Analysis of Vegetation Density Effect In Bengawan Solo Watershed To The Total Suspended Solid (TSS) In Gajah Mungkur Reservoir

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Abstract. Gajah Mungkur Reservoir located in Wonogiri Regency Central Java Province. This is a multipurpose reservoir with an area of approximately 8,800 ha. This reservoir can irrigate 23,600 ha of rice fields in Sukoharjo, Klaten, Karanganyar and Sragen districts. The amount of sedimentation increased rapidly resulting in degradation of water quality of Gajah Mungkur Reservoir. High sedimentation can be shown from the high value of Total Suspended Solid (TSS) in the waters. TSS is a solid material, including organic and inorganic matter suspended in aquatic area. TSS Dynamics in the waters of Gajah Mungkur Reservoir can not be separated from the dynamics of vegetation density change in Watershed area (DAS). The watershed that flows into the Gajah Mungkur Reservoir is Bengawan solo Watershed. Total Suspended Solid (TSS) concentration can be identified using Total Suspended Solid (TSS) algorithm in Landsat 8 Satellite imagery. This research is monitored by TSS development in 2013, 2015, and 2017 which then compared with TSS level in the field. Vegetation density was identified using the Normalized Difference Vegetation Index (NDVI) method. Based on the results obtained the most suitable algorithm in the waters of Gajah Mungkur Reservoir is TSS Syarif Budhiman algorithm with 92% regression coefficient. The concentration of TSS in the waters of Gajah Mungkur Reservoir in the period of 2013-2017 has increased. Then the result of vegetation density in Bengawan Solo watershed showed that dominates is a fairly tight class. While the density of vegetation in the watershed that flows into the Gajah Mungkur Reservoir in 2013-2017 significant changes also some Sub watershed that decreased vegetation density occurred in the sub watershed Keduang, Solo Hulu and Wuryantoro. The vegetation density of several sub watersheds has an effect on the content of TSS in Gajah reservoir at estuary of the sub-watershed.

1. Introduction
Siltation is a common problem in reservoir buildings in Indonesia. One of the reservoirs in Indonesia that has serious problems with silting is the Gajah Mungkur Reservoir of Wonogiri Regency of Central Java Province. One of the factors causing the silting problem in Gajah Mungkur Reservoir is the increasing amount of sedimentation. This high sedimentation is due to the high erosion charge of the rivers flowing into the Gajah Mungkur reservoir. The rapidly increasing and uncontrolled sedimentation resulted water quality degradation in Gajah Mungkur Reservoir. One of them is increasing Total Suspended Solid (TSS) in the reservoir.
Suspended Solid (TSS) content in reservoir area from year to year. Although there has been a normalization of reservoirs every year but high sedimentation continues in this reservoir [1].

TSS Dynamics in the waters of Gajah Mungkur Reservoir cannot be separated from the dynamics of soil surface erosion, erosion of cliff, slope avalanche, river bank erosion, and erosion of side of road. Many locations of cliffs and landslides in the catchment area, the slopes (cliffs) of the Watershed (DAS) area. The Watershed (DAS) is the total land and water surface bounded by a topographical water boundary and one way to contribute to the discharge of a river in a certain cross section. Watershed catchments are not only run-off, but also the erosion and transportation of chemicals.

Bengawan Solo watershed (DAS) is a watershed that has a stream to the Gajah Mungkur reservoir. There are at least ten Sub watersheds (Sub DAS) that flows and empties into the Gajah Mungkur reservoir. The sub watersheds include Sub-Watershed of Alang, Sub-Watershed of Durensewu, Sub-Watershed of Keduang, Sub-Watershed of Kedung Guling, Sub-Watershed of Kepuh, Sub-Watershed of Pondok, Sub-Watershed of Solohulu, Sub-Watershed of Temon, Sub-Watershed of Wiroko and Sub-Watershed of Wuryantoro. They supply water discharge and sedimentation to the Gajah Mungkur reservoir. The level of erosion hazard can be affected by several factors, one of which is the vegetation density. Decreasing of vegetation density in watershed can increase erosion hazard in the watershed. Because functionally vegetation serves as an erosion barrier in the watershed area [2].

Several sub-watersheds (Sub-DAS) areas that flows into the Gajah Mungkur Reservoir are fairly developed areas. The change of land use in this Sub DAS area triggers a decrease in vegetation density which can result in increased erosion hazard in Gajah Mungkur reservoir. In this research will be studied the development of sedimentation in Gajah Mungkur reservoir in multi temporal (2013, 2015, 2017) so that the pattern of sedimentation will be seen. Sedimentation observation method using remote sensing method of TSS Landsat-8 image algorithm from several models (syarif budiman, parwati, Woerd pastercam). Some of these models will be tested for the best approach compared to in situ TSS. The result of this best algorithm model is then used to observe the development of TSS in Gajah Mungkur Reservoir in multi temporal.

Then the development of the pattern of vegetation density change in the Bengawan Solo watershed was also observed using the NDVI Landsat-8 image technique in the same year (2013, 2015, and 2017). This observation was conducted on each sub-basin unit. Both are then linked to determine the relationship of vegetation density changes in each sub-catchment to erosion runoff results in sedimentation at the Sub-Basin estuary found in the Mungkur elephant reservoir. The result of this research is expected to give direction of sedimentation handling solution in Gajah Mungkur reservoir. The purpose and purpose of this study are: 1. Mapping of vegetation density of the Watershed which leads to Gajah Mungkur Reservoir 2. Determine the best Suspended Solid Total Algorithm for the decline in Total Suspended Solid value in the waters of the Gajah Mungkur Reservoir 3. Mapping the distribution of Total Suspended Solid (TSS) concentrations in the Gajah Mungkur Reservoir in 2013, 2015, and 2017. Then from these results the objective of this research is knowing the influence of vegetation density in every sub-watershed to the Total Suspended Solid (TSS) concentration changing in Gajah mungkur reservoir using Landsat-8 imagery.

2. Methodology
2.1. Description of Study Area
Gajah Mungkur Reservoir is a reservoir located 6 km south of Wonogiri Regency, Central Java Province. The waters of this artificial lake is made by stem the longest river in Java Island is Bengawan Solo River. It was built in the late 1970s and started operations in 1978. The reservoirs covering an area of approximately 8,800 ha in 7 districts can irrigate 23.600 ha of paddy fields in Sukoharjo, Klaten, Karanganyar and Sragen areas. In addition to supplying drinking water Wonogiri City also generates electricity from hydropower (PLTA) of 12.4 MegaWatt. The location of study area can be shown in figure 1.
2.2. Data And Equipment
The tools used in this research are:

a. Software
   - Windows 8 Ultimate Operating System
   - GIS Software
   - Image Processing Software

b. Field Measurement Equipment
   - GPS Handheld
   - Bottle where water is sampled
   - Motorboat
   - Camera

c. Data
The data used in this research are:
   - Landsat Image 8 year 2013, 2015, 2017 (source: USGS)
   - Map of Bengawan Solo Watershed (source: BPDAS)
   - Indonesian topographic Map (RBI) scale 1: 25,000 Wonogiri regency (source: BIG)
   - TSS in situ data and coordinate sampling in field for validation (source: Field sampling)

2.3. Methodology
The method of this study was followed the flowchart in Figure 2. In this study is using 4 images multi-temporal with reference to Rice Planting Time 1st in Demak 2013/2014, i.e. the image on October 30, December 1, 2013, January 2 and March 7, 2014.
2.3.1. Geometric correction. Geometric correction geo-referenced image to real-world coordinates. The geometric correction method of the image used a image to map rectification with reference Indonesian Topographical map (RBI) of Demak, scale 1: 25,000. Ground control point (GCP) on this research is taken as many as 16 points of each image. Root mean square error (RMSE) in this process were required maximum 1 pixel.

2.3.2. Radiometric correction. This stage corrected image using the conversion of a digital number to Top of Atmosphere (TOA) Reflectance. OLI band data of Landsat 8 can be converted to TOA planetary reflectance using reflectance rescaling coefficients provided in the product metadata file (MTL file). MTL is the format of metadata file for Landsat 8 imagery. The following equation is used to convert a digital number (DN) or pixel values to TOA reflectance for operational land imager (OLI) data as follows [3]:

\[
\rho_{\lambda'} = M \rho_{Qcal} + A \rho
\]

TOA reflectance with a correction for the sun angle is then [6]:

Figure 2. Flowchart of the research
where:
\( \rho_{\lambda}' = \text{TOA planetary reflectance, without correction for the solar angle. Note that } \rho_{\lambda}' \text{ does not contain a correction for the sun angle} \)

\( M_{\rho} = \text{Band-specific multiplicative rescaling factor from the metadata (REFLECTANCE_MULT_BAND_x, where x is the band number)} \)

\( A_{\rho} = \text{Band-specific additive rescaling factor from the metadata (REFLECTANCE_ADD_BAND_x, where x is the band number)} \)

\( Q_{cal} = \text{Quantized and calibrated standard product pixel values (DN)} \)

\( \rho_{\lambda} = \text{TOA planetary reflectance} \)

\( \theta_{SE} = \text{Local sun elevation angle. The scene centre sun elevation angle in degrees is provided in the metadata (SUN_ELEVATION)} \)

\( \theta_{SZ} = \text{Local solar zenith angle; } \theta_{SZ} = 90° - \theta_{SE} \)

2.3.3. Image Cropping. Cropping image was used to concentrate the area study. It reduced the file size of the image so that the processing of data to be lighter and faster. It is made in accordance with the required area or region of interest (ROI). Moreover, in this study uses data multi-temporal for classification process, so cropping of the image is needed in order to accelerate the image processing.

2.3.4. Estimating Vegetation Density. The value of vegetation density in this study was obtained from the transformation of Normalized Difference Vegetation Index (NDVI). The value of this vegetation index is calculated as the ratio between the measured reflections of the red band (RED) and the infrared band (approached by the NIR band). The use of these two bands was chosen as the vegetation index parameter because the band size results were influenced by chlorophyll absorption, sensitive to vegetation biomass, and facilitated the distinction between vegetated, soil, bare land and water.

\[
NDVI = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}}
\]

where:
NIR = band near infrared
RED = band red

The resulting coupling between the red and infrared bands results in the maximum difference between vegetation and soil. NDVI generated original values always range from -1 to +1 [4]. The original values between -1 and +1 resulting from NDVI transformations have different presentations on land use. NDVI values around 0, usually represent land use with little vegetation to no vegetation at all.

| Class value NDVI | Classification Vegetation Density | Type of Land Cover |
|------------------|-----------------------------------|--------------------|
| -1 to 0          | Water Body                        | Lake, Sea, River   |
| 0 to 0.25        | Bare Vegetation                   | Settlement, Bare Soil |
| 0.25 to 0.55     | Quite dense vegetation            | Rice field, Moor   |
| 0.55 to 0.78     | Dense vegetation                  | Rice field, Shrubs |
| 0.78 to 1        | Very dense vegetation             | Tree shrubs, Forest |

2.3.5. Estimating TSS. Sedimentation observation method using remote sensing method of TSS Landsat-8 image algorithm from several models (Syarif Budiman, Parwati, Woerd Pastercam). Some of these models will be tested for the best approach compared to in situ TSS. The result of this best algorithm
model is then used to observe the development of TSS in Gajah Mungkur Reservoir in multi-temporal. The algorithm is:

- **Parwati Algorithm**
  Algorithm which is the result of research conducted by Ety Parwati in order to make efforts to optimize the supervision of the quality of coastal waters environment due to industrial waste by using remote sensing technology. These water quality observations use reflected values that are converted into TSS values [5]. The algorithm equation is as follows:

  \[
  TSS (mg/l) = 0.6211 \times (7.9038 \times \exp(23.942 \times R)) \times 0.9645
  \]

  Where:
  - TSS = Total Suspended Solid
  - Red Band = reflectance value of the Red band

- **Woerd and Pastercamp algorithm**
  The algorithm developed by Hans van der Woerd and Reinold Pasterkamp in 2004 is the result of his research in charting suspended material in a conservation area in the northern seas of Europe [6]. The algorithm equation is as follows:

  If the value of \( X \leq 2.76 \) or the reflectance value of band 2 \( \leq 0.0282 \) then

  \[
  TSS (mg/l) = 1.0585e^{1.3595x}
  \]

  If the value of \( X > 2.76 \) or the reflectance value of band 2 > 0.0282 then:

  \[
  TSS (mg/l) = 32.918x - 46.616
  \]

  Where \( X = \left( -0.53 \times RefB2 \right) + \frac{0.001}{0.03 \times RefB2} - 0.0059 \) (7)

  Where,
  - TSS = Total Suspended Solid
  - RefB2 = reflectance value of band 2

- **Syarief Budiman Algorithm**
  The algorithm was developed in the waters of the Mahakam Delta with a method developed based on bio-optical modelling to analyze a distribution of material suspended through Remote Sensing technology. Syarif Budhiman's algorithm used the constants A and S to complete the algorithm to be built [7]. The algorithm equation is as follows:

  \[
  TSS(mg/l) = A \times \exp(S \times R(0-)Redband)
  \]

  where,
  - TSS = Total Suspended Solid
  - R(0-)redband = irradiant of reflectance

In this research, the TSS in Situ survey is used for comparative validation. This validation result is used to get the best TSS algorithm model. This will be used in TSS mapping in Gajah Mungkur reservoir. Validation was done on 26 spots that are evenly distributed in the reservoir area. The distribution of TSS in situ validation point spots can be seen in Figure 3. The results of water sampling at the validation point were tested in the laboratory.

2.3.6. **Detection of Vegetation Density Effect to TSS changing**. In this study, the result of Vegetation density and TSS multi years were calculated the different or the changing year to year. Then the vegetation density changing in the Bengawan Solo Watersheds were correlated to the the TSS changing in Gajah Mungkur reservoir. The correlated method is description correlation. The result of vegetation changing in every sub-watershed was correlated using see the TSS changing in the estuary of the main river in Gajah Mungkur reservoir. This result can detect how are it effect to the TSS in Gajah Mungkur reservoir and Which are the sub-watershed most have effect to TSS in Gajah Mungkur reservoir.
3. Result and Discussion

3.1. TSS Distribution in Gajah Mungkur Reservoir

3.1.1. Determination the best TSS algorithm in Gajah Mungkur Reservoir

The determination of the best algorithm result is intended to perform the selection of algorithm that is suitable with the condition of TSS in situ distribution, done by regressing the result of TSS algorithm calculation from the previous research with TSS of water sample test which amounted to 26 sample points. The algorithm used is the algorithm of Syarif Budhiman, Parwati Algorithm, Woerd and Pastercamp algorithm based on the reflectance value of the band. One of the three algorithms were chosen to analyse the multiplicity of TSS distribution and the effect of vegetation density to the TSS. The result of linear regression between in situ TSS and TSS algorithm is shown in Fig. 4.
Comparison of TSS value from Landsat 8 image processing data acquisition on April 25, 2017 with three TSS algorithms namely Syarif Budhiman algorithm, Parwati algorithm, and Woerd and Pastercamp Algorithm with TSS value of insitu taken on April 25, 2017 which has coefficient value of determination close to 1 is Syarif Budhiman's algorithm. Shariah alhiwah algorithm has a determination value of 0.92 or 92%. TSS value obtained from the calculation Syarif Budhiman algorithm almost have the same pattern with the value of insitu TSS scattered in Gajah Mungkur Reservoir as much as 26 points. Then it can be concluded that the best Syarif Budhiman algorithm and will be used in the process of TSS mapping in Gajah Mungkur Reservoir.

3.1.2. Distribution Analysis of Total Suspended Solid (TSS) Concentration in Gajah Mungkur Reservoir

Based on the results of the best algorithm determination Syarif Budhiman algorithm is obtained with the value of in situ TSS. Furthermore, this Syarif Budhiman algorithm is used as input for mapping of TSS distribution in Gajah Mungkur Reservoir waters in 2013, 2015 and 2017. The map of TSS distribution in Gajah Mungkur Reservoir waters in 2013, 2015 and 2017 is presented in figure 5.

Figure 5. Map of concentration distribution of TSS Gajah Mungkur Reservoir in 2013, 2015, and 2017

From the results obtained by comparison of the distribution of TSS Reservoir of Gajah Mungkur in 2013, 2015, and 2017 is presented in the graph in Table 2 and Figure 6.
Table 2. Comparison of TSS distribution area 2013, 2015, and 2017

| No | Year | 0-20 (mg/L) | 20-50 (mg/L) | 50-100 (mg/L) | >100 (mg/L) |
|----|------|-------------|--------------|--------------|-------------|
| 1  | 2013 | 97,956      | 4,779,848    | 616,404      | 503,780     |
| 2  | 2015 | 51,521      | 2,880,392    | 2,526,905    | 539,171     |
| 3  | 2017 | 51,521      | 103,573      | 4,656,853    | 1,186,042   |

Based on the calculation of TSS in the waters of Gajah Mungkur Reservoir in 2013 the spread area is found at concentration 20-50 mg/l which is 4,779,848 ha or equal to 79,690%. Followed concentration 50-100% has an area of 616,404 ha. Concentrations> 100 mg/l possess an area of 503,780 ha. And the concentration of 0-20 mg/l has an area of 97,956 ha.

In 2015 the largest area is found at concentrations of 20-50 mg/l with an area of 2,880,392 ha or 48,022%. At concentrations of 50-100 mg/l have an area of almost the same concentration of 20-50 mg/l, i.e. 2,526,905 ha or equal to 42.129%. Concentrations> 100 mg/l have an area of 539,171 ha and a concentration of 0-20 mg/l has an area of 51,521 ha.

In 2017 the extent of spread is concentrated at 50-100 mg/l of 4,656,853 ha or 77,640%. Followed concentration> 100 has an area of 1,186,042 ha. Concentrations of 20-50 mg/l possess an area of 103,573 ha. And the concentration of 0-20 mg/l has an area of 51,521 ha. Based on the TSS map results in Figure 5, seen in estuary of the Keduang Sub-Watersheds, Solo Hulu Sub-Watersheds and Wiroko Sub-Watersheds (indicated by red circle) have an increasing TSS value from 2013, 2015 and 2017. This may indicate that these three Sub-Watersheds have high erosion.

3.2. Vegetation Density in Bengawan Solo watersheds
The results of the vegetation density process using NDVI method are shown in Figure 7. From the results it is seen that there is a significant change in vegetation density in 2013, 2015 and 2017. Although in general the vegetation classes are still dominated, bare vegetation classes are annually increasing. This can increase the amount of erosion on each Sub-DAS. Moreover, most bare vegetation classes located close to the slope.
From the results obtained, the vegetation density each Sub-Watershed in 2013, 2015, and 2017 is presented in the graph in Figure 8.

**Figure 8.** Graph of changes in the area (Ha) of vegetation density classes of each Sub-Watershed in 2013, 2015, 2017
From these data can be seen on the Kedung Sub-watershed there is a decrease in the vegetation class is quite dense vegetation and there is an increase in the bare vegetation. The same thing happened Solo Hulu sub-watershed and Wiroko Sub-Watershed. The class quite dense vegetation in Kedung Guling sub-watershed decrease in 2013 to 2015. And there is an increase in 2015 to 2017. But in the vegetation dense class increased. Figure 9.

![Figure 9](image)

**Figure 9.** The bare vegetation class change in 2013, 2015, 2017

### 3.3. Correlation Vegetation Density in Several Sub-Watersheds and TSS Distribution in Gajah Mungkur Reservoir

Based on the results of the analysis on TSS in Gajah Mungkur Reservoir and Vegetation Density Change on each sub-watershed can be seen that both have a real relationship. This can be seen from the result of TSS change at sub watershed estuary that at sub watershed estuary Kedung, Solo Hulu and Wiroko have TSS value which always increases from year to year. On the other hand, the value of vegetation density in the bare vegetation class on these three sub-basins has a significant increase. This means land degradation occurs in these three sub-catchments. Or in other words a decrease in vegetation density causes erosion increase in them.

### 4. Conclusion

- The concentration of TSS in the waters of Gajah Mungkur Reservoir in the period of 2013-2017 were increased. It can be seen from the largest area in each year, 2013 at concentrations of 20-50 mg / l, by 2015 at concentrations of 20-50 mg / l and 50-100 mg / l, and by 2017 at concentrations of 50-100 mg/l.
- The vegetation density in some sub-watershed in Bengawan Solo watershed was decreased such as sub-watersheds of Kedoang, Sub Watershed of Solo Hulu and Sub watershed of Wiroko.
- The vegetation density level changing in the Bengawan Solo watershed influences the distribution pattern and changes in the TSS value in Gajah Mungkur reservoir. The relationship of both shows a direct relationship. Sub watershed that has vegetation density change significantly and has an influence on increasing TSS in the Gajah Mungkur reservoir are sub watershed of Kedung, Sub Watershed of Solo Hulu and Sub watershed of Wiroko.
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