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SPATIAL AND TEMPORAL DISTRIBUTION OF AQUATIC PLANTS IN JATILHUR RESERVOIR BASED ON SATELLITE IMAGE DATA AND THEIR INFLUENCE

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ABSTRACT

Spatial and Temporal Distribution of Water Plant Based on Satellite Imagery and the Effect in Jatiluhur Reservoir. The presence of water vegetation in lakes or reservoirs can change the water's ecology. Water vegetation in Jatiluhur Reservoirs is dominated by water hyacinth (Eichhornia crassipes). Water hyacinth in lakes or reservoirs becomes an invasive weed that can cause ecological degradation. Jatiluhur Reservoir is one of the water bodies affected by the uncontrolled growth of water vegetation. The study was conducted to determine spatial and temporal distribution pattern of water vegetation and its effect in Jatiluhur Reservoir. Spatial and temporal distribution of water vegetation was analyzed using Sentinel-2A satellite image data. The Normalized Difference Vegetation Index (NDVI) algorithm was used to see the distribution of water vegetation in the reservoir waters. The results of observations show the movement of water vegetation starts from the inlet area, then moves along with the flow of water to the center of the reservoir and finally accumulates in the outlet area. The correlation between the cover area of vegetation and month of observation obtained the equation y=662.5x + 128.1. Based on the equation, the increasing cover area of vegetation in the Jatiluhur Reservoir is predicted to reach 128.1 ha per month. Physical method used for controlling growth and distribution of vegetation (water hyacinth) in Jatiluhur Reservoir by taking in the waters. Efforts to control vegetation physically must notice the increasing rate of water hyacinth distribution.

INTRODUCTION

Several types of aquatic plants that live in the waters of lakes and reservoirs include Azolla sp., Spirodela sp., catfish eyes (Lemna sp.), kiambang (Salvina sp.), apu wood (pistia sp.), and water hyacinth (Eichhornia crassipes) [(1)]. Water hyacinth is a type of aquatic plant that is known as an invasive weed in lakes or reservoirs almost all over the world, posing a significant threat to the aquatic environment. [(2)]. Water hyacinth plants are a type of grass that lives freely floating on the water surface and can spread quickly. The water hyacinth plant originates from the Amazon River basin, South America (North America, South America, East Africa, and Asia [(6)], as well as several water bodies in Indonesia [(7–11)], comprise its current distribution. –11). Hyacinth can grow in stagnant (lentik) and flowing (lotic) waters. [(12)]. As an invasive weed, water hyacinth can cause ecological degradation in lakes [(13)].

Sediment surface conditions that are rich in organic matter and nutrients are a suitable habitat for the growth of water hyacinth. The growth of water hyacinth in water tends to be uncontrolled. We categorize this plant as an invasive weed, posing a significant threat to the aquatic environment, as it occurs in various water bodies [2]. The entry of water hyacinth into a body of water causes changes in the brightness of the water, the hydrological cycle, the concentration of dissolved oxygen, the concentration of organic matter, and other pollutants found in the water [14].

The high nutrient content in the water can trigger a fertilization process (eutrophication) that leads to the spread and growth of water hyacinth in a water area [2]. In tropical and subtropical areas, the uncontrolled presence of water hyacinth in waters has a negative impact on fisheries, navigation, hydropower, irrigation, and recreation activities in reservoirs. The conditions under water hyacinth cover become anoxic due to dead plant remains [15]. The presence of water hyacinth has an economic impact, reducing fishermen's income and increasing transportation costs [16].

Researchers have widely monitored the distribution of water hyacinth using remote sensing data and Geographic Information System (GIS) applications, including in the Saguling Reservoir, West Java [8], Lake Victoria, Kenya [16], Lake Tana, Ethiopia [2], and Lake Tondano [17]. Satellite imagery and remote sensing data provide an alternative for monitoring the distribution of water hyacinth in waters. One of the advantages of remote sensing data is its ability to retrieve data synoptically, spatially, and temporally, while also covering a wide area. In addition, the use of remote sensing data is free, so it can reduce research costs.

Jatiluhur Reservoir is a reservoir with multiple functions, including as a hydroelectric power plant (PLTA), irrigation, flood control, tourism, drinking water provider, and fisheries. [18]. Jatiluhur Reservoir became one of the water bodies affected by the uncontrolled growth and spread of water hyacinth. Some of the activities affected by the presence of water hyacinth in the Jatiluhur Reservoir include fishing activities, fishing and tourism boat transportation, and rowing sports training activities. This research aims to predict the spatial and temporal distribution of water hyacinth and its influence on the Jatiluhur Reservoir using remote sensing data from satellite images and GIS applications. The research aims to provide crucial insights for formulating management and control strategies for aquatic plants like water hyacinth in the Jatiluhur Reservoir.

MATERIALS AND RESEARCH METHODS

We conducted the research at the Jatiluhur Reservoir, located in the Purwakarta Regency area of West Java (Figure 1). Jatiluhur Reservoir has a surface area of approximately 7720 ha, a maximum length of 14 km, and a maximum width of 15.5 km [18]. Jatiluhur Reservoir's maximum depth is approximately 90 m, with an average depth of 48 m.

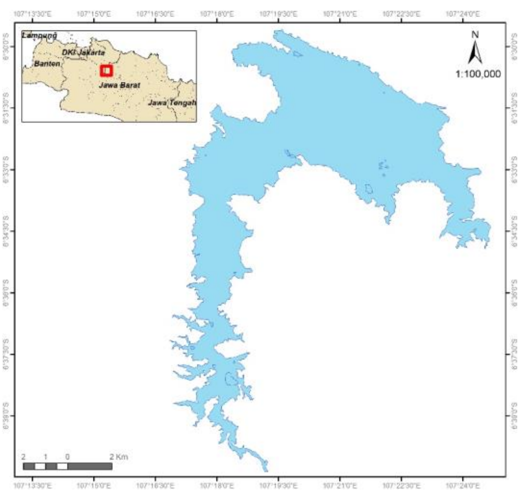

Figure 1. The map shows the location of the Jatiluhur Reservoir research site.

The research uses the following data:

The Sentinel-2A satellite image

We used Sentinel-2A satellite imagery from the January-December acquisition to describe the distribution and abundance of water hyacinth in the Jatiluhur Reservoir. Cloud cover around the research location limited satellite imagery capabilities, resulting in the analysis of only eight images in 2021 (Table 1).

No	Sentinel-2A Satellite Imagery	Acquisition	Source
1	L1C_T48MYT_A030059_20210325T030946	March 25, 2021	https://glovis.usgs.gov
2	L1C_T48MYT_A030488_20210424T030944	April 24, 2021	https://glovis.usgs.gov
3	L1C_T48MYT_A030774_20210514T030948	May 14, 2021	https://glovis.usgs.gov
4	L1C_T48MYT_A022223_20210608T031000	June 8, 2021	https://glovis.usgs.gov
5	L1C_T48MYT_A022938_20210728T031001	July 28, 2021	https://glovis.usgs.gov
6	L1C_T48MYT_A023224_20210817T031321	August 17, 2021	https://glovis.usgs.gov
7	L1C_T48MYT_A032633_20210921T030951	September 21, 2021	https://glovis.usgs.gov
8	L1C_T48MYT_A032919_20211011T031043	October 11, 2021	https://glovis.usgs.gov

We obtained water depth data by using GPS Map 527xs.

Sentinel-2A satellite imagery is a multispectral satellite image consisting of 13 channels. The channels used in this research are channels in the visible light electromagnetic spectrum with a spatial resolution of 10 m are used in this research, namely the blue channel (B2) (wavelength range 458-523 nm), the green channel (B3) (543-578 nm), the red channel (B4) (650-680 nm), and the near infrared (NIR) channel (B8) (785-899 nm). Separating water bodies from land is carried out using the Normalized Difference Water Index (NDWI) algorithm. (19). The spatial distribution of water hyacinth in Jatiluhur Reservoir was obtained from the analysis of Sentinel-2A satellite image data using the Normalized Difference Vegetation Index (NDVI) algorithm. NDVI is used to measure vegetation by comparing the difference between the Near-Infrared (NIR) channel, where vegetation reflects very strong electromagnetic waves, and the red channel (B4), where vegetation absorbs incoming electromagnetic waves. Figure 2 presents the data analysis flow.

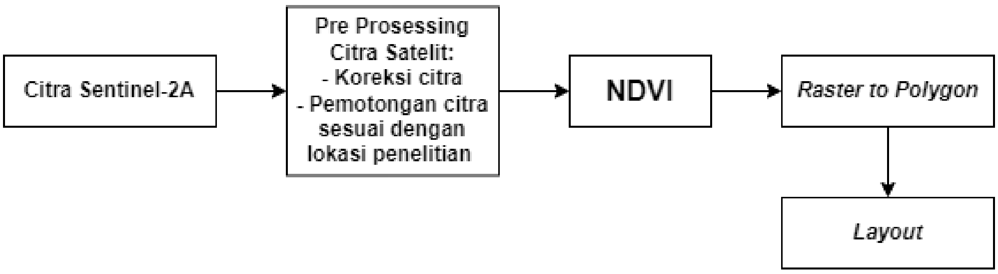

Figure 2.
Flow analysis of water hyacinth extraction from Sentinel-2A satellite imagery

Pre-processing of Sentinel-2A satellite image data was carried out using Quantum GIS (QGIS) software. Atmospheric correction is carried out using the Dark Object Subtraction (DOS) method which is integrated in QGIS. Image cropping according to the research area was carried out to facilitate the analysis process. The NDWI algorithm equation for the Sentinel-2A imagery used is:

$$NDWI = \frac{Green\ (band\ 3) - NIR\ (band\ 8)}{Green\ (band\ 3) + NIR\ (band\ 8)}$$

The NDVI algorithm equation for the Sentinel-2A imagery used is:

$$NDVI = \frac{NIR(band\ 8) - RED(band\ 4)}{NIR\ (band\ 8) + RED(band\ 4)}$$

NDVI is a vegetation index that is widely used and used in satellite assessment and monitoring of vegetation cover globally and has been proven for more than two decades.(20,21).

RESEARCH RESULTS AND DISCUSSION

Figure 3 presents a map of the distribution location of water hyacinth in Jatiluhur Reservoir and the results of the analysis of remote sensing data from Sentinel-2A satellite images using the NDVI algorithm. One of the limitations of remote sensing satellite image data is the presence of cloud cover at the research location, which causes the satellite sensors to be unable to obtain clear images. Describe the research location. In 2021, the research location only had cloud-free images for eight of the 12 months, specifically from March to October. Based on the distribution map in Figure 3, we can see that the distribution of water plants, specifically water hyacinth, in the Jatiluhur Reservoir varies by month. We will delve deeper into the reasons for these monthly fluctuations in water hyacinth cover. In general, water hyacinth movement starts in the inlet area, then moves along the water flow to the middle of the reservoir, and finally accumulates in the outlet area (DAM Jatiluhur Reservoir).

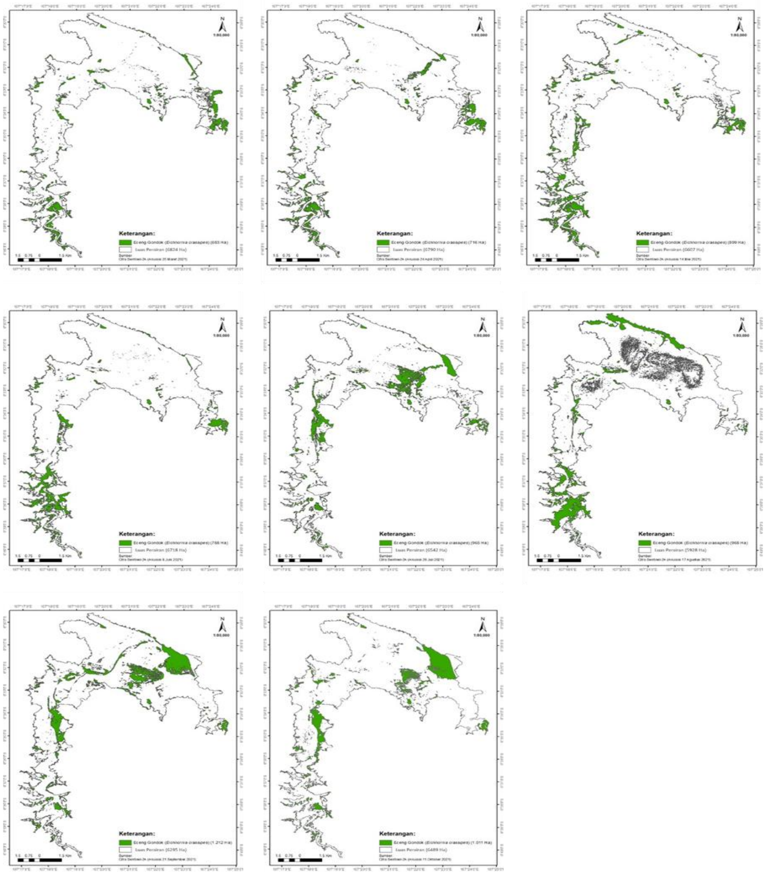

Figure 3. A map of the distribution of aquatic plants (water hyacinth) in Jatiluhur Reservoir based on a month of observation

Apart from distribution maps, the results of satellite image analysis can also predict the extent of water hyacinth cover in the waters of the Jatiluhur Reservoir. The water hyacinth area during the March-October 2021 period ranged from 683-1212 ha, with the percentage of aquatic plant cover to the reservoir area ranging from 10.01-19.25% (Table 2), higher than in the 2013-2019 period, namely 157.92-441.65 ha (22). The correlation between changes in area and month of observation yielded the equation y = 662.5x + 128.1. Based on this equation, the increase in water hyacinth area in the Jatiluhur Reservoir could reach 128.1 ha per month. The area of water hyacinth in the Jatiluhur Reservoir varies and tends to increase (Figure 4).

Table 2. Each month of observation at the Jatiluhur Reservoir reveals changes in the aquatic plant cover and reservoir water area.

Observation Month	Area of Aquatic Plant Cover (Ha)	Reservoir Water Area (Ha)	Percentage of Aquatic Plant Cover (%)
March	683	6824	10.01
April	716	6790	10.54
May	899	6607	13.61
June	786	6718	11.70
July	965	6542	14.75
August	968	5928	16.33
September	1212	6295	19.25
October	1011	6489	15.58

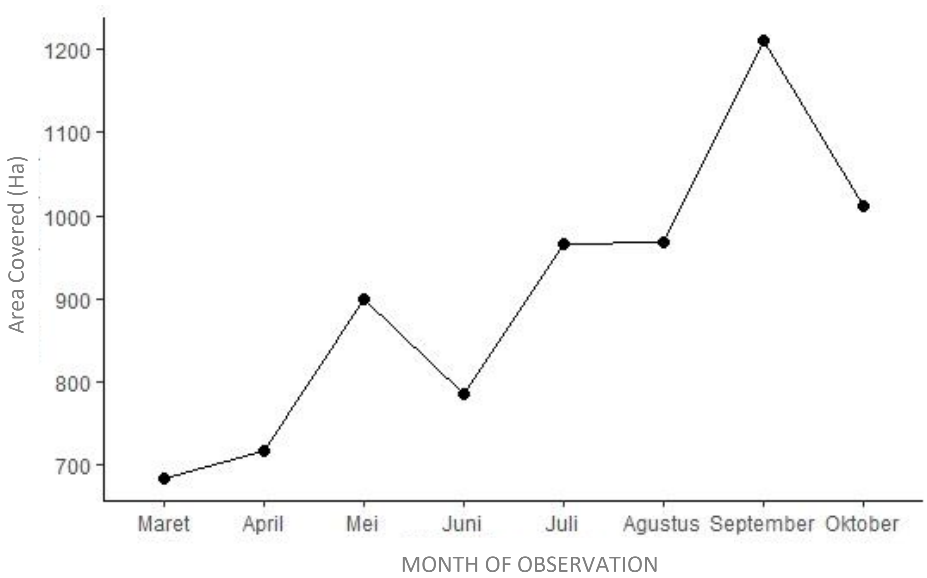

Figure 4. The graph illustrates the changes in the water hyacinth area in Jatiluhur Reservoir over a month of observation.

The highest area of water plant (water hyacinth) cover occurred in September 2021, reaching 1212 ha. This occurred; it is suspected that there was shallowing due to the reduction in the reservoir area in August (5928 ha). The aquatic plant hyacinth thrives at relatively shallow depths of less than 6 meters [2, 3]. At relatively shallow depths, water hyacinth can utilize organic material found at the bottom of the water. In deeper waters, water hyacinth tends to grow less optimally, especially in waters with low fertility levels (oligotrophic). Figure 6 presents overlapping maps of water hyacinth distribution (September 2021) and water depth (bathymetry) of the Jatiluhur Reservoir.

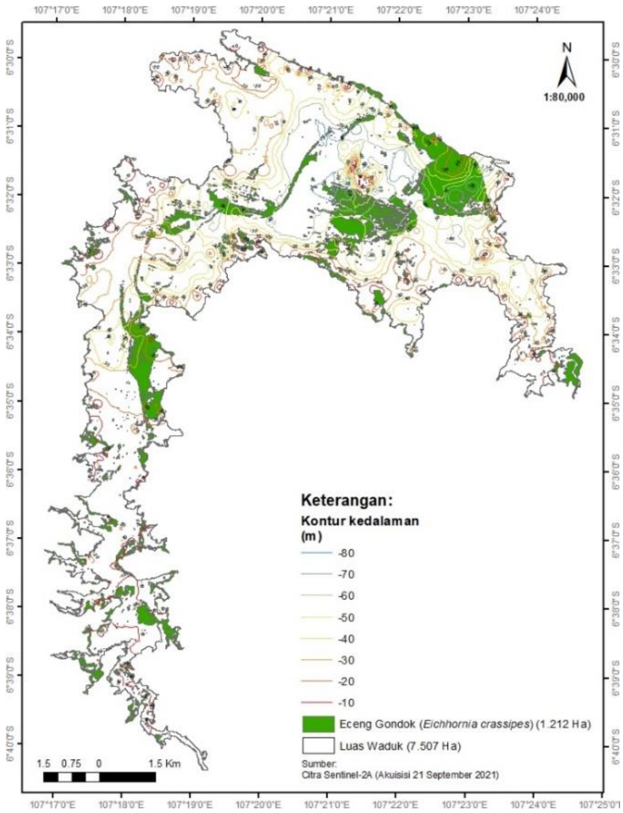

Figure 5. The map of water hyacinth distribution from September 2021 includes water depth data from Jatiluhur Reservoir.

However, the monthly distribution of water hyacinth (Figure 3) reveals the presence of this plant in nearly all water bodies, including the inlet, the waters surrounding the KJA, and the outlet of the Jatiluhur reservoir. Jatiluhur Reservoir water hyacinth distribution in 2013–2019 was similar around the inlet and KJA (22). This wide distribution can occur in very fertile (hypertrophic) waters, so water hyacinth can grow well in deeper waters. It is impossible to inhibit the growth of water hyacinth in eutrophic waters [(23)].

The presence of water plants (water hyacinth) covering some water bodies has had a negative impact on business activities in the Jatiluhur Reservoir. [(24)]. There have been numerous attempts to decrease the water hyacinth cover area through physical, chemical, and biological methods. While direct collection or the use of machines for physical control of water hyacinth is considered effective and immediate, it tends to be slow and expensive. [(25)]. Apart from that, dealing with water hyacinth physically requires a location for the disposal of water hyacinth waste taken from the waters. The management of the Jatiluhur Reservoir has employed physical methods to control water hyacinth, specifically by extracting it from the waters. Efforts to control water hyacinth physically must pay attention to the rate of increase around the water hyacinth itself. This means that the speed of physically harvesting water hyacinth is faster than increasing the area of water hyacinth. Therefore, it's possible to decrease the water hyacinth's surface area. [(2)] suggests a more in-depth study of the impact of wind on the movement of water hyacinth, which could aid in the development of control and management strategies in the future.

Efforts to mechanically control water plants (water hyacinth) in Rawapening are considered unsuccessful because the primary factors causing the growth of water hyacinth, namely nutrients, remain elevated. [(9)]. According to [(10)], all stakeholders—government and society—must collaborate to effectively use and manage reservoirs and watersheds that enter the reservoir waters, thereby improving the reservoir's quality status and preventing the rapid growth of water hyacinth. You can utilize water hyacinth not only as a weed in the water, but also as a fertilizer or craft material. In controlled quantities, water hyacinth can also benefit aquatic ecosystems by serving as a spawning area [9].

CONCLUSIONS AND RECOMMENDATIONS

The increase in water hyacinth cover during 2021 is around 128.1 ha per month. In the Jatiluhur Reservoir, the distribution of water hyacinth tends to follow the flow of water from the inlet to the outlet. The presence of water hyacinth covering parts of the reservoir waters has a negative impact on the functions and business activities in the Jatiluhur Reservoir. Efforts to control water hyacinth in the Jatiluhur Reservoir are carried out using physical methods by taking the water hyacinth in the waters. We recommend conducting routine and sustainable control efforts. This may involve periodically scheduling the physical removal of aquatic plants each month to prevent excessive accumulation. Physical efforts to control water hyacinth must consider the rate of growth in the water hyacinth's own area. In addition to physical methods, consider using biological control methods, such as the introduction of natural control insects, such as the beetle Neochetina eichhorniae, which has proven effective in controlling water hyacinth populations in some areas.

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