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Utilization of Sentinel-2 Satellite Imagery for Estimating Water Quality Changes in Rawa Pening Lake

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ABSTRACT

Rawa Pening Lake is one of the lakes designated as a revitalization priority by the Government of Indonesia in the National Medium Term Development Plan. The factor that caused Rawa Pening Lake to become a priority is water quality in Lake Rawa Pening, which continues to be degraded by soil sedimentation and water hyacinth. By being designated as a national revitalization priority lake, the availability of water quality data with various parameters is urgently needed as a basis for formulating policies and strategic steps in revitalizing Rawa Pening Lake. This study uses remote sensing data to examine changes in water quality in Lake Rawa Pening through TSS, chlorophyll-a, water brightness, and DO parameters. In 2022, the distribution of aquatic vegetation had a lower percentage than in 2020. As a result, the studied aquatic parameters will fluctuate in value over the specified time range. Modeling results indicate that Lake Rawa Pening is mostly eutrophic.

Keywords: Chlorophyll-a, Sentinel-2 satelitte imagery, TSS, Trophic Status, Water hyacinth.

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1. INTRODUCTION

Rawapening Lake is a natural lake located in Semarang Regency. Rawapening is one of the semi-natural volcanic lakes in Indonesia; therefore, Rawapening Lake is surrounded by several mountains (Marwoto et al., 2020). This lake has excellent potential and role in providing various needs of living things in carrying out activities. The role is evidenced by the ongoing ecotourism activities, fisheries, and agriculture in the Rawapening Lake environment. Furthermore, the local community also utilizes Rawapening Lake as a source of electricity. However, this potential and role are increasingly eroded due to a decrease in water quality (Nurandani et al., 2013).

Rawapening has experienced a significant decline in water quality over the past decade. Massive land use change activities not under their designation and organic waste from community activities dumped around the Rawapening Lake area are the main reasons for this. According to Distankanpangan of Semarang Regency (2017), land cover in the form of agricultural land dominates the Rawapening Catchment Area (DTA). The results of research by Fariz et al. (2022) also showed similar results, with agricultural land dominating land cover in the Rawapening catchment area. The agricultural system in the Rawapening area, which is still not environmentally providential, will produce organic waste with a high enough nutrient content. The waste will flow into the river that empties into Lake Rawapening. In addition to agricultural activities, domestic activity waste containing phosphorus and nitrogen also contributes to the decline in Rawapening water quality (Aida & Utomo, 2017).

High amounts of phosphorus and nitrogen in the water will cause eutrophication. Eutrophied waters are indicated by the rapid growth of aquatic plants. One of these aquatic plants is the water hyacinth (Eichhornia crassipes). Rawapening Lake is a water area that has a water hyacinth with uncontrolled distribution. Moreover, Rawapening has other problems in the form of siltation due to sedimentation. Sedimentation increases water hyacinth distribution and blooming by binding soil sediments rich in organic matter. The organic matter will be used as nutrients by water hyacinth in its growth process (Indrayati & Hikmah, 2018). With its various potentials and problems, Rawapening Lake is designed as a priority lake for revitalization in the National Medium-Term Development Plan (RPJMN).

Rawapening, as one of the priority lakes for revitalization in Indonesia, requires reasonable mitigation efforts to remediate the pollution. Prior to mitigation efforts, environmental spatial data is needed as a guide in formulating mitigation policies. Spatial data is essential in formulating environmental policies because it can visualize various information related to current conditions, predict future conditions, and analyze the policies of various plans and programs (Budhiati et al., 2015). Spatial data can be obtained through several approaches, one of which is remote sensing. Spatial data based on remote sensing can show the condition of an object, area, and phenomena that occur on earth (Sultan et al., 2022). In this context, spatial data based on remote sensing can show the quality of lake waters with several parameters, such as Total Suspended Solid (TSS), chlorophyll-a, and dissolved oxygen (DO) (Imran et al., 2022; Mukarugwiro et al., 2021; Nurhayati et al., 2020).

Analysis of the water quality of Rawapening Lake using remote sensing technology generally only involves water parameters such as TSS and water brightness (Heriza et al., 2018; Nurandani et al., 2013; Sasmito et al., 2022). In this study, the parameters used to analyze the water quality of Rawapening Lake are TSS, water brightness, chlorophyll-a, and DO. The addition of parameters involved in this study aims to increase the availability of lake quality data which is the target activity in the Strategic Planning of the Ministry of Environment & Forestry for the period 2020-2024 (Ministry of Environment & Forestry, 2020).

2. METHODS

The study location in this research is Lake Rawapening which is located in Semarang Regency, Central Java Province, Indonesia (Figure 1). The satellite image data used is Sentinel-2A which was acquired in 2020 and 2022. The image data is surface reflectance data obtained using the Google Earth Engine platform. Satellite imagery in surface reflectance does not require a pre-processing stage in the form of geometric and atmospheric corrections before further processing the image. The Sentinel Application Platform (SNAP) software performs the image processing stage. The water quality parameters used in this study were limited to the distribution of aquatic vegetation (water hyacinth), TSS, brightness, chlorophyll-a, and DO.

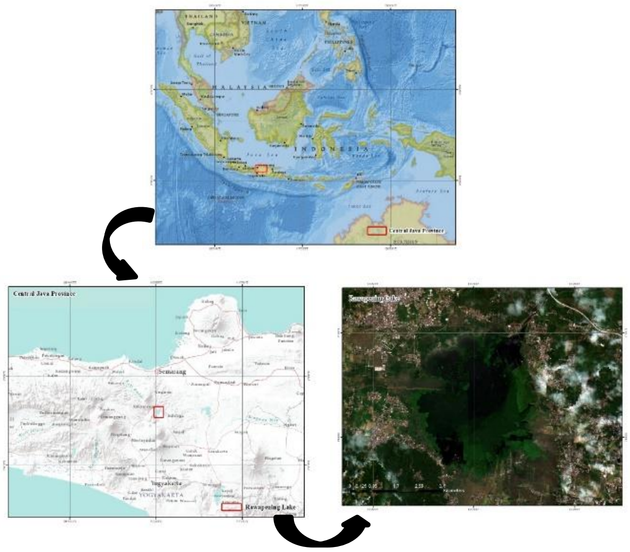

Figure 1. Research Location.

In mapping the distribution of water hyacinth, the authors perform image interpretation analysis in visual interpretation. Visual interpretation image utilized because the area around Lake Rawapening is agricultural and plantation land, so interpretation results will be obtained with a high level of incompatibility if image interpretation is carried out using digital interpretation (Ju & Bohrer, 2022; Thamaga & Dube, 2019). In addition, the authors transformed this study's Normalized Difference

Water Index (NDWI) index to separate water bodies from aquatic vegetation. The NDWI index transformation is carried out so that the results of running expressions of the water parameter algorithm are not affected by pixels of aquatic vegetation (Gerardo & de Lima, 2022).

Water quality parameter data were obtained using several algorithms that have been developed and used in lakes in various regions (Table 1). These algorithms have been used by several researchers in studying the water quality of a lake in Indonesia, such as Nurhayati et al. (2020), who examined the distribution of water quality in the Riam Kanan Reservoir, and Du et al. (2022) who studied the characteristics of TSS in the Eastern Plain Lake (EPL) Zone, China. The author determines the parameters of water quality in the form of TSS, brightness, chlorophyll-a, and DO in this study because these parameters influence each other in determining water quality. In addition, the parameters used can represent water quality (Gholizadeh et al., 2016).

Table 1. Algorithm for Extracting Water Parameter Values

Researcher's name	Algorithm Expression	Function
Liu et al. (2017)	2950 * B71,357	Extraction of TSS values
Trisakti et al (2014)	375,71* EXP (−0,123*TSS)	Extraction of water brightness values based on the TSS algorithm used
Wouthuyzen (1991)	10,359 * (B3/B2) - 2,355	Extraction of chlorophyll-a values
Mujito (1997)	5,2550 - 3,58125 * (B2/(B4+1))	DO value extraction

Brightness and chlorophyll-a values can estimate changes in the water quality of Rawapening Lake based on its trophic status, which refers to the Regulation of the Minister of State for the Environment No.28 of 2009 (Table 2). Based on this, this study partially determined the trophic status by using chlorophyll-a and brightness parameters only.

Table 2. Regulation of the State Minister for the Environment No. 28 of 2009

Trophic status	Average Rate			
	N Total (mg/L)	P Total (mg/L)	Chlorophyll-a (ug/L)	Brightness (m)
Oligotrophic	< 650	< 10	< 2	> 10
Mesotrophic	< 750	< 30	< 5	> 4
Eutrophic	< 1900	< 100	< 15	> 2.5
Hypertrophic	> 1900	> 100	> 200	< 2.5

3. RESULTS AND DISCUSSION

Rawapening's water quality measurements indicate different outcomes in 2020 and 2022. A decrease in the abundance of water hyacinth is one of the critical causes that can lead to this. The water hyacinth is an aquatic plant with high environmental adaptability. Since water hyacinth is one of the world's most invasive and aggressive plant species, it is essential to routinely map its spread to stop it from blossoming in specific bodies of water (Pandurang & Sagar, 2017). Under various circumstances, this plant can act as a remediation agent against various pollutants and pollutant agents (Nazir et al., 2020; Ting et al., 2018). Due to the abundance of nutrients in these waters, the water hyacinth in Rawapening develops as a polluting agent. According to the results of the visual interpretation, Rawapening's water hyacinth covers an area of about 1170.58 hectares and 236.03 hectares, respectively, in 2020 and 2022 (Figure 2). Lake Rawapening's topography has a significant impact on the vegetation cover area.

Located in a valley and surrounded by hills and mountains, Rawapening Lake is a low-lying body of water. The ecosystem has undergone extremely high dynamics in the hilly and mountainous regions. Changes in land use and cover that are inconsistent with their designation are among the causes of high dynamics in the hilly and mountainous areas, among other things. Natural phenomena have the potential to degrade an environment if its land use and cover do not match its designation. Erosion is one of these natural occurrences. According to Indriyanto et al. (2019) research findings, the amount of land used for settlements and industry in the Rawapening Water Catchment Area (DTA) expanded dramatically between 2013 and 2018 by 56.63% and 10.38%, respectively. The land was produced when vegetation-covered ground in the upstream region was turned into a development site. Rawapening Lake receives its primary water supply from the upstream Rawapening Catchment Area so this action will impact the lake's water quality. Water runoff will increase in watershed areas where built-up land predominates if water from the hydrological cycle flows on the ground surface without being absorbed first. Due to the removal of the subsurface layer, this land has a low capacity for infiltration and percolation processes, making it highly vulnerable to erosion. Soil layers holding different nutrients will be removed through erosion and transferred into water bodies, culminating in the sedimentation phenomenon.

Currently, it is thought that Rawapening has more than 1000 tons of sediment. This figure is approximate and subject to change due to the numerous neighborhood activities in the Rawapening region. Different aspects of water quality, including TSS, chlorophyll-a, and DO, are impacted by sediments. TSS is sediment-associated suspended particles having a diameter greater than 1 mm. As a result of this parameter, sunlight won't be able to penetrate the water body because it will make it appear murky. The photosynthesis of phytoplankton depends on sunshine. Low concentrations of dissolved oxygen (DO) and chlorophyll-a in water are caused by phytoplankton that receives insufficient sunlight. Aquatic biotas depend on both of these for survival and reproduction. On the other side, the high nutritional content of the TSS in Lake Rawapening also affects the high chlorophyll-a content. According to the expression algorithm's findings, the average values for the parameters TSS, chlorophyll-a, DO, and brightness, respectively, in 2020 and 2022 were 43,256 mg/L; 7,427 ug/L; 5,07 mg/L and 29,282 mg/L; 9,23 ug/L; 5,12 mg/L; 3,230 m (Figure 2).

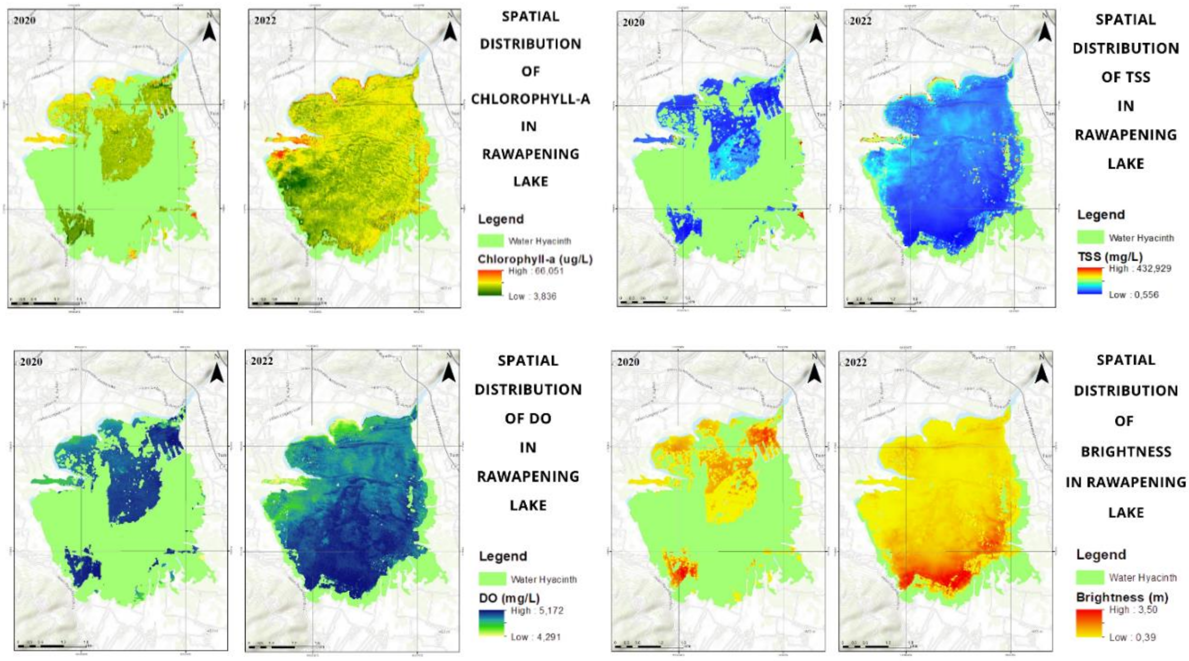

Figure 2. Map of water quality in Rawa Pening with the studied parameters.

TSS, chlorophyll-a, DO, and brightness parameter values exhibit different outcomes in 2020 and 2022. The distribution of water hyacinth significantly influences the importance of the parameters examined in this study. Compared to 2020, the area occupied by water hyacinths will shrink by 934.55 ha in 2022. The Pemali Juana River Basin Agency (BBWS) and the Diponegoro Regional Military Command can work together to achieve this aim (BBWS Pemali Juana, 2021). This work involved extensively cleaning and removing water hyacinths in Rawa Pening, which led to a sharp decline in the water hyacinth cover.

The massive decline in water hyacinth cover significantly impacts the quality of the waters of Rawapening Lake. When the water hyacinth is subjected to weathering, organic materials will be produced as nitrate and phosphate. As a result, there will be more nutrients, which will cause the eutrophication problem (Wulandari, 2022; Noegraha et al., 2014). Additionally, there is a favorable association between Lake Rawapening's sedimentation phenomenon and water hyacinth weathering (Apriliyana, 2015). As a result, periods with a high distribution of water hyacinths will have more excellent water turbidity levels. The capacity of sunlight to penetrate these waterways is negatively correlated with water turbidity. If the ability to penetrate sunlight into water is at a low level, the oxygen content in the water will be low. The primary cause of this is the limited amount of sunlight that the phytoplankton receives of how much sunlight the phytoplankton gets.

The level of contamination in Lake Rawapening, as indicated by the sodium and phosphorus content, is determined using parameter values. Chlorophyll-a and water brightness levels were used in this study to quantify the trophic state of Lake Rawapening. Lake Rawapening has a eutrophic status for the most part, according to the findings of the chlorophyll-a test and the brightness of the water. The trophic status of water in lakes with excessive fertilizer levels is called eutrophic. This rating means that Lake Rawapening's water has been contaminated with higher quantities of phosphate and nitrogen (Astutui et al., 2022).

The lake Rawa Pening water quality status that was determined is an estimation of the outcomes of the algorithm's expression. This paper's limitation is that the algorithm expressions' results must be validated. Furthermore, the values of chlorophyll-a and brightness separately are used to determine trophic status. However, this report has shown that remote sensing data may be used to evaluate water quality, making it more effective and efficient.

4. CONCLUSIONS

Estimation of changes in water quality in Lake Rawa Pening is limited only by the distribution of water hyacinth and water parameters such as TSS, chlorophyll-a, DO, and water brightness. In 2022, there will be a decrease in the percentage of water hyacinths and the water parameters studied in this paper compared to 2020. The reduction in water hyacinth cover is due to synergy activities between the government and the military. The modeling results indicate that Lake Rawa Pening is mostly at eutrophic status. The water quality status of Lake Rawa Pening obtained is an estimation of the expression of the algorithm used with limitations based only on the level of water brightness and chlorophyll-a and without validation. These results also indicate that water quality modeling can be estimated using remote sensing data, making it more effective and efficient.

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