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THE EFFECT OF VEGETATION DENSITY ON THE TOTAL SUSPENDED SOLID (TSS) CONCENTRATION IN THE AQUATIC AREA OF POMALAA DISTRICT

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Abstract: Analysis of the influence of vegetation density levels on the concentration of Total Suspended Solids (TSS) in aquatic areas is crucial in the Pomalaa District, an area characterized by extensive mining activities. This research aims to examine changes in vegetation density conditions and analyze the influence of vegetation density levels on TSS concentrations in the aquatic region. Changes in vegetation density conditions are analyzed through multi-temporal remote sensing image processing using the NDVI method. The TSS concentration is analyzed using the gravimetric method. Meanwhile, the influence of vegetation density level on TSS concentration is analyzed using the Pearson correlation coefficient equation. The results of the research show that there has been an increase in the area with very low levels of vegetation density and a decrease in the area with high levels of vegetation density in the period 2014 to 2023. The calculated results of TSS concentrations at the research location are 78 mg/l to 111 mg/l. The correlation analysis shows that the broader the area with very low vegetation density, the higher the TSS concentration in the aquatic environment. Additionally, the larger the area with high vegetation density, the lower the TSS concentration value of the water at the research locations.

Keywords: vegetation density; total suspended solid; Pomalaa District

INTRODUCTION

The existence of vegetation plays a fundamental role in life. This role is related to ecological, economic, social, and aesthetic functions (Hidayat et al., 2019). Vegetation has a vital role in maintaining natural ecosystems (Noraini, 2022). One function of vegetation is to absorb and store carbon to prevent the effects of greenhouse gases (Dewa & Sejati, 2019). The lack of vegetation can cause an increase in surface temperatures in an area (Mulyana et al., 2023). Lack of vegetation can also affect the physical properties of soil related to volume, capacity, and infiltration rate in a land (Kadir et al., 2022). This further affects the flow of water (surface runoff) over the land surface so that it can cause erosion, landslides, sedimentation, increased suspended solids in waters, and a decline in water quality in coastal areas (Erfina & Sjarmidi, 2019).

One factor that greatly influences the condition of vegetation in an area is human activity, for example, the conversion of

forest areas into cultivation areas. Vegetation conditions are also often influenced by forest fires which often become a global concern (Kumulawati, et al., 2021). Another activity that can cause changes in vegetation in an area is mining activities.

The Pomalaa District area, Kolaka Regency, is one of the regions in Indonesia with enormous mining potential and activity. Mining activities in this region have started since 1974. Mining activities have a positive impact as a source of national and regional income. On the other hand, mining activities will greatly affect environmental conditions, especially the reduction in vegetation and forest areas due to land clearing in mining activities which can cause a decrease in environmental quality.

This research aims to examine conditions of changes in vegetation density and analyze the influence of vegetation density levels on the concentration of Total Suspended Solids (TSS) in the waters of Pomalaa District, Kolaka Regency. TSS is the quantity of material or particles suspended in water (Kurniadin & Maria, 2020). This is one of the parameters for assessing water quality. The greater the concentration of TSS, the more turbidity it will cause in the waters and prevent the penetration of sunlight into the waters, which can hamper the growth of aquatic organisms such as plankton and coral reefs.

This research utilizes remote sensing technology through the use of Landsat-8 images in 2014 and 2018 and Landsat-9 images in 2023 to analyze changes in vegetation density at the research location during that period. The advantage of using remote sensing technology is that it can analyze vegetation density over a wide area without requiring a long time and at an affordable cost. The availability of image data from time to time is also an advantage so that changes can be analyzed that occur over a certain period. Meanwhile, the effect of vegetation density on TSS concentrations in the water areas of each sub-district was analyzed using correlation analysis.

The influence analysis of vegetation density levels on TSS concentrations in aquatic areas is crucial to carry out in the Pomalaa District, Kolaka Regency, which is an area with very massive mining activities. This is an environmental monitoring activitiy to minimize environmental quality degradation so that other resources such as agriculture and fisheries at the research location remain optimal. This research is closely related to the environmental theme. The results of this research are also intended to enrich insight and be used as a reference in environmental management by mining area managers, local governments, and local communities.

LITERATURE REVIEW

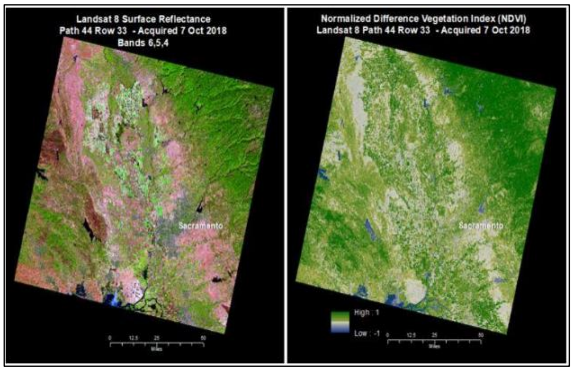
Vegetation Density

Vegetation is a collection of various types of plants in an area that interact with other biotic and abiotic elements in the environment (Yanti, et al., 2020). The percentage of plant species that grow in a certain area is called vegetation density (Wahrudin et al., 2019). The benefits of vegetation which is part of the forest ecosystem are very significant for the existence of fauna and humans. Vegetation is one of the most important aspects of life, as a carbon dioxide absorber and as a habitat for fauna (Masyita, 2022).

A method of determining the level of vegetation density is through remote sensing

image processing using an algorithm *Normalized Difference Vegetation Index* (NDVI). This algorithm utilizes near-infrared (NIR) waves and red visible waves. In Landsat-8 and 9 images, these waves are on channels 5 and 4 (U. S. Geological Survey, 2019). Examples of remote sensing images and NDVI analysis results are presented in Figure 1.

Figure 1. The Results of NDVI Analysis Through Utilization of Landsat-8 Imagery



Source: US Geological Survey, 2021

Landsat image

Landsat imagery is a type of data produced from remote sensing technology for monitoring the environment and various resources. The first generation of Landsat satellites was launched in 1972. Initially with two sensors, namely the Return Beam Vidicon (RBV) and the Multispectral Scanner System (MSS). This sensor has a spatial resolution that is not as detailed as today, namely a resolution of 80 meters with 4 channels/bands (Fawzi & Husna, 2021). In 2013, the Landsat-8 series was launched with two sensors, namely the Onboard Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) with varying spatial resolutions starting from a resolution of 15 meters for the panchromatic channel and 100 meters for the thermal channel.

Most recently, the United States Geological Survey (USGS) in collaboration with the National Aeronautics and Space Administration (NASA) launched the Landsat-9 satellite in 2021. Even though it has sensors and several channels that are no different from previous generations, Landsat-9 provides data that is superior in terms of radiometric and geometric quality compared to Landsat-8 products (U. S. Geological Survey, 2022).

Total Suspended Solid (TSS)

Total Suspended Solid (TSS) is defined as solid particles found/suspended in waters originating from organic and inorganic materials with a size of more than two micrometers (Adhar et al., 2021). TSS is a material consisting of settleable solids, suspended solids and colloids originating from erosion, wastewater discharge, and agricultural waste (Martinez et al., 2021). TSS is one of the optical parameters used as a variable in monitoring turbidity and water quality (Wirabumi et al., 2020).

Determination of TSS or suspended sediment load generally uses the gravimetric method, which is a filtering technique using filter paper. Then the weight of the filter paper before and after filtering is compared based on SNI 6989.3:2019 (Kifly et al., 2021). Other methods related to TSS estimation have also been widely used and developed. This includes estimating TSS using remote sensing technology (Yonar et al., 2021).

RESEARCH METHODS

Research Location

This research was conducted in the administrative area of Pomalaa District, Kolaka Regency, Southeast Sulawesi. The

research location can be seen in Figure 2. Analysis of changes in vegetation density was carried out in the entire Pomalaa District area. Meanwhile, TSS concentration analysis was carried out by taking water samples at six points along the coastal area of Pomalaa District.

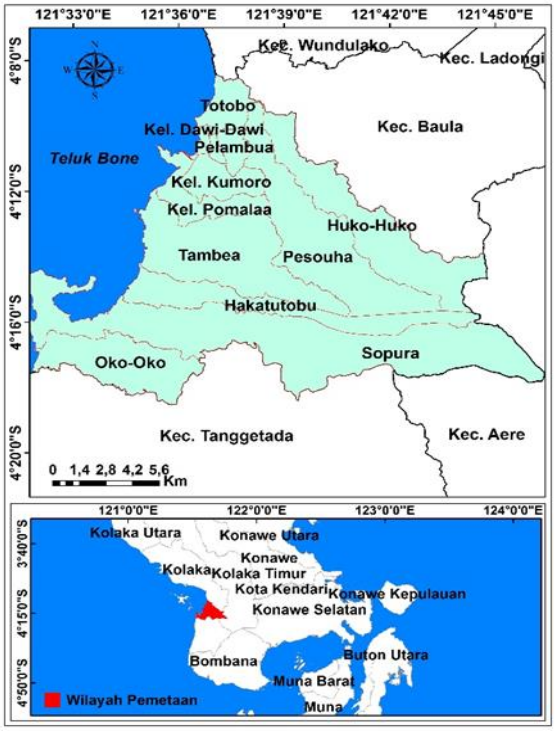


Figure 2. Map of Research Locations

Data Analysis Method

1. Vegetation Density Analysis Using the NDVI Method

Processing and analyzing vegetation density data using the Normalized Difference Vegetation Index (NDVI) method utilizing the ArcMap 10.8 application. The NDVI algorithm utilizes near-infrared (NIR) and visible red (Red) waves in band 5 and band 4 of Landsat 8 and 9 OLI images (Hardianto et al., 2021). Image processing uses the NDVI algorithm to obtain vegetation density values. Each NDVI analysis results on images from a different year were categorized into five classes, namely areas with very high, medium, low, and very low density, and areas without vegetation, and the area of each class was calculated. Method NDVI mathematically uses Equation 1.

$$\textbf{NDVI} = \frac{\text{NIR (Band 5)} - \text{Red (Band 4)}}{\text{NIR (Band 5)} + \text{Red (Band 4)}} \quad \text{.....(1)}$$

Information:
NDVI = Vegetation Density Index
Ed = Red band
NON = Near-infrared band

2. Calculation of Total Suspended Solid (TSS) Concentration

The value or concentration of Total Suspended Solid (TSS) was analyzed using water samples taken throughout the waters of Pomalaa District. The TSS concentration is calculated using the gravimetric method, namely checking the amount of substance by weighing the results of the precipitation reaction. The general work steps are the test sample is filtered using filter paper which has previously been weighed. Then, dried until it reaches constant weight at a temperature of 103ºC - 105ºC. The increase in filter weight represents the amount of TSS concentration. Calculation of TSS concentration using Equation 2.

$$\textbf{TSS (mg/l)} = \frac{(A-B)\ X\ 1000}{V} \quad \text{.....(2)}$$

Information:
A = Weight of filter paper + dry residue (mg)
B = Weight of filter paper (mg)
V = Test sample volume (l)

3. Analysis of the Effect of Vegetation Density on Total Suspended Solid (TSS) Concentration

The influence of vegetation density on the concentration of Total Suspended Solids (TSS) in the waters of Pomalaa District, Kolaka Regency was analyzed using two

variables. The first variable is the area with very low vegetation density and the area with high density within a certain radius, 2 kilometers inland from the TSS sampling point. The second variable is the TSS concentration of the water area which is analyzed using the gravimetric method in the laboratory. Next, these two variables were analyzed using Pearson correlation analysis to produce a correlation coefficient for the two variables. Correlation coefficient using Equation 3.

$$r = \frac{n\sum XY - \sum X \sum Y}{\sqrt{(n\sum X^2 - (\sum X)^2)(n\sum Y^2 - (\sum Y)^2)}} \quad \text{.....(3)}$$

Information:
X = Independent variable
Y = Dependent variable
n = Number of samples

RESULTS AND DISCUSSION

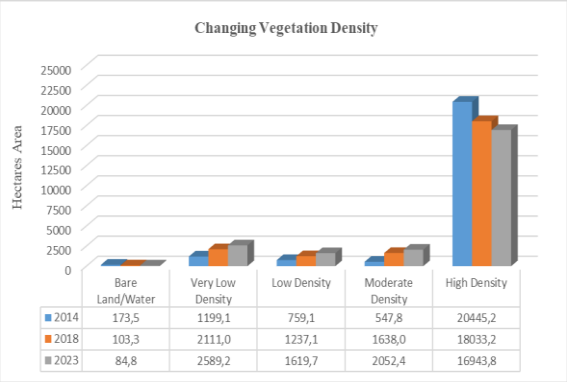
Changes in Vegetation Density in Pomalaa District

Based on the results of processing Landsat-8 image data for 2014, 2018, and Landsat-9 images for 2023 using the Normalized Difference Vegetation Index (NDVI) method, extensive changes in vegetation density were obtained in the Pomalaa District, Kolaka Regency. Changes in the area of each classification of vegetation density can be seen in Table 1 and Figure 3.

Table 1. Changes in Vegetation Density in Pomala District from 2014 to 2023

Classification of Vegetation Density	Area (Hectares)		
	2014	2018	2023
Bare Land/Water	173.5	103.3	84.8
Very Low Density	1,199.1	2111	2,589.2
Low Density	759.1	1,237.1	1,619.7
Moderate Density	547.8	1638	2,052.4
High Density	20,445.2	18,033.2	16,943.8

Figure 3. Graph of Vegetation Density Changes in Pomalaa District from 2014 to 2023



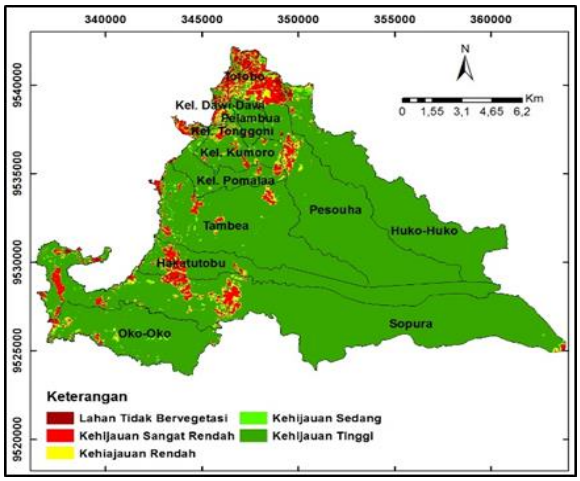
Source: Processing Personal Data

Based on the table and graph information on vegetation density levels, it can be seen that there has been a significant change in the area of each classification in the period 2014 to 2023. The classification of areas with very low vegetation density, low vegetation density, and medium vegetation density tends to increase. In 2014, the areas classified as very low vegetation density, low density, and medium density were respectively 1,199.1 hectares, 759.1 hectares and 547.8 hectares.

Then in 2023, each area increases to 2,589.2 hectares for areas with very low vegetation density, 1,619.7 hectares for areas with low vegetation density, and 2052.4 hectares for areas with medium vegetation density.

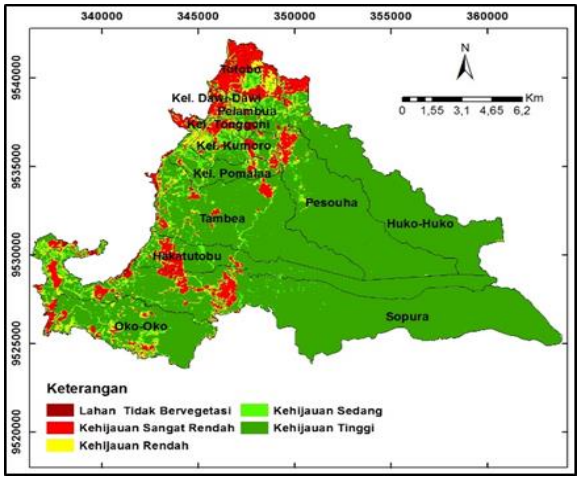
Meanwhile, there was a decrease in the area classified as having high vegetation density, where in 2014 the area reached 20,445.2 hectares. Then it decreased to 18,033.2 hectares in 2018 and in 2023 the area will be 16,943.8 hectares. The distribution of vegetation density classifications in the Pomalaa District, Kolaka Regency can be seen in Figures 4, 5, and 6.

Figure 4. Map Distribution of Vegetation Density Levels in Pomalaa District in 2014



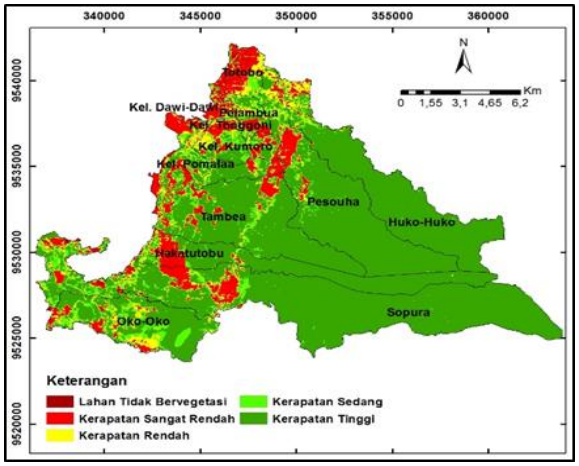
Source: Processing Personal Data

Figure 5. Map Distribution of Vegetation Density Levels in Pomalaa District in 2018



Source: Processing Personal Data

Figure 6. Map Distribution of Vegetation Density Levels in Pomalaa District in 2023



Source: Processing Personal Data

The distribution of areas with very low, low, and medium levels of vegetation density is spread across various villages/sub-districts in Pomalaa District, especially in the northern, western and southern parts of Pomalaa District. In the northern part of Pomalaa District, especially in Totobo Village, low vegetation density is caused by the dominance of land use in the form of ponds. In other sub-districts and villages, namely Dawi-dawi Village, Tonggoni Village, Kumoro Village, Pomalaa Village, Hakatutobu Village, Pelambua Village, the western part of Sopura Village, and the Oko-Oko Village area, the level of vegetation density is low because land use is dominated by residential areas. Nickel mining activities and deforestation (land clearing) in the area are also the main causes of the decline in vegetation density in the area.

Meanwhile, the majority of areas with high vegetation density are spread across the eastern part of the Tambea Village, Pesouha Village, Hakatutobu Village, and Sopura Village areas as well as the Huko-Huko Village area. Some appearances of vegetation density in Pomalaa District can be seen in Figure 7.

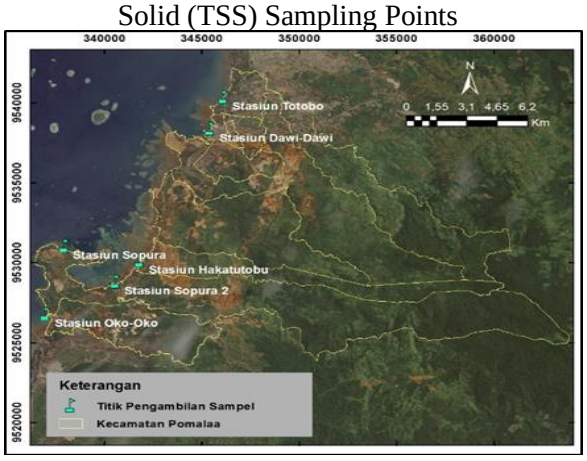
Figure 7. The Vegetation Density Profile in Tonggoni Village in 2023

Source: Processing Personal Data

Concentration Total Suspended Solid (TSS) Water Area

The concentration of Total Suspended Solids (TSS) in the waters of Pomalaa District based on calculations using the gravimetric method of 6 water samples taken throughout the waters ranges from 78 mg/l to 111 mg/l. The distribution of sampling points and the TSS concentration of each point is presented in Figure 8 and Table 2 below.

Figure 8. Map Distribution of Total Suspended Solid (TSS) Sampling Points



Source: Processing Personal Data

Table 2. Sampling Station and Total Suspended Solids (TSS) Concentration in Pomalaa District

Sampling Station Points	**Coordinates**		***TSS Concentration* (mg/l)**
	X	**Y**	
Totobo	346127.1	9540392.8	111
Dawi-dawi	345447.5	9538407.2	100
Hakatutobu	341816.3	9530162.2	98
Sopura	337940.1	9531079.3	78
Sopura 2	340582.0	9528842.9	95
Oko-oko	336984.0	9526827.7	100

Source: Processing Personal Data

The results of the TSS concentration calculation show that the area with the highest TSS levels is the Totobo Village water area with a TSS concentration value of 111 mg/l. Meanwhile, the water area with the lowest TSS concentration is the Sopura water area with a TSS value of 78 mg/l.

Based on the Decree of the State Minister for the Environment Number 51 of 2004 concerning Sea Water Quality Standards, the seawater quality standard for marine tourism is less than 80 mg/l. Meanwhile, the quality standard for marine biota such as mangroves is 80 mg/l and 20 mg/l for coral and seagrass. So, based on the TSS parameters, only the waters of Sopura Village are suitable for use for marine tourism activities and the habitat of several marine biota.

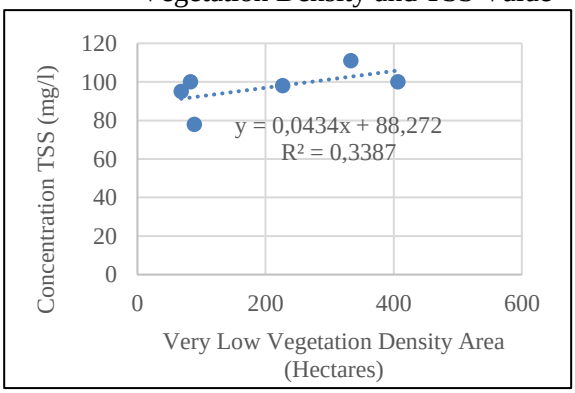
Effect of Vegetation Density Level on Concentration Total Suspended Solid (TSS)

The influence of vegetation density levels on TSS concentrations in the waters of Pomalaa District was analyzed through correlation analysis of two variables. The first variable is the area of vegetation density as an independent variable. This vegetation density level variable includes areas with very low vegetation density and areas with high vegetation density which are determined as far as two kilometers inland from the water sampling point through the buffer process in the ArcGIS application. Calculations are carried out to determine the area of each level of vegetation density. The distance of two kilometers from the water sampling point is assumed to still be a coastal area which can affect water conditions.

The second variable as the dependent variable is the TSS concentration of the water which has been calculated using the gravimetric method in the laboratory. The results of the correlation analysis between the area variable which has a very low level of vegetation density and the water TSS concentration variable show a positive correlation coefficient (r) of 0.58. This value

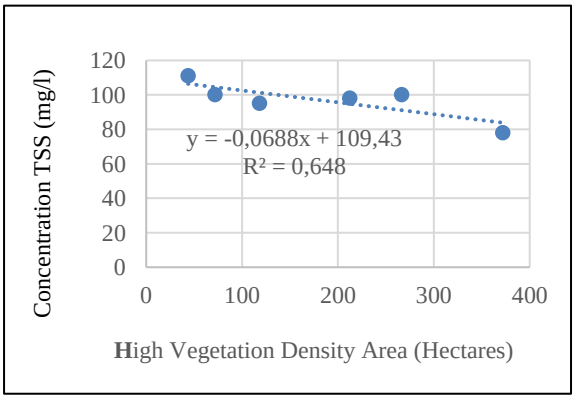
means that areas with very low vegetation density have a strong influence on the high TSS concentration of water areas. Meanwhile, correlation analysis of the variable area that has a high level of vegetation density with the TSS concentration variable shows a negative correlation coefficient (r) of -0.8. This shows that the area with a high level of vegetation density has a very strong influence on the low TSS concentration in the waters of Pomalaa District. The influence of these variables is depicted in Figures 9 and 10 below.

Figure 9. The Correlation Between Very Low Vegetation Density and TSS Value



Source: Processing Personal Data

Figure 10. The Correlation Between High Vegetation Density and TSS



Source: Processing Personal Data

The density of vegetation in an area can influence various things, including the condition of the water area. Areas with low levels of vegetation density will cause high rates of erosion, the erosion of soil particles by water due to the lack of vegetation which can act as a protector of the soil surface and play a role in reducing surface runoff. On the other hand, areas with high levels of vegetation density can protect the soil, thereby minimizing soil erosion which can cause an increase in the concentration of suspended solids in the water.

The results of this research are related to research studying changes in vegetation density in the Blorong watershed on the TSS dynamics of the waters around Kendal Harbor using Landsat 8 imagery conducted by Pratama, et al., (2020). The changes in vegetation density influence changes in TSS area in the Blorong watershed. The results of calculating the correlation between vegetation density and TSS are 0.876.

Meanwhile, research conducted by Sihombing et al., (2017) relating to a study of mangrove density on sedimentation rate which is still related to this research concluded that the relationship between mangrove density and sedimentation rate shows a negative correlation of -0.842. This means, that when the mangrove density is high, the sedimentation rate will be low. Conversely, when mangrove density is low, the sedimentation rate will be high.

CONCLUSION

The area with a very low level of vegetation density in Pomalaa District, Kolaka Regency tends to increase, reaching 1,199.1 hectares in 2014 and reaching 2,589.2 hectares in 2023. On the other hand, the area with a high level of vegetation density tends to decrease, reaching 20,445.2 hectares in 2014 to 16,943.8 hectares in 2023. Meanwhile, the Total Suspended Solid

(TSS) concentration value in the waters of Pomaala District ranges from 78 mg/l to 111 mg/l. Correlation analysis shows that the larger the area with very low vegetation density, the higher the TSS concentration in the water. This is based on the positive correlation coefficient (r) value 0.58. Furthermore, the larger the area with a high level of vegetation density, the lower the TSS concentration value in the water. This result is based on the correlation coefficient (r) value of the two variables which is negative, namely -0.8.

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