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Research Paper

Plant Density on Tidal Marsh Land Using Sentinel-2A NDVI Analysis Based on Land Drainability in Sri Mulyo Village, Indonesia

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Abstract

Tidal marshlands have significant potential for agriculture, despite being affected by fluctuations in sea and river water. This study aims to analyze changes in vegetation density on agricultural land in Sri Mulyo Village, Air Saleh Sub-district, Banyuasin Regency, South Sumatra, using Sentinel-2A satellite imagery and the NDVI (Normalized Difference Vegetation Index) method. Observations were conducted in February, during the wet season, recorded a rainfall of 381 mm, while August, in the dry season, recorded a rainfall of 17 mm, based on data from the BMKG Climatology Station in Palembang for the year 2024, focusing on land cover changes in vegetation density under two different seasonal conditions. The analysis showed a decrease in the area with high vegetation density in August (56.01%) compared to February (63.97%), due to low rainfall and decreased soil moisture in the dry season. In contrast, the medium vegetation category increased in August. These findings suggest that seasonal variations significantly affect vegetation cover and productivity of tidal marshlands. as a consequence, during the dry season, increased drainability and reduced soil moisture contribute to a decline in vegetation density, with the percentage of areas categorized as "High Greenness" decreasing to 56.01% and those categorized as "Moderate Greenness" increasing to 36.17%. These findings emphasize the crucial role of rainfall in sustaining vegetation in tidal marshlands, particularly under varying seasonal conditions.

Keywords

Tidal swamp land, NDVI, Sentinel-2A, Seasonal variation, Vegetation density

1. INTRODUCTION

Tidal marshland is an area that is influenced by the tides and rivers (Susilawati et al., 2016). In general, tidal marshland will be affected by changes in sea and river levels (Arsyad et al., 2014). Although known as suboptimal land, tidal marshlands have great potential to significantly increase productivity (Subagio, 2019). In Indonesia, tidal marshlands cover an area of about 20.12 million hectares, consisting of potential land, acid sulfate land, and saline land. Of this total, around 8,535,708 hectares are tidal marshlands that have the potential to be developed as agricultural areas (Ritung et al., 2014). Given the vast area of tidal marshland that has the potential to be used as agricultural land, Rasyid and Imanudin (2021) emphasized that land production in tidal marshlands is highly dependent on the physical conditions of the land, such as water status and soil fertility. With great development potential, tidal marshlands have significant opportunities to be utilized as productive agricultural land.

Tidal marshland is an area directly affected by tidal and river fluctuations, which contribute to changes in its hydrological conditions (Susilawati et al., 2016; Arsyad et al., 2014). Land drainability, which refers to the ability of the land to lower the groundwater level to the average level of the water surface in the river or channel, is one of the important factors that determine the management potential of tidal marshland. Based on the level of drainability, tidal marshland can be grouped into three types, namely the type with shallow drainability (less than 30 cm), the type with medium drainability (between 30 and 60 cm), and the type with deep drainability (more than 60 cm) ((Herawati et al., 2020).

The potential drainage depth of tidal marshland describes the ability of the land to lower the water table, which affects plant growth (Batara, 2016). Land drainability is influenced by factors such as land elevation, tidal influence, and channel characteristics, which determine the effectiveness of lowering the water table (Syah, 2016). The greater the tidal fluctuation, the higher the potential for land drainage, which impacts the depth of groundwater and the level of inundation as an indicator of drainability (Imanudin et al., 2023). Therefore, an understanding of tidal marshland drainability is essential for optimal management, especially in the context of agriculture which is highly dependent on the physical and hydrological conditions of the land. Tidal marshland productivity is influenced by water status and soil fertility Imanudin (2017). Variations in water status require proper management, one of which is by controlling the water table to create optimal conditions for plant root growth (Imanudin et al., 2020sitasi). Water level regulation can be done by using control sluice gates in tertiary channels to maintain proximity to the root zone (Bakri et al., 2018). To increase rice productivity, the development of tidal swamp land is one solution, although there are limiting factors in its utilization (Alwi, 2014; Shabrina et al., 2021).

Sentinel-2 has an important role in land monitoring, providing baseline data that can be used for various environmental monitoring and planning applications (Awaliyan and Sulistioadi, 2018). Sentinel-2A imagery, with its high spatial and temporal resolution, opens up opportunities for more detailed and accurate analysis. With its ability to capture multispectral data, Sentinel-2A enables more precise identification of vegetation and land cover changes (Phiri et al., 2020). Land cover change is a significant aspect as it impacts ecosystems and the environment as a whole. Sentinel-2A imagery has a number of advantages in the analysis of land cover and vegetation density, such as high resolution (10-20 meters), short visit frequency, and the red-edge band which is very useful for vegetation mapping (Silveira, 2019). The combination of these spectral bands enables the development of vegetation indices that provide quantitative information related to vegetation condition, such as plant health, water content, and stress levels. One such index, the NDVI (Normalized Difference Vegetation Index), has long been utilized in classification studies due to its ability to distinguish between vegetation and non-vegetation as well as wet and dry areas (Sibanda et al., 2015). Sri Mulyo Village, where most of the population is engaged in rice farming, was the location of this study. This study aims to observe the differences in land cover and identify the percentage of land cover change.

2. EXPERIMENTAL SECTION

2.1 Research Location

This research was conducted in February and August 2024 in Sri Mulyo Village, Air Saleh Sub-district, Banyuasin Regency, covering an area of 1,751 hectares. The following map shows the specific location of the study area in Sri Mulyo Village

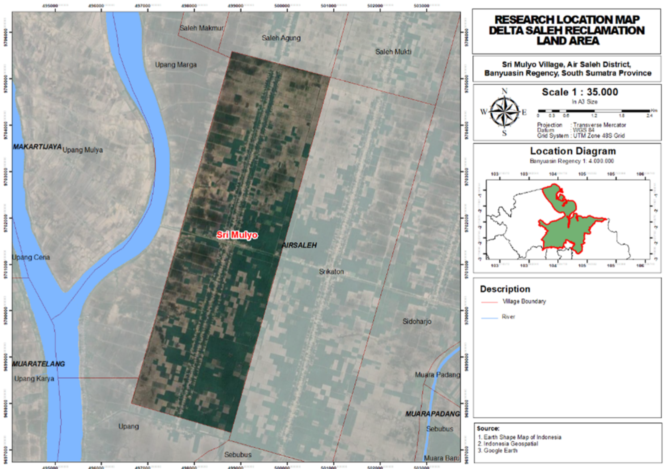

Figure 1. Research Location Map

2.2 Material and Method

The tools used in this research include, 1) Groundwater Level Monitoring Tool (Wells Pipe), 2) Laptop Furthermore, the materials used in this research activity include, 1) Sentinel-2A image, 2) Google Earth Satellite Imagery, 3) BMKG (Meteorology Climatology and Geophysics Agency) Rainfall Data for February and August, 3) Indonesian Landform Map of South Sumatra at the Regency, District and Village Levels. This research method uses a method by collecting data sources from Sentinel 2A images. The research was carried out in several stages starting from a literature review, by reading journals and articles related to remote sensing, vegetation density, NDVI, and others.

2.3 Data Collection

Rainfall data were obtained from the BMKG Climatology Station records in Palembang City, while groundwater level measurements were conducted using pipe wells located in Sri Mulyo Village. Groundwater levels were measured to assess the drainability of the land by determining the deepest water table depth that can be drained. Based on drainability criteria, tidal marshlands can be classified into three types: shallow drainability (less than 30 cm), medium drainability (30–60 cm), and deep drainability (more than 60 cm) (Herawati et al., 2020). Then proceed with image processing using relevant spectral bands from sentinel 2A images to analyze vegetation density. In this research, the data used is sentinel-2 image data. This image data was chosen because this image is good for conducting vegetation analysis because it has a high resolution (Fahmi et al., 2023). The data used in this study used Sentinel-2 images in 2024 in February and August. The sentinel-2 image has 12 bands as listed in the Table 1:

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Table 1. Types of 12 Bands in Sentinel 2A Imagery

Sentinel-2 Band	Cetra Wavelength	Reso-lution
Band 1 – Coastal aerosol	0,443	60
Band 2 – Blue	0,49	10
Band 3 – Green	0,56	10
Band 4 – Red	0,665	10
Band 5 – Vegetation Red Edge	0,705	20
Band 6 – Vegetation Red Edge	0,74	20
Band 7 – Vegetation Red Edge	0,783	20
Band 8 – NIR	0,842	10
Band 8A – Vegetation Red Edge	0,865	20
Band 9 – Water vapour	0,945	60
Band 10 – SWIR – Cirrus	1,375	60
Band 11 – SWIR	1,61	20
Band 12 – SWIR	2,19	20

2.4 Data Analysis

Image processing is done by classifying land cover using the Maximum Likelihood Classification algorithm to distinguish land cover based on vegetation density. The image correction stage was carried out using ArcGIS software, with atmospheric correction aimed at clarifying objects in the image so that they are easier to analyze during NDVI processing (Isbaex and Coelho, 2021). This stage uses the latest cropped image with the best quality to be segmented.

The classification process is performed iteratively with evaluation at each cycle to improve accuracy and effectiveness. Each accuracy result is used to optimize the model until it reaches the desired classification. This Spiral method allows a flexible and adaptive approach to data variations, resulting in a more accurate and reliable classification (Abbas et al., 2020). Digital image segmentation is performed by determining the combination of band parameter values used in NDVI processing, separating objects based on vegetation density.

The analysis results are divided into 5 classifications according to the NDVI class parameters, which can be seen in Table 2. In Sentinel-2 images, the bands used for NDVI processing are Band 4 (red wave) and Band 8 (Near Infrared/NIR). Below is the NDVI (Plant Density Index) formula, among others:

$$NDVI = (NIR - Red)/(NIR + Red)$$

Description:

NIR = near infrared radiation channel of the pixel,
Red = red light radiation channel of the pixel

NDVI values range from -1 (unvegetated land) to +1) dense and thick vegetation). There are 5 classes in NDVI :

Table 2. Criteria NDVI (*Normalized Difference Vegetation Index*)

Class	NDVI	Description
1	-1 s/d -0,03	Non-Vegetated Land
2	-0,04 s/d 0,15	Very Low Greenness
3	0,16 s/d 0,25	Lace Greenness
4	0,26 s/d 0,35	Moderate Greenness
5	0,36 s/d 1,00	High Greenness

(Source: Regulation of the Indonesian Minister of Forestry number P.12/ Minister of Forestry - II/2012 in (Fadlillah et al., 2018)

3. RESULTS AND DISCUSSION

3.1 Rainfall

Based on Rainfall Data Sourced from the South Sumatra Climatology Station in February with a total of 381 mm and August with a total of 17 mm which can be presented in graphical form in the form of a comparison as follows

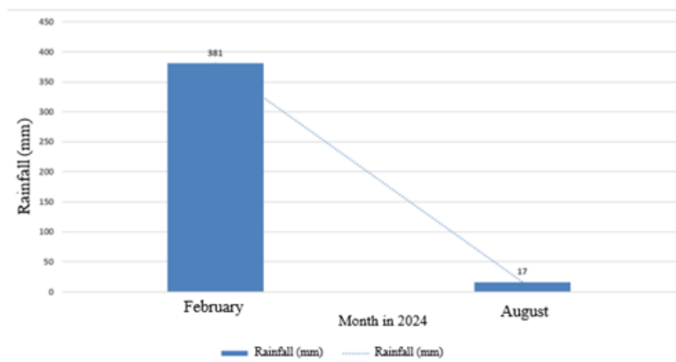

Figure 2. Rainfall Comparison Chart

From the data above we can see the wet months and dry months where (Months With Rainfall > 100 mm) and the number of dry months, (Months With Rainfall < 60 mm) (Laimeheriwa et al., 2020). Which can be seen in the graph above, February is a wet month while August is a dry month. From the data that has been presented, we can understand the pattern of land cover change and environmental conditions in Sri Mulyo Village based on differences in rainfall between February and August 2024. Based on the criteria of wet months with rainfall of more than 100 mm and dry months with rainfall of less than 60 mm (Laimeheriwa et al., 2020), it can be seen that February is a wet month, while August is classified as a dry month. This condition has a significant impact on differences in soil moisture and vegetation cover in the study area.

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3.2 Land Drainability

Land Drainability data is taken by direct observation in the field throughout the month of observation to determine the condition of the groundwater level at the study site and data processing is carried out in the form of looking at the smallest, average and largest data values at the study site, the following are the results of observations of the groundwater level at the study site

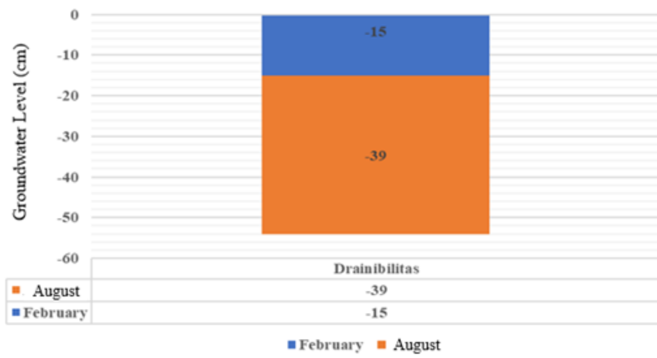

Figure 3. Groundwater Level Graph

The graph shows a comparison of groundwater levels in Sri Mulyo Village in February and August in three categories: minimum, average and maximum, in cm. The minimum water table was recorded at -39 cm in August while in February it was -15 cm. The Potential Drainability class in tidal marshland with overflow type B in February was only less than 30 cm with shallow drainability while in August the Drainability was moderate because the water table was 30 cm to 60 cm with moderate drainability category. In February, the water table was lower and in the Shallow Drainability category with a depth of less than 30 cm, corresponding to the Potential Drainability overflow class B. Meanwhile, in August, the water table was in the range of 30 cm to 60 cm, which falls into the Medium Drainability category. This difference in conditions indicates that soil moisture is higher in August, which could potentially affect the drainage ability of the land and could have an impact on plant growth and vegetation density in Sri Mulyo Village. Type B belongs to tidal land that is only inundated with water during high tides. (Masulili, 2015sitasi). The potential drainage depth of tidal marshland describes the ability of the land to lower the water table, which affects plant growth Batara (2016). Land drainability is influenced by factors such as land elevation, tidal influence, and channel characteristics, which determine the effectiveness of lowering the water table (Syah, 2016).

3.3 Plant Density Index (NDVI)

Sentinel 2 image data was chosen because this image is good for conducting vegetation analysis because it has a high resolution (Fahmi et al., 2023). The Spidral method allows a flexible and adaptive approach in the face of data variations, resulting in more precise and reliable classification results (Abbas et al., 2020). Vegetation has various types that can be seen in the image recording results that represent differences in vegetation types. This difference will result in different biomass due to differences in volume density between different vegetation types (Iskandar et al., 2015).

Various images can be used to help analyze vegetation, one of which is sentinel imagery, which is selected according to need. Sentinel-2 imagery consists of 13 spectral bands, including 4 bands with a 20 m spatial resolution and 3 bands with a 60 m spatial resolution, covering a swath width of 290 km, as shown in Table 1. Sentinel-2 can be used for land monitoring purposes, basic data for land use that can be used for various environmental monitoring and planning applications (Awaliyan and Sulistioadi, 2018).The results of the plant density index analysis on tidal marshlands in Srimulyo Village can be visualized using the map below so as to get the category, presentation and area of comparison between the two different drainability classes in two different months affected by rainfall and different drainability classes compared to those presented below.

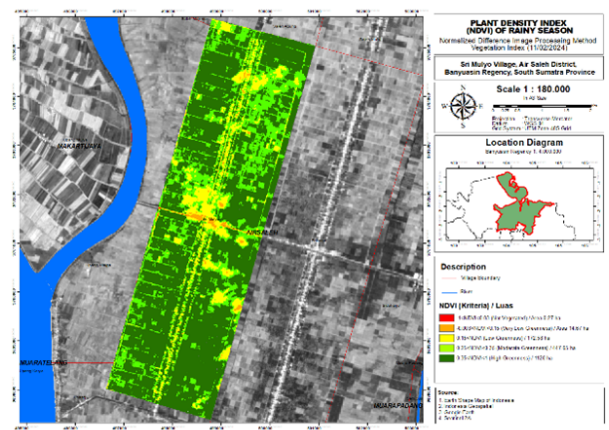

Figure 4. NDVI Wet Month (February)

From the results of the NDVI analysis above, it can be seen that the percentage results and the comparison area between the two lands are as shown in Table 3.

The Table 3 shows the classification of vegetation density (NDVI) in Sri Mulyo Village in February and August 2024, with land categories from "No Vegetation" to "High Greenness". Each category displays the area in hectares (Ha) and its percentage. Below is a graph of the percentage distribution of plant density.

Furthermore, the classification of vegetation density through NDVI (Normalized Difference Vegetation Index) also shows significant variations between the two months. In February, the majority of the land fell into the "High Greenness" category with an area of 1,120 Ha or 63.97% of the total area. However, in August, the land with "High Greenness" decreased to 981 Ha or 56.01%. In contrast, the

Table 3. Area distribution and percentage of plant density index

NDVI	February 2024		August 2024	
	Area (Ha)	Percentage (%)	Area (Ha)	Percentage (%)
Non-Vegetated Land	0,27	0,02	1,64	0,09
Very Low Greenness	14.67	0,84	5,03	0,29
Lace Greenness	172.58	9,86	130,20	7,44
Moderate Greenness	447.65	25,57	633,24	36,17
High Greenness	1120	63,97	981	56,01
In Total	1,751	100	1,751	100

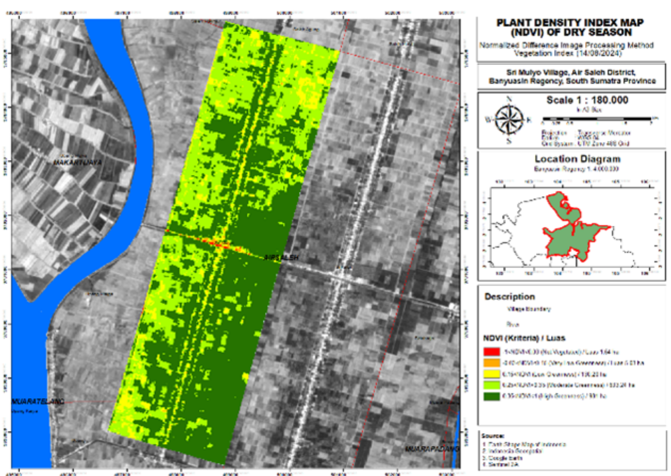

Figure 5. NDVI Dry Month (August)

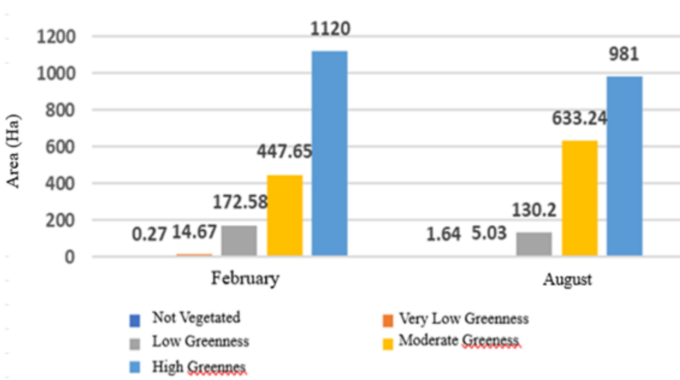

Figure 6. Percentage Chart of Plant Density Index

area of land with "Moderate Greenness" increased to 633.24 Ha or 36.17% in August, indicating a decrease in vegetation density associated with the dry season.

Overall, these data indicate that the decrease in vegetation density and groundwater table in August was caused by lower rainfall and drier soil moisture conditions compared to February. This confirms that the difference in rainfall conditions between the wet and dry seasons directly influences the reduction in paddy field areas. This is evident from the maps in Figures 3 and 4, which illustrate the differences in the condition of rice fields planted during February (wet season) and the dry season, with a noticeable reduction in Greenness due to harvested rice and vegetation density in Sri Mulyo Village. Evolving remote sensing technology, with a variety of sensors and sensing systems, allows for more detailed and accurate vegetation analysis Andiko et al. (2019)

4. CONCLUSION

The difference in rainfall has a direct impact on the drainability of the land. In February, the water table is less than 30 cm deep, categorized as shallow drainability, which supports good water retention in the soil. In contrast, in August, the depth of the water table reached 30 cm to 60 cm, categorized as medium drainability. This indicates an increase in drainability during the dry season. The influence of rainfall and land drainability can be seen in the NDVI analysis results. Vegetation density in Sri Mulyo Village decreased in August due to reduced soil moisture. In February, 63.97% of the area was categorized as "High Greenness," while in August, the percentage decreased to 56.01%. In contrast, the land area categorized as "Moderate Greenness" increased to 36.17% in August. This indicates that the dry season reduces vegetation density due to decreased rainfall and soil moisture.

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