INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 14, No. 5, p. 93-101, 2019
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

# Mapping of sedimentation distribution at Citarum River Estuary, Muara Gembong District, Bekasi Regency

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Article published on May 30, 2019

**Key words:** Sedimentation, Remote Sensing, Citarum River Estuary.

**Abstract**

Based on the measurement result of total sediment flowing from Citarum River into the sea, which is 1.79442x10$^6$ tons/year, the sedimentation around Citarum river estuary is caused by large supply of sediment from the Citarum River. The sedimentation has created additional sedimentation area. Research on the addition of sedimentation area needs to be conducted to discover its potentials in the future. The purpose of this study is to analyze the addition of sedimentation area around Citarum river estuary using satellite remote sensing. This research was conducted around Citarum river estuary, Muara Gembong District, Bekasi Regency, Indonesia in 2014. The data collection was conducted using field observations and processing of satellite image data. Based on the processing result of satellite image data, sedimentation caused 1,060.63ha additional sedimentation area in 2000 and 3,828.26ha in 2014. The addition of sedimentation area during 2000-2014 was 2,767.63ha. The large addition of sedimentation area during 2000-2014 was due to the factor of increasing erosion on the watershed caused by the conversion of the land into industrial, agricultural land, and residential areas. The tendency of sedimentation distribution to move eastward indicates that, when there is large supply of sediment from Citarum River, the ocean current moves eastward. This condition occurs during rainy season, when the sediment discharge is much greater than during dry season and the ocean currents moves eastward.

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## Introduction

Citarum River is the longest river in West Java, Indonesia. It stretches from the upstream in Bandung Regency and empties into the Java Sea, more precisely in Muara Gembong District, Bekasi Regency. Along Citarum River, three large reservoirs had been constructed, namely Saguling Reservoir in the upstream, Cirata Reservoir in the middle, and Jatiluhur Reservoir in the downstream. Citarum River has been designated as a national strategic river. The river is considered strategic because its water is used as raw water source by the residents, agricultural irrigation water, fish farms, power plants and raw water source for industry (KPURI, 2010).

Nowadays Citarum River is suffering from water pollution, so the quality of water in Citarum River is dropping dramatically. One of the water pollution parameter is total suspended solid (TSS)/sediment (Indonesia Minister of environment, 2004; State Secretary of The Republic of Indonesia, 2001). Total suspended solid/sediment levels in Citarum River flow cause sedimentation in the estuary of Citarum River. Sediment levels is derived from erosion in Citarum watershed. The erosion causes sediment dischard into Citarum River, than resulting sedimentation in Citarum Estuary.

The dynamic runoff and sediment have great impacts on erosion–deposition variation in the River estuary (Cui & Li, 2011). Potential sediment resulted from downstream Citarum watershed is 1,579,652 tons/year (BP DAS Citarum-Ciliwung, 2009).

The potential of the sediment would result in sedimentation in Citarum estuary. Sedimentation in estuaries affected by the tidal current. Gao *et al.* (2012) explained the sediment from areas with water depth being less than 5 m was transported from the sea towards the land. Based on the result of measurements of total sediment from Citarum River that flow to the sea, which is $1.79442 \times 10^6$ tons year$^{-1}$, the high sedimentation rate around Citarum estuary is due to the large supply of sediment from Citarum River. Geyer *et al.,* (2004) explained that the rivers provide the dominant pathway of terrigenous sediment to the ocean. Sedimentation creates additional land area around Citarum estuary. Local residents call this additional sedimentation area as "tanah timbul." The purpose of this research is to calculated of sedimentation area around Citarum estuary, Muara Gembong District, Bekasi Regency, Indonesia using satellite remote sensing.

## Material and methods

*Sampling site*

This research was conducted around Citarum estuary. The waters around Citarum estuary are within the administrative area of Muara Gembong District, Bekasi Regency, West Java, Indonesia. The research location is coastal waters with a high sedimentation rate. In this region there is wide of "tanah timbul." This research was conducted in 2014.

*Sampling methods*

The research data used includes primary and secondary data. The primary data is the data from satellite landsat 8 image and the data of total sediment flow in Citarum River. The use of satellite remote sensing for the calculation of the sedimentation area more effective. The satellite remote sensing and GIS have emerged as the most powerful tools for inventorying, monitoring and management of natural resources and environment and wetland ecosystem (Garg, 2013; Ridwansyah, 2010). The landsat 8 image data selected is the data from 2014 downloaded from the official website of NASA (http://usgs.gov.us) on August 31, 2015 in the form of TAR file (*.tar). Landsat 8 satellite image has been radiometrically corrected but not yet geometrically corrected.

This research was conducted by integrating remote sensing data (landsat satellite image) and geographic information systems (GIS). The chronology of research activities includes inputting data, compiling data and analyzing data. The inputted data was obtained from field measurements, image data, map of Indonesian (RBI) with the scale of 1: 25.000 and the secondary data that has been collected.

*Data Analysis*

Research data processing was performed by processing the data of landsat 8 satellite image to determine the extent of sedimentation discovered around Citarum estuary. The initial stage of research data processing was making training area in the form of land, sea and mangrove by digitizing the map of Indonesia (RBI) with the scale of 1: 25,000. The next stage of the research was using the data of training area to determine supervised classification, which is the color setting on region color to search for differences between land, sea and mangrove, then it was stored in the form of *ERS. Subsequently, NDVI (Normalized Difference Vegetation Index) formula was entered to determine the indicator of greenness from satellite images using infrared (NIR) and red band (VIS) channels. The flow of data processing of landsat satellite images is presented in Fig. 2.

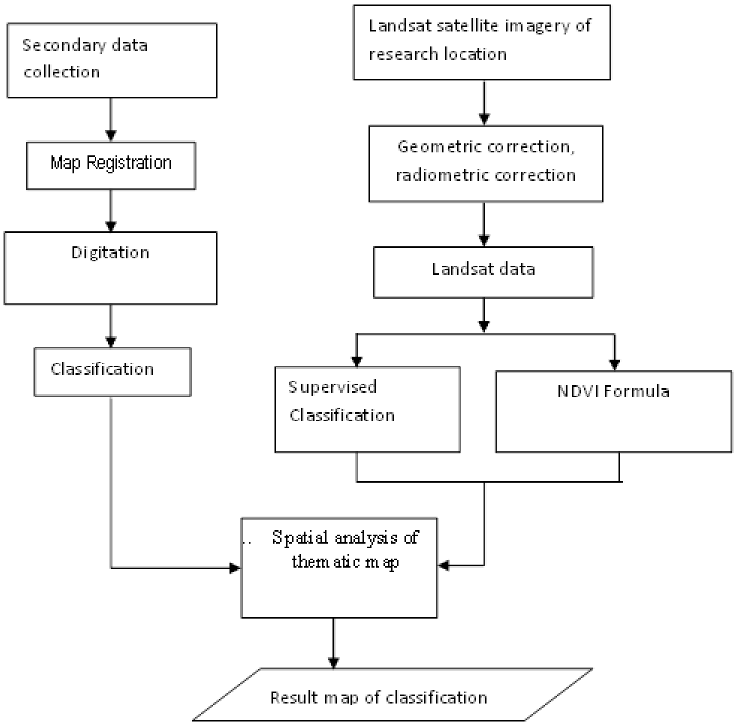


**Fig. 1.** Diagram of the research stages.

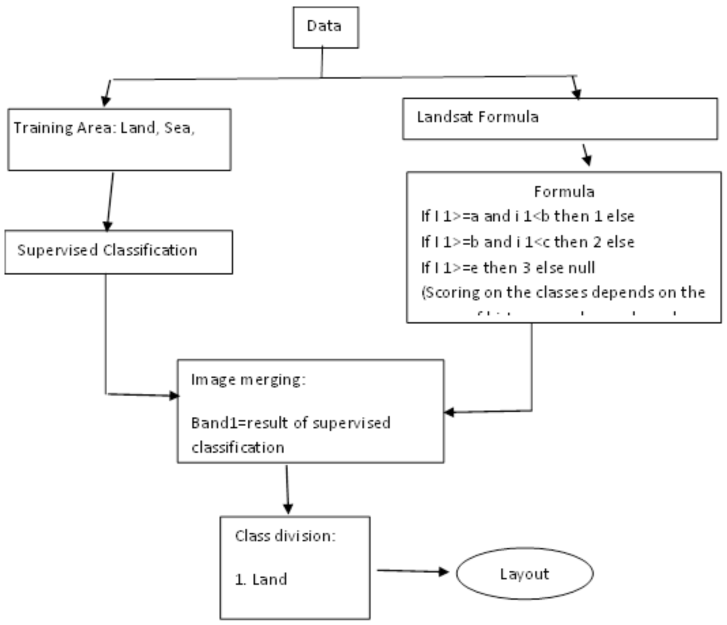


**Fig. 2.** Diagram of satellite image data processing.

*Broadly speaking, the processing of satellite image data consists of three stages, namely pre-processing, image enhancement, and result classification.*

*Pre-processing*

The stage of pre-processing was conducted by cropping the image, because landsat satellite image obtained was not fully used in data analysis. Image cropping was done to limit the necessary image for the purpose of analysis based on the location that would be studied. Image cropping consists of two processes, namely radiometric correction and geometric correction. Radiometric correction was performed to eliminate the factors that degrade the image quality. Radiometric correction used is histogram adjustment. Meanwhile geometric correction is required to correct the error in the position of objects recorded on the image caused by geometrical distortion/differences.

Geometric correction begins with georeferencing stage, a process of determine the coordinate system and projection into a raster map (image), where the map used as a reference is the map that has been corrected (master map) and can be in the form of image or vector (map). In geometric correction, the capture of ground control points (GCP) of the image that would be corrected must have the same position as the reference map/image. The capture of ground control point in this correction is Universal Transverse Mercator coordinate system (UTM) and was conducted to help the process of classification and to improve the accuracy of the result of image interpretation. The capture of ground control point was done using the tools of the Global Positioning System (GPS). The capture of ground control point is recommended to be done as much as possible, so it will be spread evenly and capable to represent each object. After image cropping, the next step done was image enhancement.

*Image Enhancement*

Image enhancement process was conducted using a composite 542 RGB band. The enhancement process was conducted to gain the image value of sedimentation extent by differentiating the density of mangrove and the surrounding waters. Image enhancement for mangrove vegetation was transformed with NDVI (Normalized Difference Vegetation Index), which principally separates the reflectance spectral of vegetation on land and water that lies behind them. The formula on landsat used to distinguish between vegetation, land and water is based on channels on satellite imagery using the following equation:

$$NDVI = \frac{(IR - R)}{(IR + R)}$$

Where,

NIR (Near InfraRed) : Digital value of close infrared channel image

IR (InfraRed) : Digital value of infrared channel image

*Image Classification*

Image classification is a process of grouping the reflectance value of each object into certain classes so it can be easily interpreted. The classification used in this research is supervised classification with maximum likelihood standard analysis. Supervised classification is an image classification method based on field data, maps or visual interpretation of aerial photographs or relevant imagery. Supervised classification typically generates more realistic and relatively more accurate information than unsupervised classification, since unsupervised classification only produce spectral classes that require further interpretation. Image classification using supervised classification technique is a method of grouping pixel values based on the latest available information from the surface of the earth. Supervised classification process begins with the identification of spectral patterns in the image based on the results points of ground truth in the field.

The next stage was creating training area based on the spectral patterns shown. Training area was created using area of interest (AOI). Image classification process was done automatically by the computer based on the results of training area created. In the analysis of land covering, after the classification result was obtained from the attribute image, there were still several attributes for the other types of land covering, so the data recording of classification result was required in order to combine the areas that had the same types of land covering. After the classification process, evaluation of image accuracy was conducted. Accuracy is a way to evaluate the accuracy of the classification result that has been done with the actual conditions in the field. Assessment of the accuracy level was performed by comparing the data obtained from ground truth with the classification result obtained.

**Result and discussion**

Sedimentation becomes an environmental problem in many coastal areas in northern coast of Java, Indonesia. Sedimentation cause a lot of losses in fishery, marine transportation and marine tourism. One of the coastal areas experiencing sedimentation is Citarum estuary. The sedimentation is caused by deposition of sediments from Citarum River flow.

The calculation of sediment loads result Citarum River that flows into Citarum estuary in Muara Gembong District, Bekasi Regency, is $1.79442x10^6$ tons/year. The volume of sediments causes extensive sedimentation in the area around Citarum estuary, resulting in the addition of sedimentation area around Citarum estuary in Muara Gembong District, Bekasi Regency (Febriansyah, 2008; Soewandi, 1992). The additional sedimentation area is commonly called "tanah timbul". To discover the extent of additional sedimentation area around Citarum estuary, a relatively fast measurement method is required. A type of measurement method for sedimentation area is the use of satellite remote sensing. Calculation of Sedimentation Area using satellite Remote Sensing Analysis.

Calculation of sedimentation area around Citarum estuary was conducted using data analysis of landsat image satellite. The image data was acquired in 2015. The image data acquired is landsat image data of 2000 and landsat image data of 2014. Acquisition result of image data was subsequently processed through several stages until the area of the object observed was obtained. These data processing stages include image cropping, image enhancement, and image classification.

Image cropping was conducted in accordance with research area, which is coastal waters in Muara Gembong District, Bekasi Regency. After the cropping process was completed, the image enhancement process was conducted. Landsat image enhancement process was conducted by creating composite color of Red Green Blue (RGB). Because the location of sedimentation, as the object of the research, is bordered by mangrove vegetation and marine waters, the use of composite RGB. This three channels are able to distinguish objects with a high level of contrast between waters objects, vegetation and dry land. Composite red color gives reflection to detect dry land, composite green color to detect mangrove vegetation and composite blue to detect the color of waters.

Image classification aims to facilitate the analysis of each object according to their respective classes. The classification process used supervised classification with maximum likelihood standard analysis. Image classification process was preceded by the capture of training area. Training area used is sedimentation area in the form of "tanah timbul," marine waters area, and mangrove forest area. After the classification process was completed, color rendering was done with adjustment to the desired object, namely yellowish-red for raised ground, green for mangrove forests, and blue for marine waters. Before doing the mapping of sedimentation area, landsat satellite image was classified into two classes, namely land and marine classes.

The results of the classification are shown with two different colors, sedimentation areas are highlighted in yellowish-red color and marine areas are shown in blue. The result of image processing to map the sedimentation area around Citarum estuary is presented in Fig. 3 and Fig. 4. Based on the results of mapping of the sedimentation area presented in Fig. 3 and Fig. 4, the data about additional sedimentation area in 2000 and 2014 is presented in table 1.

**Table 1.** Sedimentation area around Citarum estuary, Muara Gembong District, Bekasi in 2000 and 2014.

| Year | Sedimentation area | |
|---|---|---|
| | $m^2$ | hectar |
| 2000 | 1,060,300 | 1,060.63 |
| 2014 | 38,282,644 | 3,828.26 |

Based on the data of sedimentation area in table 1, there are changes in terms of land area, namely 1060.63 ha in 2000, and 3828.26 ha in 2014. From this data from 2000 to 2014 there was 2,767.63 ha additional sedimentation area. The large addition of sedimentation area around Citarum estuary during 2000-2014 is due to the factors increasing erosion on watershed and dinamic of tidal current in estuary. The suspended sediment concentration is related to the tidal current during a tidal cycle (Bin & Kai, 2008; Kim *et al.,* 2006; Liu *et al.,* 2010). Sedimentation events in the mudflat resulting from spring tides are less frequent during dry periods, and sedimentation a smaller quantity of sediment [15,16]. Because of the lower flow rates coupled with the impacts of local development, the flood tides have become dominant. High level of erosion on land area was due to the deforestration/ conversion of the land into the construction of industrial, farming, and residential areas. According to Gelagay & Minale (2016) that soil loss by runoff is a severe and continuous ecological problem in watershed, the deforestation, improper cultivation and uncontrolled grazing have resulted in accelerated soil erosion.

Sediment carried by Citarum River entering the sea is dominated by sediment from the downstream Citarum watershed, which includes Cikao sub watershed, Cibeet sub watershed, Citarum downstream sub watershed, and Jatiluhur reservoir catchment area. Among these 4 (four) sub-watershed, Cibeet sub-watershed experiences massive changes over the land function into industrial and residential areas in the last decade. Industrial development that moves towards Karawang and Purwakarta has resulted in the conversion of land into industrial and residential areas. These changes on land could potentially cause major erosion that ultimately leads to sedimentation in the river estuary. Mean while Jatiluhur Reservoir catchment area contributes relatively small amount of sediment compared to other sub-watershed, because most of the sediment entering Jatiluhur Reservoir is deposited in Jatiluhur Reservoir. Consequently, only small amount of sediment is carried by the outlet of Jatiluhur Reservoir towards Citarum estuary.

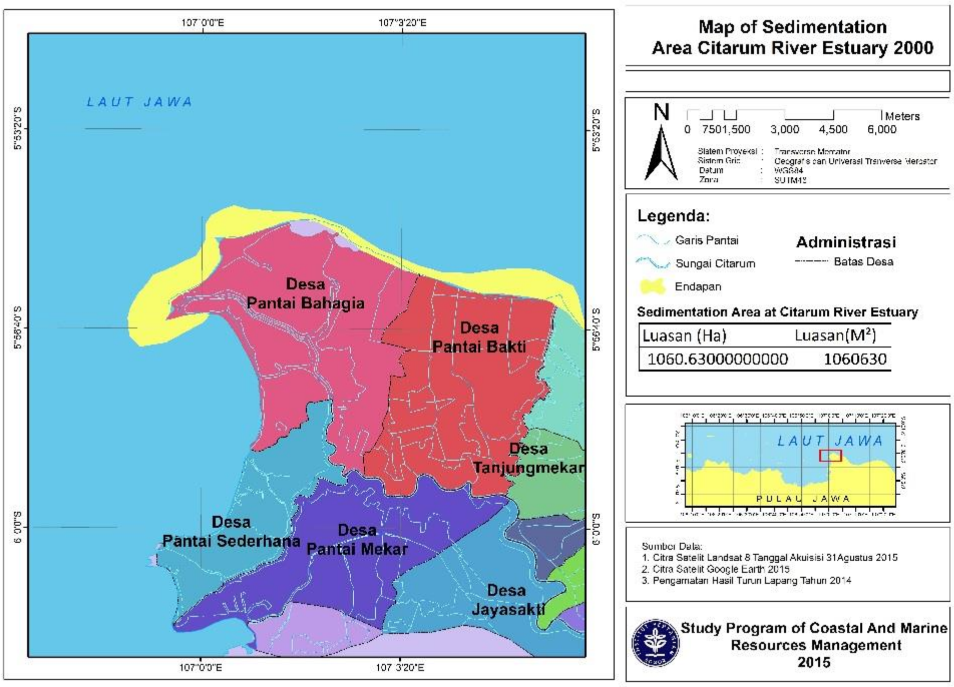


**Fig. 3.** Map of sedimentation area around Citarum estuary, Muara Gembong District, Bekasi, 2000.

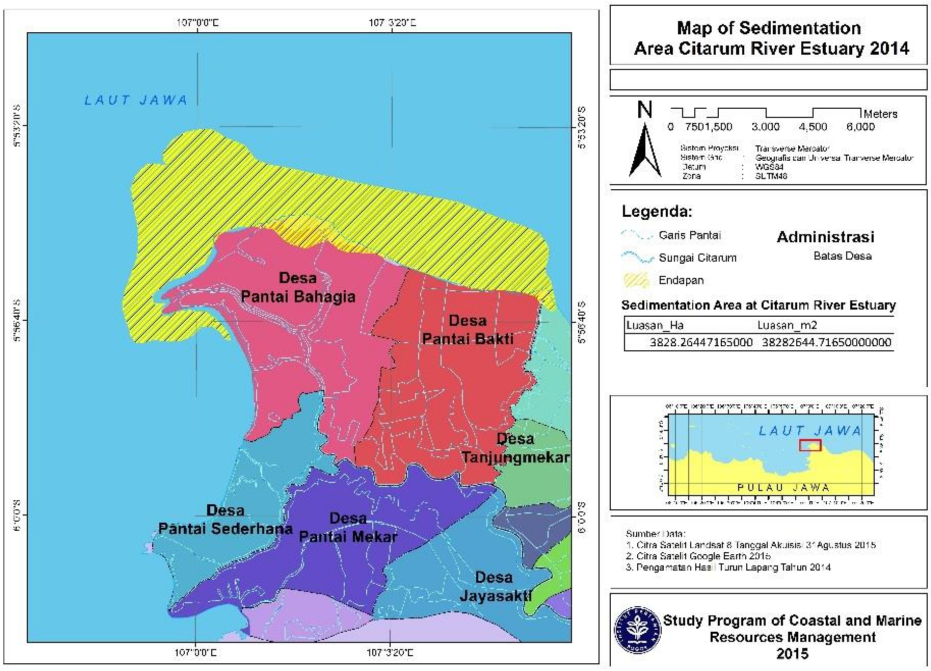


**Fig. 4.** Map of sedimentation area around Citarum estuary, Muara Gembong District, Bekasi, 2014.

*Direction of Sedimentation Area*

The results of satellite image data processing presented in Fig. 3, Fig. 4 and Fig. 5 show that the direction of sedimentation distribution around Citarum Estuary tends to move eastwards. Arah sebaran sedimen dilokasi ini dipengaruhi oleh pasang surut dan arus laut (Gunarso, 2012; Geofana, 2012; Yosi, 2006). The distribution of sedimentation that tends to move eastward shows that, when there is a large amount of sediment supply from Citarum River, the ocean current moves eastward.

This condition occurs during rainy season when sediment discharge is much greater than during dry season. During rainy season, ocean current flows eastward. Based of remote sensing analysis at east of Jakarta Bay (Muara Gembong District) along 6 year that sedimentation area in the west of Citarum River estuary relatively small (Sandaya, 1996).

**Conclusion**

The Citarum estuary in Muara Gembong District, Bekasi Regency, show the addition of sedimentation area caused by sedimentation process coming from Citarum River flow. Based on the measurement results of total sediment from Citarum River entering marine waters, which is $1.79442x10^6$ tons/year, the sedimentation around Citarum estuary is caused by the flow of sediment from the river, not by the sediment from other marine areas. Based on the results of satellite image data processing, sedimentation causes 1060.63 ha additional sedimentation area in 2000 and 3828.26ha in 2014. The addition of sedimentation area from 2000 to 2014 was 2,767.63ha. The large addition of sedimentation area from 2000 to 2014 around Citarum estuary was due to the factor of increasing erosion on the land area caused by the conversion of the land into industrial, agricultural land, and residential areas. The distribution of sedimentation area that tends to move eastward shows that, when there is a large amount of sediment supply from Citarum River, the ocean current moves eastward. This condition occurs during rainy season, when sediment discharge is much greater than during dry season. During rainy season, ocean current flows eastward.

**Recommendations**

According to result of sedimentation area measurement using remote sensing year 2014, area of the sedimentation which reaches 3,828.26ha. The sedimentation area has yet to be used by community, making it possible to be made mangrove forest. The study to analyze the use of sedimentation area around Citarum River estuary for mangrove forest are required.

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