7877.
24. Vanhellemont Q, Ruddick K. Acolite for Sentinel-2: Aquatic applications of MSI imagery. Eur Sp Agency, (Special Publ ESA SP. 2016;SP-740(May):9–13.
25. McFeeters SK. The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features. Int J Remote Sens. 1996;17(7):1425–1432.
26. Jawak SD, Kulkarni K, Luis AJ. A Review on Extraction of Lakes from Remotely Sensed Optical Satellite Data with a Special Focus on Cryospheric Lakes. Adv Remote Sens. 2015;04(03):196–213.
27. Sheng Y, Song C, Wang J, Lyons EA, Knox BR, Cox JS, et al. Representative lake water extent mapping at continental scales using multi-temporal Landsat-8 imagery. Remote Sens Environ. 2016;185:129–141.
28. Bourouhou I, Salmoun F. Sea water quality monitoring using remote sensing techniques: a case study in Tangier-Ksar Sghir coastline. Environ Monit Assess. 2021;193(9):1–12.
29. Sukmono A. Monitoring of total suspended solid (TSS) in waduk gajah mungkur period 2013-

2017 using Landsat 8 satellite imagery. Ellipsoida. 2018;01(1):33–38.

30. Szymczak E, Burska D. Distribution of Suspended Sediment in the Gulf of Gdansk off the Vistula River mouth (Baltic Sea, Poland). IOP Conf Ser Earth Environ Sci. 2019;221(1):1–10.
31. Sun Q, Du Y, Xie SP, Zhang Y, Wang M, Kosaka AYU. Sea surface salinity change since 1950: Internal variability versus anthropogenic forcing. J Clim. 2021;34(4):1305–1319.
32. Wang C, Wang L, Wang D, Li D, Zhou C, Jiang H, et al. Turbidity maximum zone index: A novel model for remote extraction of the turbidity maximum zone in different estuaries. Geosci Model Dev. 2021;14(11):6833–6846.
33. He C, Yao Y, Lu X, Chen M, Ma W, Zhou L. Exploring the influence mechanism of meteorological conditions on the concentration of suspended solids and chlorophyll-a in large estuaries based on MODIS imagery. Water (Switzerland). 2019;11(375):1–17.
34. Karbela B, Afgatiani PM, Parwati E. Interseasonal Variability In The Analysis Of Total Suspended Solids (Tss) In Surabaya Coastal Waters Using Landsat-8 Satellite Data. Int J Remote Sens Earth Sci. 2020;17(2):175–188.
35. Sathasivam S, Kankara RS, Murugan U, Gunasekaran P, Palanisamy T, James RA. Influence of suspended sediment loads on coastal hydrodynamics at Vengurla and Ratnagiri part of the Western Coast of India. Arab J Geosci. 2021;14(21):1–14.
36. Ou J, Dong H, Jia L, Luo X, He Z, Chen K, et al. Short-term variations and influencing factors of suspended sediment concentrations at the Heisha Beach, Guangdong, China. Acta Oceanol Sin. 2022;41(5):51–63.