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Estimation Of Changes in Water Quality Parameters in Rawa Pening Lake Based on Remote Sensing Data

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Abstrak

Danau Rawa Pening di Indonesia merupakan salah satu danau super prioritas revitalisasi. Penelitian ini mengkaji perubahan parameter kualitas air di Danau Rawa Pening dari data penginderaan jauh dengan Google Earth Engine (GEE). Parameter fisik yang digunakan untuk menilai kualitas air adalah konsentrasi Total Suspended Solid (TSS) dan luas vegetasi air (eceng gondok). Hasilnya menunjukkan bahwa kualitas air Danau Rawa mengalami perubahan pada kadar TSS dan sebaran vegetasi perairan. Secara umum, dari tahun 2017, 2019, dan 2021 terjadi fluktuasi persentase eceng gondok dan TSS. Hasil pemodelan menunjukkan bahwa Danau Rawa Pening sebagian besar bersifat hipereutrofik.

Abstract

Lake Rawa Pening, in Indonesia, is one of the super lakes of revitalization priority. This study examines changes in water quality parameters in Rawa Pening Lake from remote sensing data with Google Earth Engine (GEE). The physical parameters used to assess water quality are the concentration of Total Suspended Solid (TSS) and the area of water vegetation (water hyacinth). The results indicate that the water quality of Rawa lake has changed in the TSS level and the distribution area of aquatic vegetation. In general, from 2017, 2019 and 2021 there were fluctuations in the percentage of water hyacinth and TSS. Modeling results indicate that Lake Rawa Pening is mostly hypereutrophic

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INTRODUCTION

Lakes are natural bodies of water on land. Lakes are one of the water sources used by the community (Pratiwi & Heriyanti, 2024). Lakes are not only a component of the earth's hydrosphere but can also be an indicator to determine regional climate changes in different time scales and human activities around lakes (Yao et al., 2018). One of the natural lakes that is very interesting to study is Rawa Pening in Semarang Regency, Indonesia. This semi-natural volcanic lake is surrounded by several mountains, making it a famous tourist destination (Marwoto et al., 2020). In addition to tourism, Rawa Pening Lake is also used for irrigation, fisheries, electricity generators, and household needs such as drinking water (H. C. D. Nugroho et al., 2020; A. Piranti et al., 2019; Seftyono, 2014).

From various potential of Rawa Pening, the decline of water quality becomes a primary problem that makes Rawa Pening a priority lake for revitalization in the National Medium Term Development Plan (RPJMN) (Amalia et al., 2024; BAPPENAS, 2019). In addition, Rawa Pening Lake is located upstream of the Tuntang Watershed, which is one of the priority watersheds for revitalization (Gubernur Jawa Tengah, 2023). One of the factors causing problems in Rawa Pening lake is the level of water quality below the threshold due to eutrophication (A. S. Piranti et al., 2018; Purwanto et al., 2020). In addition, another problem is silting due to sedimentation and water hyacinth (*Eichhornia crassipes*) (Izzati, 2023; N. P. Nugroho, 2022; Prasetyo et al., 2022). Thus, providing a spatial water quality model in Lake Rawa Pening is very important and valuable for policy formulation related to lake revitalization (Setiawan et al., 2019).

TSS modeling and aquatic vegetation are commonly used in remote sensing-based spatial models that show the quality of lake waters (Heriza et al., 2018; Imran et al., 2022). However, in remote sensing-based TSS modeling, there are obstacles, e.g., cloud cover, that is also a challenge in Rawa Pening Lake, which is topographically located on the slopes of Mount Merbabu, Mount Telomoyo, and Mount Ungaran (Karbela et al., 2021; Markert et al., 2018; Paramita et al., 2022; Widhaningtyas et al., 2020). This cloud cover problem can be overcome by using the GEE (Google Earth Engine) platform, which can provide and analyze remote sensing data so that users can get cloud-free satellite imagery (Fariz & Nurhidayati, 2020; Wahap & Shafri, 2020). Therefore, our paper will model the dynamics of water quality in Lake Rawa Pening based on remote sensing. The main difference from the previous study by Heriza et al. (2018) and Chulafak et al. (2021) is the use of GEE so that the resulting model is free from cloud cover. The provision of a spatial dynamics model of lake quality will also increase the availability of lake quality data which is the target of activities in the Strategic Planning of the Ministry of Environment & Forestry for the 2020-2024 period (Kementrian Lingkungan Hidup dan Kehutanan, 2020).

RESEARCH METHOD

The water quality parameters in this article are limited by the distribution of water vegetation (*water hyacinth*) and TSS. The study location in this research is Lake Rawa Pening which is located in Semarang Regency, Central Java Province, Indonesia (Figure 1). The image data used is Landsat-8 satellite imagery which was acquired in 2017, 2019, and 2021. The satellite imagery data used is surface reflectance (SR) data from GEE, so there is no need for pre-processing such as geometric and radiometric correction. Data management and analysis stages consist of mapping water vegetation (water hyacinth) and then continuing with TSS mapping.

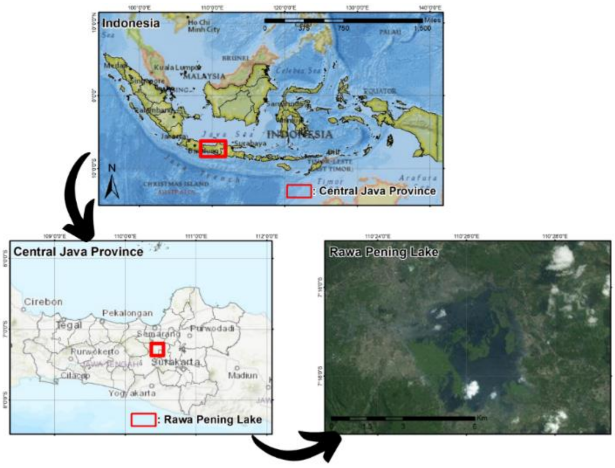

Figure 1. Location of Rawa Pening Lake

Water hyacinth mapping uses image interpretation analysis, i.e., visual interpretation. Visual interpretation uses keys such as tone/color, shape, site, and others. Our consideration for visual interpretation was a mix of pixels between water hyacinths, water bodies, and other vegetation, making it difficult to discriminate against using digital interpretation (Thamaga & Dube, 2018).

TSS mapping using image processing analysis with TSS modeling algorithm. TSS was suspended materials (diameter > 1 m) retained on a millipore sieve with a pore diameter of 0.45 m. TSS consists of mud and fine sand, and micro-organisms. The ultimate cause of TSS in waters is soil erosion carried into water bodies. If the TSS concentration is too high, it will inhibit light penetration into the water and disrupt the photosynthesis process (Nurandani et al., 2013). In this paper, we use the algorithm developed by Parwati because it has the highest correlation and coefficient of determination in modeling the distribution of TSS in Rawa Pening Lake (Heriza et al., 2018; Parwati & Purwanto, 2017). This algorithm uses a red band which is sensitive to TSS (Lobo et al., 2015). The expression of this algorithm is as follows:

$$\mathbf{TSS(mg/L) = 3.3238*EXP(34.099*Red\ Band)} \quad (1)$$

After the TSS model is made, the next step is calculating the brightness level based on the TSS value from the modeling results. The estimated brightness value was obtained from an equation constructed from several studies of the relationship between TSS and the brightness of lake waters in Indonesia (Trisakti et al., 2017). The expression of this equation is as follows:

$$\mathbf{375.71 \times exp(-0.123 \times TSS)} \quad (2)$$

The brightness value obtained will be used to estimate Rawa Pening Lake's water quality changes. Determination of quality is based on trophic status, which refers to the Regulation of the State Minister of the Environment No.28 of 2009 as follows:

Table 1. The brightness index

Status	Average			
	N Total (mg/L)	P Total (mg/L)	Klorofil-a (ug/L)	Brightness (m)
Oligotrofik	< 650	< 10	< 2	> 10
Mesotrofik	< 750	< 30	< 5	> 4
Eutrofik	< 1900	< 100	< 15	> 2.5
Hypertrofik	> 1900	> 100	> 200	< 2.5

RESULTS AND DISCUSSION

Satellite imagery data Preparation for modeling

The use of GEE in modeling water quality in Rawa Pening Lake has advantages because there is no need to download satellite imagery and pre-process data. We can get cloud cover-free satellite imagery at GEE by applying a median reducer and cloud masking. The median reducer gets the image at a particular time, which we use from March to November (Figure 2). The selection of time intervals is based on the seasons in Java, Indonesia, where the year's beginning and the end is the peak of the rainy season. The rainy season affects the percentage of cloud cover on satellite imagery obtained, whereas, in that period, the quality of satellite imagery tends to be low (P. Li et al., 2018).

Illustration of research data in the form of pictures can be in the form of photos, flowcharts, graphs, charts, or maps. For maps, such as sample maps, only display legends, scales, insets if needed, and maps without logos and author's names. Images or tables can be placed in a text box placed

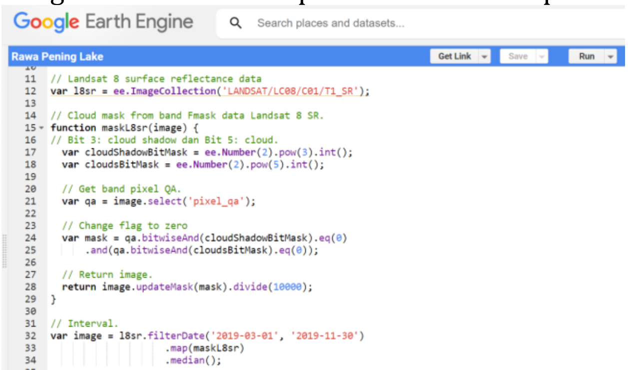

Figure 2. Script used to get cloud cover-free satellite imagery

After applying the median reducer and cloud masking, satellite imagery free of cloud cover is obtained and ready to be used to map water hyacinths and TSS (Figure 3). The key to this method's success is the study's location and the amount of data available. If an area has a lot of cloud cover every month, such as mountainous areas or the equator, the results of cloud masking will find holes with a null value. The amount of available data also affects because the more data available, the more data is used to fill gaps. Thus, the method will work better when using Landsat-8 than Landsat-5, which has fewer data.

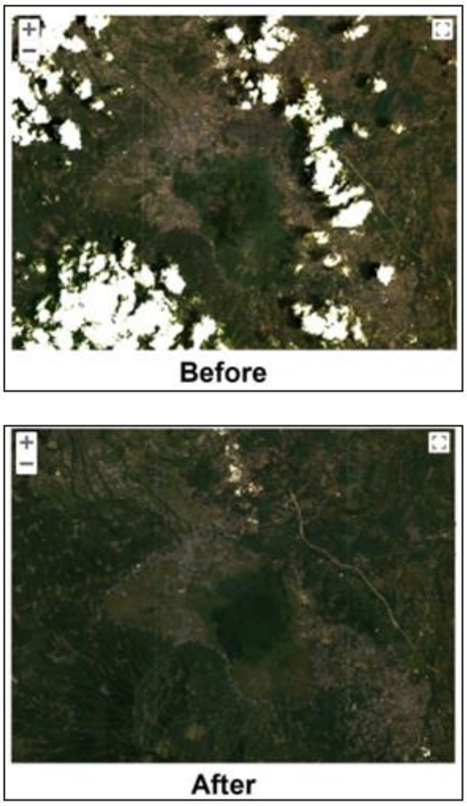

Figure 3. Comparison of satellite imagery before and after processing

Modeling changes in water quality in Lake Rawa Pening

The water quality parameters modeled in this paper are the distribution of water hyacinth and TSS. Water hyacinth (*Eichhornia crassipes*) is a floating aquatic plant commonly found in Rawa Pening Lake. This plant, which has a local language, namely water hyacinth, can adapt to extreme changes in water levels, water currents, and changes in nutrient availability. Water hyacinth is one of the world's most aggressive invasive plant species, so it is necessary to monitor its distribution through mapping (Pádua et al., 2022).

The results of the visual interpretation showed that the water hyacinth cover in Rawa Pening waters fluctuates. In 2017, the waters of Lake Rawa Pening were partially covered by water hyacinth, up to 62.4%. In 2019, water hyacinth cover increased to about 81.1%. Remarkably, in 2021, the water hyacinth cover in Rawa Pening decreased drastically to 19.6%. The drastic decrease in water hyacinth cover was due to collaborative activities between the government and the military, namely the Pemali Juana River Basin Agency (BBWS) and the Diponegoro Military Command (BBWS Pemali Juana, 2021). This activity took the form of cleaning and lifting water hyacinths in Rawa Pening on a large scale, resulting in a drastic reduction in water hyacinth cover.

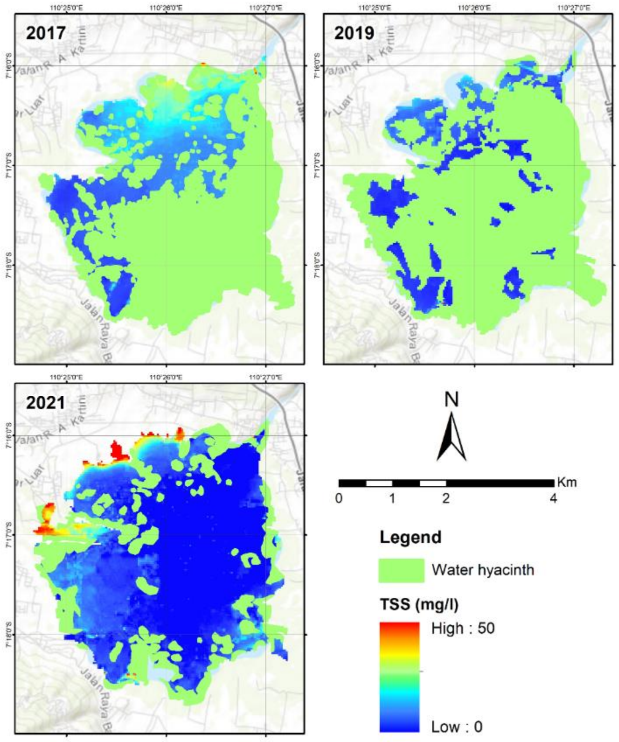

Figure 4. Water quality map in Rawa Pening with water hyacinth and TSS

Fluctuating results were also obtained in estimating the TSS value from the model. In 2017 the average TSS content in Rawa Pening Lake was around 9.13 mg/l; in 2019, it decreased to 7.13 and again increased to 7.75 mg/l in 2021 (Figure 4). Based on the TSS value obtained, we can estimate the average water brightness value to determine the trophic status of Lake Rawa Pening. The calculation results showed that sequentially from 2017, 2019, and 2021 the average brightness value in Rawa Pening waters is 1.22m, 1.56m, and 1.44m. These results indicate that Lake Rawa Pening is mostly hypertrophic. Hypertrophic is the trophic status of lake water with very high levels of nutrients. This status indicates that the water has been heavily polluted by increased levels of N and P (Astuti et al., 2022; Heriza et al., 2018).

The status of Lake Rawa Pening's water quality is an estimate from the model made. The limitation of this paper is that we do not validate the model made, other than that the determination of the trophic status is only based on the brightness value. In order to get more representative results, in addition to validating the model, we also suggest that the model is built from high-resolution data such as UAV (Unmanned Aerial Vehicle) data. UAV data is able to discriminate against objects such as building types and vegetation types (Fariz et al., 2023; Z. Li et al., 2021). This makes UAV data can be used to estimate the quality of lake waters through mapping water hyacinth or TSS content (Pádua et al., 2022; Silveira Kupssinskü et al., 2020; Wongsupathai et al., 2021). From this paper, we can convey that water quality modeling can be estimated with medium resolution remote sensing data, making it more effective and efficient. We also proved that using GEE for the data collection and analysis benefits in model development process regarding time efficiency.

CONCLUSIONS

Modeling of water quality in Rawa Pening Lake is limited to the distribution of water hyacinth and TSS only. In general, in 2017, 2019, and 2021 there were fluctuations in the percentage of water hyacinth and TSS. Especially for water hyacinth in 2021, there will be a drastic decline due to synergy activities between the government and the military. Modeling results indicate that Lake Rawa Pening is mostly hypereutrophic. The status of Lake Rawa Pening's water quality is an estimate from a model made with limitations based only on the brightness level of the waters and without model validation. These results also indicate that water quality modeling can be estimated using remote sensing data, making it more effective and efficient. We also proved that using GEE for the data collection and analysis benefits the model development process regarding time efficiency.

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