The impact of human activities in the Wulan Delta Estuary, Indonesia

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Abstract. The increasing of human population in the watershed and the coastal area and the need of life exert pressure in the delta that provides various resources. Wulan Delta is one of active Delta in Central Java, Indonesia. It has been experienced multiple pressures because of natural factors and human factors. In order to provide the scientific solution and to analyze the impact of human intervention in delta, we collected several pieces of evidence based on secondary data and primary data. The secondary data is water quality data on sites 6 and 7, meanwhile the secondary data is the water quality data in site 1 to 5. This paper present a review and problems identification in Wulan Delta, based on hydrological condition, land use, and human activities in the delta. Meanwhile, the human intervention in the land which is land use exchange leads to several problems such as the land use changes, high sediment load, and water degradation. Almost 80% of Delta has been transformed into the fish pond by local communities.

1. Introduction

Delta system is significantly threatened by various kind of drivers, such as aquaculture, agriculture, fish catching, transportation, climate change, and another human activities [2]. The delta and estuaries region is a dynamic area. It represents transactional zone between land and sea, characterized by high sediments and rich of bio-diversities [1]. Due to that factors, this region has become critical studies for multidisciplinary studies [11]. Delta is part of watershed system [15]. The watershed system which is connected by rivers plays significant role as a link in sediment transport and nutrient transport [22]. The watershed characteristic in term of land use, topography, hydrology in the upstream area will affect the downstream area [8].

Indonesia is an archipelago which has 5,8 million km of shoreline (KEP.18/MEN/2011) which consist of small islands and big islands. The increasing of human population in the coastal area and global climate change influence the productivity and environmental health in the delta system. The decreasing of water quality condition in the delta is a response of physical processes that altered by hydrodynamics processes in the deltaic environment [4]. Hydrodynamics is important in deltaic environment due to its contribution to sediment transport processes, nutrient transports, and mixing processes.

The Wulan Delta is one delta in Java Island, Indonesia. This delta situated in Demak and Jepara City, Indonesia, between latitude 6°43’30” S and 6°46’30” S and longitude 110°32’0” E to 110°36’0” E. The area covers 31.75 km2. The delta is located in the Serang Watershed’s estuary. Wulan Delta has been developing until recently [21]. The development of Wulan Delta has been noticed since 1920 [16] and noted by several research until now. Not only disturbed by huge sediment load, but this location is also affected by human intervention in the form aquaculture and settlement in the delta. It has potential to harm the water environment and the delta morphology. The research aims to find evidence of the impact altered by human intervention in the delta. This review is beneficial to predict the future condition and formulate the policy regarding delta management [6].

2. Method

The present study was carried out using primary and secondary data sources. The information of delta shoreline and hydrological data were obtained from governmental and non-governmental organization. The water quality data was collected from governmental and field survey. The data obtained from the government were Temperature, pH, Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), and Total Suspended Solid (TSS) data in 2014 and 2016 (Site 6 and 7). Primary data of water quality in Wulan Delta were collected in 2016 (Site 1 to 5). The primary data collected was TSS, DO, and Nitrat (NO_3). The sampling was conducted twice in May and August 2016. The sample were taken at the highest high water level (HHWL) in each month and taken in ebb tides and flood tides. There were 5 sampling sites to represent the estuary (figure 1). The water quality data in the Wulan Delta were compared to Water Quality Standards (WQSs) for Estuary.

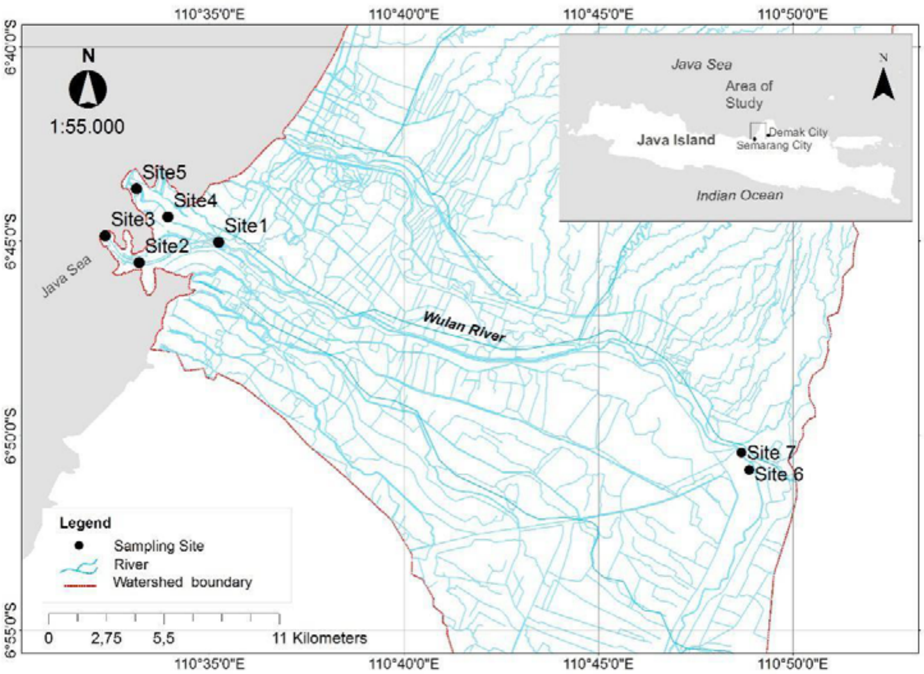

Figure 1. Water Quality Sampling Sites in Wulan River. The data in Site 1 to 5 were collected in 2016 during Field Survey. Meanwhile, the data for Site 6 and 7 were a secondary data which collected in 2014 and 2016.

Data were also collected from the local people in the Menco hamlet or sub-village, Berahan Wetan and Berahan Kulon Village, Wedung District, Demak, Indonesia using Focus Group Discussion (FGD) method. The informants for FGD are consisting of 10 people. All of them ate fish farmers whose own fish pond in Wulan Delta. The FGD data were used to validate the accretion and erosion processes and gain information regarding waste disposal system in the Delta Wulan's aquaculture. The land use data were gained from base map of Peta Rupa Bumi Indonesia in 2008 and Satellite Images of IKONOS in 2016. The satellite interpretation was used to investigate the changing of land use between the years of 2008 to

2016 in a simple way. The accretion and erosion data were collected from several publications conducted in Wulan Delta.

3. Result and Discussion

3.1. Hydrological characteristic of Wulan Delta

The Wulan River is bifurcated into 2 channel, namely Wulan Baru (New Wulan) and Wulan Lama (Old Wulan). According to the history, the Wulan Lama formed first, and the Wulan Baru formed latter due to dredging projects. The Serang River runs from the South to The North Coast of Java Island over a length of 48,62 km. The Wulan Baru is approximately 6 km long and the Wulan Lama is 5 km long. The average rainfall in Wulan Delta is 2187 mm/year. The mean water discharge in 2016 is 102 m^3s^{-1}. Based on Schmidt-Fergusson climate classification, this area climate is moderate.

3.2. Land use change in Wulan Delta

Along with the increasing of daily needs, the delta nowadays was changed into fish pond. Figure 2 shows the difference of land use in Wulan Delta in 2008 and 2016. The major use of delta was fish pond. Most of saltwork land, rice field, and crop transformed into fish pond. The fish pond expands from 21,862,251.84 m^2 in 2008 to 24,946,439.35 m^2 in 2016. The fish pond percentage expansion increase from 82.94 % (2008) to 91.55 % (2016) of major use in Wulan Delta. Table 1 and table 2 indicate the difference of the total land between the years of 2008 to 2016. There was sedimentation in the West Part of Wulan Delta (figure 2).

The evidence shows that the wetland increase of 888,787.8 m^2 in 2016 due to sediment accretion. The delta development rate before 1994 was 0.000338 km^2/year [21]. However, the delta development rate in 2000-2011 was 0.085 km^2/year and in 2011-2015 was amounted up to 0.06 km^2/year [18]. The delta development allegedly affects its surrounding. The morphological changes in delta are assumed as one the main factor of fish pond loss in Jepara and Demak due to the changing pattern of longshore current in the north coast.

Table 1. Land Use in 2008.

Land Use	Area (m^2)
Fish Pond	21,862,251.84
Bush	1,166,519.20
Salt work land	52,074.26
Salt Marsh	856,661.12
Farm	77,972.13
Settlement	279,492.47
Grass	363,689.83
Swamp	608,678.60
Rice Field	648,953.53
Crop/moor	441,905.14
Total	26,358,198.11

Table 2. Land Use in 2016.

Land use	Area (m^2)
Fish Pond	24,946,439.35
Bush	1,166,519.20
Salt marsh	412,872.92
Farm	77,972.13
Settlement	279,492.47
Grass	363,689.83
Total	27,246,985.91

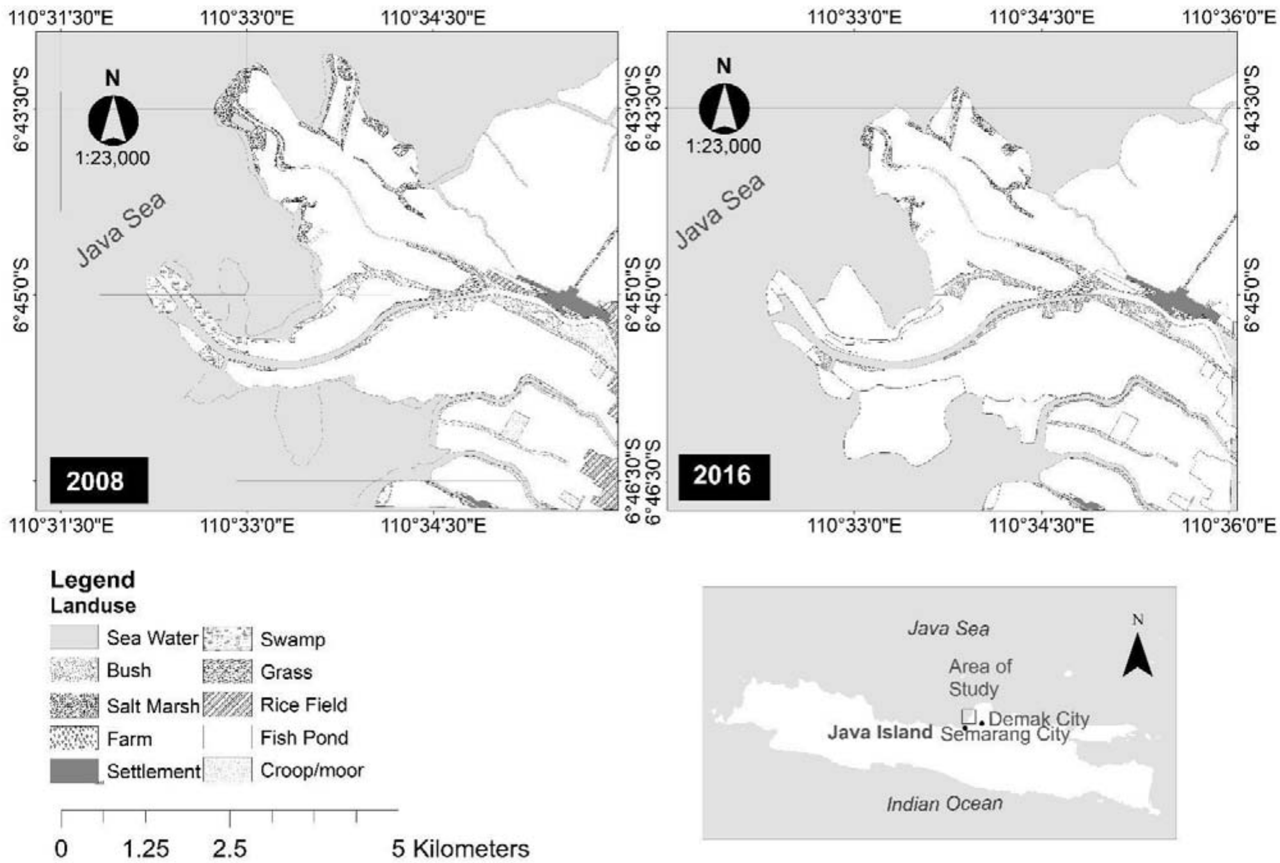

Figure 2. The Land use change in Wulan Delta in 2008 and 2016. It also shown that there was an accretion process in the delta in the West part of the delta.

3.3. Possibility of water quality degradation

The aquaculture in Wulan Delta is supplied by Wulan River and The North Coast. The Wulan River flowed into the fish pond into channels which connected the river and the sea directly. The tidal cycle which occurs in everyday potentially bring nutrient as well as pollutants in the estuary. It may affect the aquaculture and the benthic ecosystem in the delta estuary. The estuary receives threats not only from the deltaic system, but also from the upstream area such as agriculture and domestic use. Several parameters are sensitive to aquaculture, i.e. BOD, DO, and TSS. We compare the laboratory and direct measurement for several parameters mentioned to Water Quality Standards (WQSs) for Estuaries and Aquaculture according to Decree of The Minister of State for The Environment of Republic of Indonesia Number 51/MENKLH/2004 for marine biotic. The WQSs is important for preserving aquatic ecosystem and human health and establish the standard for aquatic ecosystem protection [13].

Dissolved Oxygen (DO) is fundamental in the coastal water as well as in the other water bodies and its used as indicators of pollution in the aquatic areas [19]. The decreasing of DO may happen due to biological processes such as photosynthesis and respiration of the benthic organism or algae. Several studies have shown that the limit of DO for benthic organism is 2mg/L [17]. The Indonesian Water Quality Standard for DO in the estuary is 5 mg/L. The average DO in Wulan Delta in 2016 is 6.82 mg/L.

DO is sensitive parameter towards temperature. In high temperature, the respiration and photosynthesis of aquatic organism was increase, which makes decreasing of DO concentration in the water column.

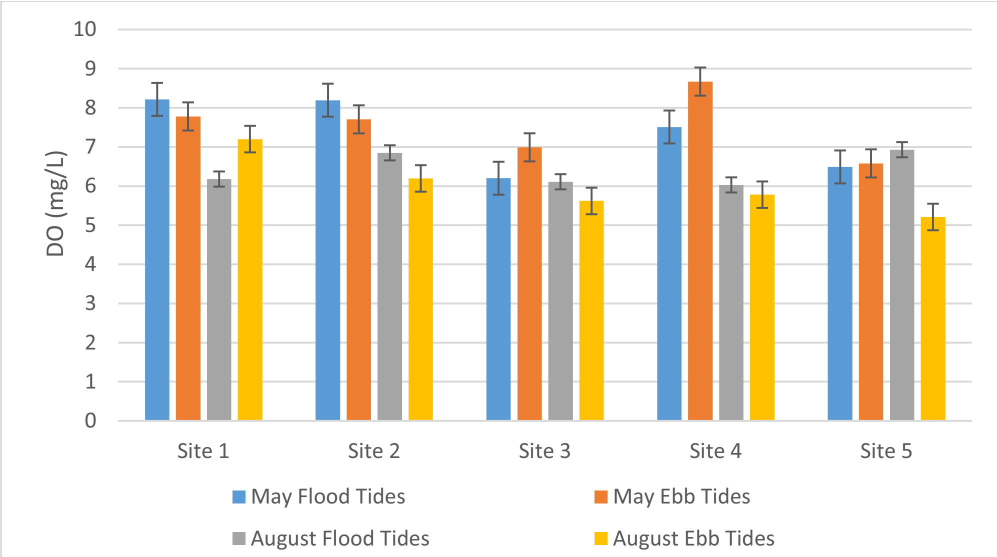

Figure 3. The Dissolved Oxygen Concentration during Field Survey in 2016.

The water quality standard of TSS for aquaculture is < 25 mg/L, while TSS between 25-80 mg/L is considered to have bad impact on the aquaculture. Average TSS concentration in Wulan Rivers is 22,4 mg/L in 2016 during the field survey. Yet, form the secondary data shows high concentration of TSS in April 2016, both in the upstream station and downstream area (table 3). This condition may occur due to flood or high water discharge. TSS concentration commonly equivalent to the water discharge. The higher the water discharge, the higher TSS concentration [9]. High concentration on TSS will increase turbidity and prevent light to penetrate in the water column and disturb the photosynthesis process [5]. High concentration of TSS happens due to high intensity of erosion and land degradation in the upstream area, or the river bank erosion. In general, TSS in the river mouth sites is higher than any sites in the delta estuary.

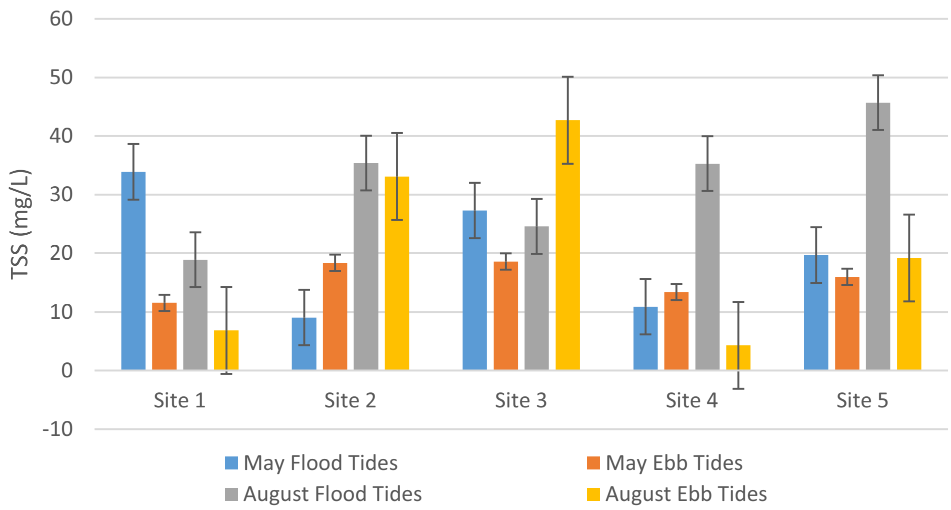

Figure 4. The TSS concentration during Field Survey in 2016.

Biochemical Oxygen Demand (BOD) is useful parameter to trace the wastewater effects in aquatic ecology. This parameter provides information about the potential of microbial respiration to breakdown the organic material present in the water [19]. Indeed, from the BOD data (**Table 3** and **4**). The BOD Shows high concentration which is > 3 mg/L. According to Indonesian Water Quality Standards it shows that in the Site 6 and 7 (Fig), the BOD was above the WQSs, the indication of high organic contamination from agriculture or industrial activities. in the upstream area [10]. Site 6 and 7 was far from the estuary, so that the aquaculture may not be the reason for high contamination. Yet, the BOD was not collected in the Site 1 to 5.

Table 3. Water Quality in Wulan River (Site 6).

	Temperatur	**pH**	**TSS**	**BOD_5**	**DO**	**Total Coliform**
May 2014	30.8	8	26	8.256	7.07	450
August 2014	30.6	8.2	21	11.45	5.61	4500
April 2016	28.2	7.8	2275	14.95	2.16	92000
August2016	30	8.1	24	3.28	6.31	450

Table 4. Water Quality in Wulan River (Site 7).

	Temperatur	**pH**	**TSS**	**BOD_5**	**DO**	**Total Coliform**
May 2014	31.9	7.8	54	71.96	5.49	680
August 2014	31.5	7.6	38	66.02	2.81	26000
April 2016	29	7.8	2592	21.45	1.19	93000
August2016	30	7.7	58	16.86	6.05	680

The main source of ammonia in the water column includes the decomposition of organic material from mangroves, shrimp, or fish in the bottom of the pond [7]. The concentration of Ammonia (NH_3^--N) in the Delta Estuary are still in a good condition, there was no data exceed the WQSs. Water bodies which have DO> 5 usually do not have high concentration of Ammonia. This means that the aquaculture didn't give bad impact to water bodies in Estuaries. However, the Total Maximum Daily Load is better method to understand the limitation of river to accommodate the pollution load which enters the water bodies.

Table 5. The Average Ammonia Concentration (mg/L).

Sampling Site	**May Flood Tides**	**May Ebb Tides**	**August Flood Tides**	**August Ebb Tides**
Site 1	0,0000	0,0275	≤0,0094	≤0,0094
Site 2	≤0,0094	≤0,0094	≤0,0094	≤0,0094
Site 3	≤0,0094	≤0,0094	≤0,0094	≤0,0094
Site 4	≤0,0094	0,0200	≤0,0094	≤0,0094
Site 5	≤0,0094	≤0,0094	≤0,0094	≤0,0094

3.4. The role of local society to preserve the delta

In the new land formed by sedimentation in delta, the aquaculture gradually becomes dominant. Most of the delta was transform into fish pond. The local said that during the raining season, flood comes along with huge sediment and formed new land which can be used as fish pond. Fish pond waste may induce water degradation. The waste was carried out by tides back to the pond and affects the fish farming [14]. The unplanned fish pond may destroy the environment and ecosystem [12].

Contrastingly, the water quality in Delta Wulan Estuary in general didn't show the bad impact of fish farming. The water quality in the fish pond areas deteriorates because of excessive feeding of food and in several countries use antibiotics as medicine [12]. Meanwhile, in Wulan Delta most of the fish pond is managed in traditional way. Farmers build his muddy pond in the delta and allow water from the river and the sea to enter the pond naturally and rely on natural food. During ebb and flood tides, the tides flush the pollution in the fish pond. They build the channels from the fish pond directly to the sea. This type of fish farming is beneficial for environment, yet it gives low productivity in the fish production [20].

4. Conclusion

This study presents the evidence of human intervention impact in the Wulan Delta. It shows that due to complicated reason, the Wulan Delta has been experiencing land use change from many land use type into fish pond. The human intervention in delta may alter water quality degradation due to aquaculture, domestic, and industrial. However, the water quality data shows there were no significant impacts of aquaculture to the decreasing of water body. The traditional aquaculture management which conducted based on natural food and tides system was suitable for the delta ecosystem and can be used as a key to preserve the deltaic environment. Based on this simple research, we can estimate the delta development in the future. The Estuaries monitoring are needed to control the pollution or sediment load in the Serang Watershed.

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