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Water Quality Assessment of Remote Sensing Techniques: A Comparative Insight between Yangtze of China and Porong of Indonesia

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***Abstract*—The river water quality, exceptionally the total suspended solid (TSS) in China and Indonesia, has deteriorated due to human activities. Remote sensing makes it easier for observers to monitor river water quality, especially TSS. However, measuring the river water quality by remote sensing is still in the model and algorithm development stage in China and Indonesia. This study aims to identify the river water quality on remote sensing in China's Yangtze River and Porong River, East Java, Indonesia, and to analyze comparisons of river water quality on remote sensing in Yangtze River, China, and Porong River, East Java, Indonesia. This method uses a literature review based on journals, articles, and primary sources to review related literature on TSS concentrations in rivers and remote sensing in China and Indonesia. River water monitoring methods can measure the TSS in China and Indonesia using remote sensing. Many water quality models for waterways are based on different satellite images. In the Yangtze Downstream River, the algorithm of TSS uses the latest random forest on Landsat-8. The algorithm of TSS in the Porong River estuary used linear regression on sentinel-2 imagery. These TSS algorithms can more precisely assess TSS in water quality for scientific studies. The results show that the latest random forest is a more precise remote sensing algorithm in China than Linear regression in Indonesia. The suspended solid models and remote sensing images such as China's MODIS, Landsat-8, and MERIS are accurate in China. Therefore, developing more precise remote sensing techniques, total suspended solid models composed of Wiggin's Algorithm and Markert Algorithm, NDWI Algorithm, and remote sensing imagery such as Sentinel-2 and Landsat-8 in Indonesia is crucial to determine total suspended solids. The researchers additionally contribute to advanced research toward advancing suitable remote sensing techniques in various areas in Indonesia.**

***Index Terms*—Water quality, remote sensing, total suspended solid, China, Indonesia.**

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I. INTRODUCTION

High demand from individuals who utilize river water can lead to issues with river water quality [1]. From the 19th century until now, the measurement of river water quality still tends to be traditional, using simple tools to measure each parameter of river water quality. The Secchi disk tool measures the brightness level of water [2]. Measuring river water quality using laboratory tests tends to be expensive, such as a TSS meter tool to measure water quality in waterways. In Indonesia, the method of monitoring river water quality in the field is generally carried out by observers. However, observation of river water quality in the area is highly dependent on river conditions and requires a long time. Spatial and temporal scales limit the field survey process, and survey results cannot accurately reflect overall changes in previous years [3]. Due to this, technical river water quality monitoring across broad areas is challenging.

Remote sensing mainly solves two environmental and ecological problems due to population growth [1]. Scientists have developed remote sensing methods for estimating water quality in the early 2000s [4]. Remote sensing provides plenty of potential for detecting issues with river water and adequately assessing the water quality. The latest advances in remote sensing enable it to be feasible to monitor and evaluate the characteristics that influence water quality objectively. Remote sensing provides accurate, quick, and affordable estimations of water quality on a global scale. Due to its versatility and capacity to be valid at many scales, remote sensing offers an efficient way to monitor water dynamics and anticipate water quality. Yet, four factors render remote sensing imaging disadvantageous. The elements involve calculating optically inactive water parameters, cloudy and rainy weather, low water reflectance, massive data, and processing from remote sensing [5]. Observing how remote sensing for aquatic environments evolves in future decades will be crucial.

The development of measuring river water quality in Indonesia began in the 20th century using remote sensing technology. Hence, river water quality methods in Indonesia include remote sensing and river water monitoring in the field [6]. For widespread river water quality monitoring, remote sensing is a valuable technique. Optical characteristics, including absorbing and scattering beams, are utilized in remote sensing [7]. With the benefits of extensive observation, prolonged picture acquisition, and high image resolution, remote sensing is the optimal approach for monitoring river water quality [8].

Remote sensing for measuring river water quality in Indonesia is in the modeling and algorithm development stage. Most of the models and algorithms are new. They estimate water quality parameters in specific areas, such as TSS concentrations at the Yangtze Downstream River in China and the Porong Downstream River in Indonesia [9]. Therefore, comparative insight is needed to assess total suspended solids (TSS) in the study area. To manage rivers effectively and engage in human activities, it is essential to understand river water quality.

By preceding research, using Google Earth Engine and considering the date, time, and place for every TSS measurement, the surface reflectance for samples was acquired from Landsat imagery in China [10]. The correlation value in the Yangtze River has 0.90 involving Landsat-8. In the previous research, ten points were distributed across the Kali Porong River as part of the in-situ data for which the validation test was conducted. The estimated TSS values in Google Earth Engine were compared with the in-situ measurements and evaluated for correlation. The correlation value in the Porong River has 0.652 involving Sentinel-2 [9].

Hence, the study is necessary to determine the river water quality in China and Indonesia by applying remote sensing. This study examines total suspended solids in China and Indonesia through algorithms and imagery for evaluating water quality. The data is obtained using remote sensing and machine learning through R software and Google Earth Engine programs to monitor river water dynamics and calculate river water quality. Hence, this study aims to identify the river water quality using remote sensing for the latest random forest model on Landsat-8 in Yangtze River, China, and a linear regression model on sentinel-2 imagery in the Porong River, East Java, Indonesia. This study analyzes the comparisons of river water quality using remote sensing for the latest random forest model on Landsat-8 in the Yangtze River, China, and a linear regression model on sentinel-2 imagery in the Porong River, East Java, Indonesia.

II. Related Work

A. Water Quality for Total Suspended Solid

A transparent, tasteless, and odorless liquid qualifies as clean water [11]. River water quality by selecting physical parameters such as calculating the number of dissolved solids (TDS) based on remote sensing and tools [12]. The maximum limit for water turbidity is 25 NTU [13]. The feasibility of river water is very important for daily clean water by predetermined conditions. The impact of river water quality can also affect the community's quality of life to be decent [14].

B. Remote Sensing for Water Quality

Parameters relating to water quality are frequently measured using remote sensing techniques [15]. Many remote sensing techniques are available to pinpoint the biological, chemical, and physical characteristics of water [4], such as turbidity, Chlorophyll-a, total suspended solids (TSS), sea surface salinity (SSS), water temperature (WT), total phosphorus (TP), colored dissolved organic matter (CDOM), Secchi disk depth (SDD), dissolved oxygen (DO), pollutants, coliform concentrations (CC), potential hydrogen concentrations (pH), phosphate (PO4), free carbon dioxide (CO2), total hardness (TH), nitrate (NO2) [15], total alkalinity (MgCaCO3), total hardness (MgCaCO3), calcium (Ca), magnesium (Mg), sodium (Na), chlorine (Cl), bicarbonate (HCO3), total dissolved solids (TDS), biological oxygen demand (BOD), and chemical oxygen demand (COD) [16]. Big data, cloud computing, and machine learning are recent developments in remote sensing that will benefit current and future generations [5].

The total suspended solids (TSS) in estuaries have been estimated using machine learning models such as random forest and linear regression. The algorithm of TSS uses the latest random forest model on Landsat-8 in the Yangtze Downstream River through Google Earth Engine and R software. The random forest algorithm merges the bagging algorithm and numerous different trees. By bootstrapping calibration data, each tree model was created. The total suspended solids are mapped using the decision tree model, the random forest model [12]. The most effective multispectral model was the latest random forest model [17].

The algorithm of TSS in the Porong River estuary used a linear regression model on sentinel-2 imagery through Google Earth Engine. High accuracy is achieved through the linear regression model [9]. The prediction variables were used as the ratio, single band, and difference indices [12]. Ratio, single band, and difference indices were added as independent variables in the linear regression models created in SPSS. Variables with high correlation and low autocorrelation were elected to estimate TSS through the linear model that involves or omits independent variables based on the selection criteria [18].

C. Google Earth Engine for Satellites

A data processing technology called Google Earth Engine (GEE) may be used to swiftly and precisely determine water quality [19]. Google Earth Engine (GEE) provides an extensive collection of remote sensing data such as sentinels [20], Landsat-8, MODIS, and MERIS are used for river water quality monitoring [12]. Remote sensing applications obtain information about river water quality, providing a new perspective in analyzing remote sensing data [21]. Remote sensing applications improve operational classification and better river water quality detection [22].

III. Research Method

This type of research is quantitative descriptive research. The descriptive analysis explains one or more variables without comparing and connecting other variables. The location of this study is in two rivers, namely the Yangtze River, China, and the Porong River, East Java, Indonesia. The Yangtze River is in China's urban areas. The Porong River is located in the Lapindo Mud.

This quantitative descriptive research is based on a literature study on river water quality by remote sensing in two rivers, namely the Yangtze River, China, and the

Porong River, East Java, Indonesia, obtained from various selected journals, articles, and references and supported by theories and sources, and related concerns. The variables in this literature review include physical water quality, namely total suspended solid and remote sensing, including Sentinel-2, Landsat-8, MODIS, and MERIS. The process of data collection is PRISMA. The detailed reviews of data collection use R Software and Vosviewer.

Data for this literature review comes from selected journals, articles, and references on river water quality by remote sensing in China and Indonesia. The research areas are shown in Figures 1 and 2.

Fig. 1. Research area on the Yangtze River, China, on Google Maps in 2022

The study area is in China, downstream of the Yangtze River. The longest river in China is the Yangtze (Fig. 1). The Yangtze River is the longest in China. The Qinghai-Tibetan Plateau is where it rises, and it flows eastward to the East China Sea [23]. In China, an urban region with various industrial enterprises is located downstream of the Yangtze River [24].

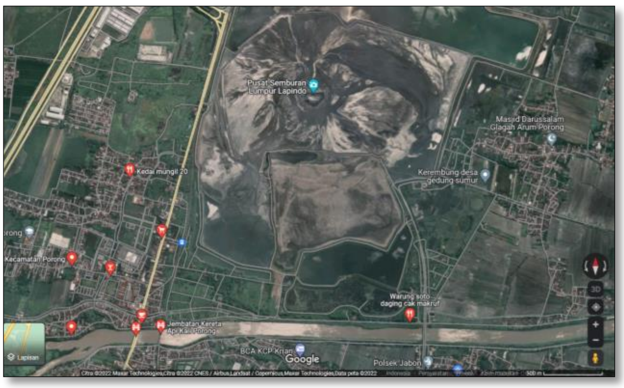

Fig. 2. Research area on the Porong River, Indonesia, on Google Maps in 2022

In the southern region of East Java, Indonesia, the Porong River Downstream is the study area (Figure 2). The natural environment of the Porong River Downstream provides ponds, villages, industry, and other economic activity along the shore. An enormous process of sediment deposition occurs at the Porong River's estuary [25]. The Lapindo Mud, which exploded in 2006 and continues to exist there in the present day, is also deposited Downstream of the Porong River [26].

Table 1.
Scopus Data *Index Queries*

Database	Keyword
Scopus Data	TITLE-ABS-KEY ("water quality" AND "river" AND "Google Earth Engine") AND PUBYEAR > 2020 AND PUBYEAR > 2020
Scopus Data	TITLE-ABS-KEY ("water quality" AND "river" AND "GEE") AND PUBYEAR > 2020 AND PUBYEAR > 2020

To locate these results, utilize the "Basic Search Tool" on the Scopus Index website. The data is searched in the Scopus e-library system via the paper title, abstract, and keywords. The keywords are water quality, river, GEE, and Google Earth Engine in the basic search tool. The latest research time from 2020 to the present.

Data analysis in this quantitative research is an activity after collecting data. Data processing begins with obtaining river water quality data by remote sensing in China and Indonesia. Thus, identifying river water quality is by remote sensing in the Yangtze River, China, and the Porong River, East Java, Indonesia.

The authors identified 25 journals and included several proceedings from the Scopus Index database. Publisher of several journals, including ScienceDirect, Springer, Taylor & Francis, MDPI, IOP, and others with indexes Q1, Q2, Q3, and Q4. The Scopus index for proceedings of 25 journals includes several articles, including proceedings published from 2021 and 2022. Tables 1 and 2 present a detailed analysis of each piece and some proceedings. The process of searching and organizing data is as follows:

1) Data source

The articles and included proceedings are from the Scopus index database for schematic reviews. The Scopus index database is the primary source for reviewing data. It covers many disciplines such as geography, mapping science, social sciences, and others published by ScienceDirect, MDPI, Springer, Taylor & Francis, IOP, and others. The Scopus Index site provides a "Basic Search Tool" to find these results. The data sought and collected is based on research themes and retrieved in the e-library system at Scopus.

This schematic study reviews water quality, river, GEE, and Google Earth Engine keywords. This query is essential for finding relevant articles. First, relevant articles are identified and collected with the given keywords.

2) Eligibility criteria

The author determines the theme to identify and filter articles and includes several proceedings through the Scopus Index Database. A total of 25 research articles and including several proceedings, were found based on the research theme with ten copies. Twenty-five articles and some of the proceedings have been screened and reviewed. Six articles and including some completed proceedings for the relevant full-text writing.

3) Data extraction

Data extraction was obtained in November 2022 to complete the study. After reviewing the studies, themes were identified. The data was extracted and collected in tables based on four themes: water quality, river, GEE, and Google Earth Engine. Therefore, the data was extracted and arranged based on these four themes.

A PRISMA-based literature review (Fig. 3) is a method to discover the most recent information on a complex research topic [27]. The PRISMA method can evaluate related research, support current studies, and critique earlier research that provided disparate results [28]. The reason table is filtered and examined primarily to establish a state-of-the-art based on PRISMA, including (1) meeting the demands of the study objectives, (2) the final publication stage, (3) the type of journal source, (4) English, (5) journal index Q1, Q2, Q3, and Q4, (6) Scopus index proceedings, (7) according to the theme, (8) keywords: water quality, river, GEE, and Google Earth Engine, and (9) types of articles and proceedings documents. Journals and proceedings from ScienceDirect, MDPI, Springer, Taylor & Francis, IOP, and other publishers are assessed for PRISMA. Each study implements a specific region or location, such as applying remote sensing to the river water quality in China and Indonesia.

IV. Result

The relevant journals, articles, and references on river water quality through remote sensing in China and Indonesia provided the data for the systematic review. Applying R Software and Vosviewer, the detailed research reviews are analyzed from 2020 to the present. These analyses are based on the keywords and occurrences related to the research topics. The detailed research reviews on R Software and Vosviewer are displayed in Figures 4 and 5.

Data for the systematic review comes from selected journals, articles, and references on river water quality by remote sensing in China and Indonesia. The detailed research reviews are examined from 2020 until the present using R Software and Vosviewer. These analyses are based on the keywords and occurrences determined by the research topics. The detailed research reviews on Vosviewer are shown in Fig. 4 and 5.

A detailed review of the research is provided in Figure 3. R Software was utilized for the analysis. Analysis of the most common words chosen based on the keywords and occurrences retrieved from the study. This analysis generates four keywords, each of which appears once. Total suspended solids, Landsat images, the latest random forest, and estuary are the most frequently cited terms in research in China and Indonesia, according to the R Software image findings in figure 4.

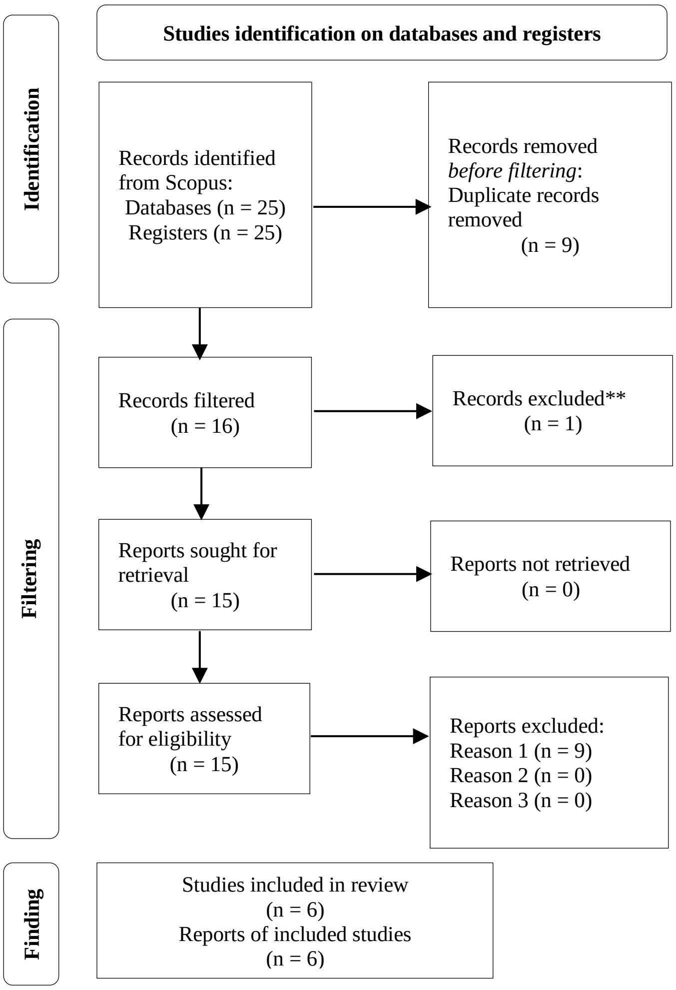

Fig. 3. Selecting Studies Process for Reviewing by PRISMA

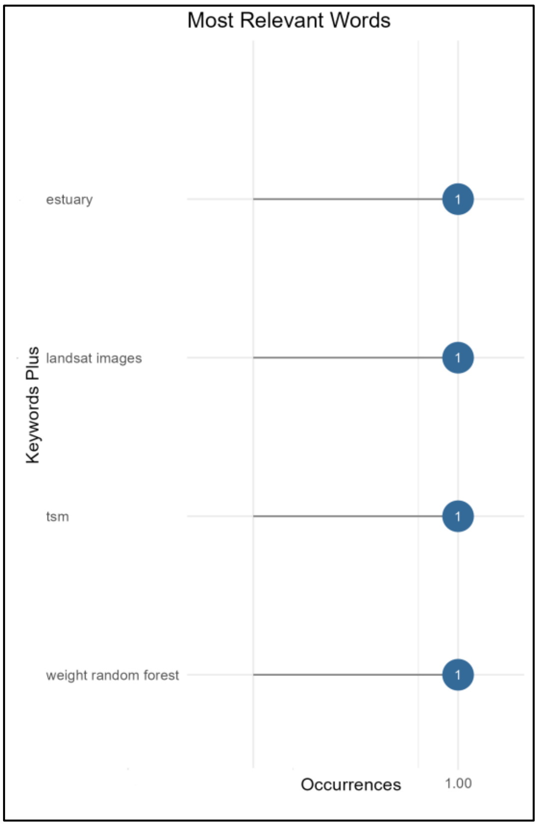

Fig. 4. Most Frequent Words on R Software in 2023

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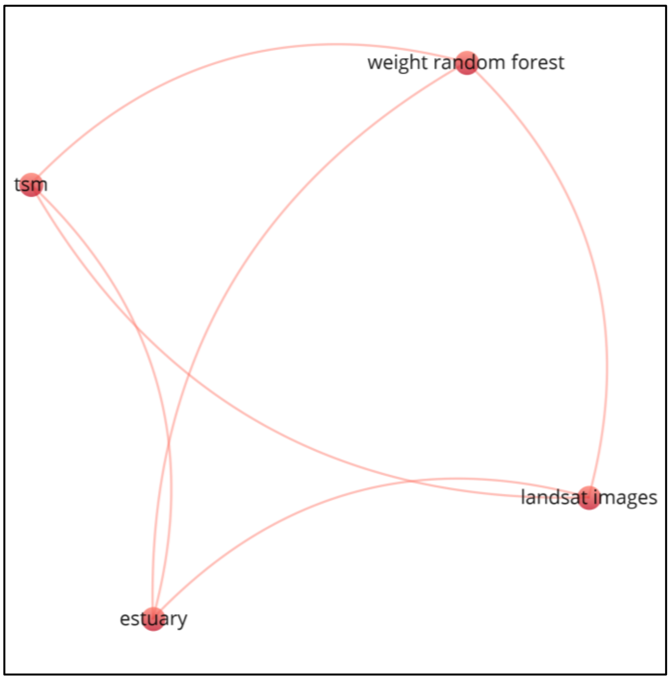

Fig. 5. Most Frequent Words on Vosviewer in 2023

A thorough analysis of the research is presented in Figure 5. Vosviewer was utilized for the study. The full counting method is the word-counting method applied in this research. Text mining analysis uses the full counting method to generate words or keywords. Four words are clustered along in a single cluster as an outcome of the study of the full counting method, which groups the findings based on the keywords determined by the research topics. The network visualization's red clusters that provide variable information are interrelated. The study provides remote sensing data such as Landsat imagery and the latest random forest as an algorithm to estimate total suspended solids in the estuary in China and Indonesia, which are interrelated research variables. The outcomes of the above Vosviewer images demonstrate how total suspended solids along the shoreline are analyzed utilizing remote sensing data, including Landsat images and the latest random forest algorithm.

A. Total Suspended Solid

The total suspended solid (TSS) is a parameter that can be identified by remote sensing for coastal and estuarine waters [29]. A crucial indicator of water quality is total suspended solids (TSS), including inorganic and organic particle materials. Total suspended solids (TSS) can regulate how much light enters the estuary water column, which can impact photosynthesis and ecosystem output [30]. The process of sedimentation impacts variations in the water depth and underwater topography [31]. Transport and deposition Total suspended solid (TSS) also influence shoreline evolution through sediment accumulation and erosion [3]. Ocean waves and currents concentrate much of the total material substance in the estuary [20]. Therefore, accurate TSS evaluation is very important for estuarine system management.

B. River Water Quality Based on Remote Sensing in China

There are many methods for estimating river water quality, such as monitoring river locations, monitoring river water quality in the field, physical models, numerical simulations, and remote sensing in China [12]. River water monitoring methods to measure river water quality rely on data collected at separate stations in China and laboratory measurements, which are expensive and time-consuming [3]. Thus, remote sensing can make it easier for observers to predict river water quality monitoring [12]. In China, methods and algorithms for assessing river water quality using remote sensing are being developed [32].

In the 2000s, remote sensing was used to measure river water quality in China. Remote sensing is a technique for determining river water's physical, chemical, and biological characteristics [8]. River water quality can be measured by physical parameters: total suspended solids (TSS) [12]. Remote sensing in measuring the river water quality in China has developed modeling and algorithms [32]. The development of modeling and algorithms in remote sensing is because most of the existing models estimate some water quality in certain areas, such as physical parameters, namely total suspended solid (TSS) at the mouth of the Yangtze River [12].

C. Remote Sensing for River Water Quality in China and Indonesia

The approach commonly used in water remote sensing is empirical modeling using spectral or combination bands and in-situ measurements as input [12]. Many systems and sensors exist for river water quality monitoring [33]. For example, Landsat and Sentinel images in Indonesia are generally used for monitoring river water quality [20]. Sentinel-2 imagery can estimate total suspended solid (TSS) with a correlation in the Porong River [9].

In China, Landsat-8, MODIS, and MERIS imagery are used for monitoring river water quality [12]. The red band model based on Landsat is suitable for total suspended solids (TSS) estimation. Upcoming satellite data (such as Sentinel-2, Gao-Fen series, HJ A/B, and Landsat 9 with red band) to obtain spatial updates [7].

Remote sensing, a Landsat with high spatial resolution and extensive dynamic range, as well as red and blue bands, can be absorbed by algae [4]. The total suspended solid concentration in surface water can be detected from remote sensing [9]. Agribusiness, urban planning, forest monitoring, human and environmental health, energy and water management, disaster recovery, and agriculture may all benefit from the more than 40 years of crucial global land observations made by the Landsat series. The total suspended solid (TSS) for inland and coastal waterways has been mapped in previous empirical investigations using Landsat series data [34].

D. The Comparative Review of River Water Quality Based on Remote Sensing in China and Indonesia

Based on satellite pictures and simulations, several suspended solid models were created for coastal seas. Among the factors employed are a single spectral band,

band ratio, band contrasts, and the primary elements of several spectral bands. Therefore, the literature review results are expected to provide vital information about total solutes (where total suspended solids (TSS) increases significantly or is abnormally high or total suspended solids (TSS) dynamics) in the China and Indonesia regions.

Urban areas surround the lower Yangtze River. Remote sensing modeling on the Yangtze River uses the latest random forests via Landsat-8, MODIS, and MERIS. The use of the latest random forest models (machine learning) in remote sensing to identify river water quality in the Yangtze River [12].

In the Yangtze Downstream, the total suspended solids (TSS) River uses the latest random forest model in 2019 on Landsat-8. TSS concentrations on 18 January 2019 and 4 December 2019 in winter, TSS concentrations on 10 May 2019 in spring, and TSS concentrations on 29 July 2019 in summer. The total suspended solid results show that the total suspended solid decreased in spring due to ice melting in winter. In summer, the total suspended solid (TSS) increases because no water comes from the mountains due to melting ice.

Remote sensing in measuring river water quality in Indonesia is in the modeling and algorithm development stage. The development of modeling and algorithms in remote sensing is because most of the existing algorithms for assessing total suspended solids (TSS) in rivers and specific areas, such as the Porong River, East Java, Indonesia. The Porong River is mainly surrounded by agricultural land, settlements, and Lapindo [20].

In the Porong Downstream River, total suspended solids (TSS) used a linear regression model in 2021 on Sentinel-2 imagery. Remote sensing modeling on the Porong River uses linear regression, Wiggin's Algorithm and Markert Algorithm, and NDWI Algorithm on Landsat-8 and Sentinel-2 [20]. From January to March, the total suspended solid value decreased. Meanwhile, from March to June, the total suspended solid value increased. An increase in the total suspended solid (TSS) value means a reduced water quality in the Lower Porong River [9]. Total suspended solid (TSS) decreases due to flowing rainwater in the rainy season. Total suspended solid (TSS) increases because the river water is not added during the rainy season, resulting in low water quality in the dry season.

TSS concentration in the Yangtze River in China and the Porong River in Indonesia was estimated using the latest random forest and linear regression models. The prior studies utilize the latest random forest model to create a reliable TSS model for the estuaries in China. The RMSE is 0.56 mg/L, and the validation R2 is 0.90 [12]. The latest random forest algorithm is highly accurate. Hence, the latest random forest can be assessed for total suspended solids worldwide. With in-situ data, TSS is determined by linear regression plots. The correlation value is 0.652 for TSS in Indonesia. The correlation value of TSS indicates a substantial connection between the in-situ data and the projected data derived from Sentinel-2 data [9]. Therefore, the research's estimation results are further supported.

The earlier research applied the random forest model to map clearly and determine variations in TSS dispersion amongst numerous estuaries from northern to southern China to present an enhanced and effective TSS model and mapping method for diverse estuaries in China. The NIR band, band ratio, and band difference indicators applied in the NIR band were responsive to greatly turbid estuaries with elevated TSM concentrations. The band difference index outperformed the band ratio index in determining TSM concentrations in fewer turbid estuaries. On the contrary, estuaries with inadequate TSM concentrations were hypersensitive to the red band, band ratio, and band difference indices, which all required the red band as a variable [12]. Hence, plenty of ratios, bands, and difference indices were utilized as the estimated variables for estuaries across the world in the years to come.

By remote sensing, water monitoring can measure total suspended solids (TSS) in China and Indonesia. Many water quality models and algorithms for waterways are based on different satellite images. For plenty of estuaries globally, we encouraged the development of new TSS models, random forest methods, and mapping methods. Further studies will require spectral data and TSS measurement data. The researchers also contribute to advanced research toward advancing suitable remote sensing techniques.

V. Conclusion

Due to human activity, river water quality in China and Indonesia faces severe issues in both urban and rural areas. Consequently, both humans and the natural environment are adversely affected by rivers' lack of water quality. This necessitates a comparison study utilizing R Studio and Vosviewer, which evaluates information on remote sensing techniques for determining precise total suspended solids in China and Indonesia. Hence, we compared the quality of river water, particularly total suspended solids, using remote sensing data between China and Indonesia. Previous studies evaluated more accurate remote sensing algorithms involving the latest random forest, suspended solid models, and remote sensing images, including Landsat-8, MODIS, and MERIS in China. Therefore, it is necessary to develop more accurate remote sensing methods such as linear regression, total suspended solid algorithms consisting of Wiggin's Algorithm and Markert Algorithm, and NDWI Algorithm, and remote sensing images such as Sentinel-2 and Landsat-8 in Indonesia.

Developing improved TSS models, remote sensing algorithms, and mapping techniques across numerous estuaries worldwide are necessary. Data on spectral and TSS measurements will be essential to further research. The findings of this study are valuable to the government, associated organizations, and the communities that live in the area under study region. They additionally contribute to advanced research toward advancing suitable remote sensing techniques in various areas.

The research has several limitations. The location of this study is limited to water quality assessment of remote sensing at the Yangtze River in China and the Porong River in Indonesia. Thus, it is required to calculate the total suspended solids of the water quality parameter on remote sensing in various countries and locations. Furthermore, the additional water quality parameters based on remote sensing are investigated at depth in the future and worldwide.

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