Effects of land use on sedimentation rates at Cimanuk watershed, West Java

I Munfarida¹, M Munir² and A Rezagama³

¹Environmental Department, Faculty of Science and Technology, UIN Sunan Ampel Surabaya
Jl. Ahmad Yani No. 117, Surabaya, Indonesia
²Biology Department, Faculty of Science and Technology, UIN Sunan Ampel Surabaya
Jl. Ahmad Yani No. 117, Surabaya, Indonesia
³Environmental Engineering Department, Faculty of Engineering, Diponegoro University, Jl. Prof. Soedarto, SH Tembalang, Semarang, Central Java, Indonesia.

Abstract. Watersheds can be seen as natural systems where hydrological and biophysical processes take place as well as complex socio-economic activities of the community. As an integrated water system, watershed is influenced by the upstream conditions and the biophysical conditions of catchment areas which in many places are vulnerable to the threat of human disturbance. Hence, this study was aimed at assessing the patterns of land use on sedimentation rates at Cimanuk watershed, West Java. We calculated the sediment concentration, river debit and prediction of sedimentation rates based on regulation of the Minister of Forestry No. P. 61 /Menhut-II/2014. The study revealed that land use effect the sedimentation rates from agriculture, forestry, rice fields, settlement, sauce and soy sauce factory, and leather factory with the sedimentation rates are 2,86 ton/day; 58,73 ton/day; 33,64 ton/day; 33,80 ton/day; 78,85 ton/day and 56.83 ton/day respectively. We concluded that Cimanuk watershed is characterized by deterioration with mismanagement of natural resources. Unmanaged of land use were affecting the hydrology of the Cimanuk watershed. Control potentials of watershed sedimentation include management of land use, optimization of water resources and reducing sediment load from its surrounding area.

Keywords: land use, sediment, sedimentation rates, watershed

1. Introduction
Watershed is an ecosystem unit whose main elements consist of land, water and vegetation natural resources as well as human resources as actors of the utilization of these natural resources. Watersheds in several places in Indonesia carry a heavy burden due to the level of population density and intensive use of natural resources so that there are recent indications that watershed conditions are declining with indications of increased incidence of landslides, erosion and sedimentation, flooding and drought. For example, the high sedimentation rates affect vertical accretion and soil surface elevation gains in Porong River Sidoarjo Indonesia (Sidik, Neil, & Lovelock, 2016). As an integrated water system, watershed is influenced by the upstream conditions, especially the biophysical conditions of catchment...
areas and water catchment areas which in many places are vulnerable to the threat of human disturbance.

There are 16 watershed in Java Province was an critical watershed due to sedimentation (Mawardi, 2010). The addition of this critical watershed is due to land conversion in the upstream area becoming an agricultural area for instance. Land use affects the river discharge. Muchtar (2007) found that the river discharge seen to fluctuate declining during 10 years from 1996 to 2006. And the average river discharge seems to decrease when land use increases, and on the contrary the river discharge increases when the land use decreased (Muchtar, 2007). Critical watershed may cause flooding. In Indonesia, floods have occurred for a long time. In Jakarta, for example, floods have occurred since 1959, when the population was relative small population. The Jakarta flood occurred since 1621, then followed by floods of 1878, 1918, 1909, 1918, 1923, 1932 inundated residential areas due to overflow of water from Ciliwung, Cisadane, and Angke Rivers (Rosyidie, 2013).

Sedimentation is the transportation of material resulting from erosion either through wind or water which is then deposited in the river. Material transported during sedimentation is called sediment. The main cause of sedimentation is the occurrence of erosion in the upstream or watersheds. Sedimentation can cause a decrease in volume which indirectly results in the effectiveness of river performance.

The Cimanuk watershed originates in Garut Regency and flows northeast through the Sumedang Regency and Majalengka Regency then into the Java Sea in the Indramayu and Balongan regions, Indramayu Regency. The Cimanuk watershed has a lot of potential for reservoirs, ponds and swamps that used for various activities, such as agriculture, plantations, fisheries, utilization of forest products, power plants and so on. One of the reservoirs being built is Jatigede Reservoir. The water resource infrastructure that has been built on the Cimanuk River, in the form of a Bendung Rentang, with an irrigation system covering 90,000 hectares, is located in the Majalengka Regency, Cirebon, Indramayu, which is entirely dependent on the availability of water in the Cimanuk River (KepmenPU, 2010). Considering its wide utilization, it is necessary to study the Cimanuk watershed sedimentation in order to conserve water resources.

2. Methods

The parameters measured for this analysis, namely the concentration of suspended sediment Cs (mg/L), river water discharge Q (m³/sec) and sediment discharge or discharge of suspended sediment Qs (gr/sec) was measured based on regulation of the Minister of Forestry No. P. 61 /Menhut-II/2014. The values of Q, Cs, and Qs use the following formula:

The analysis of floating sediment load (BEL) is carried out by determining the calculated concentration by using the following equation (Tjakrawarsa, 2014):

\[ Cs = \frac{G_2 - G_1}{V} \]  \hspace{1cm} (1)

Cs = sediment concentration (mg /liter)
G2 = sediment weight and filter paper in dry conditions (mg)
G1 = filter paper weight (mg)
V = volume of sediment samples (liter)

River Water Discharge (DLAS) is obtained by measuring the cross-sectional area of water discharge and river velocity in each section of the designated measurement and sampling section, the calculations of which use the DLAS general equation, as follows:

\[ Q = V A \]  \hspace{1cm} (2)

Q = river discharge (m³/sec)
V = river velocity (m/sec)
A = cross-sectional area of river (m²)
The prediction of the sedimentation rate can be predicted using the sediment discharge equation \(Q_s\) (gram/sec) as follows. The general equation of correlation between \(Q\) and \(Q_s\) as follows:

\[Q_s = Q \cdot Cs\]  

\(Q_s\) = river sediment discharge (gram / sec)
\(Q\) = river discharge (m\(^3\)/sec)
\(Cs\) = sediment concentration (mg / liter)

3. Results and Discussions

We choose 6 sampling area to measure the sedimentation based on different land use in surrounding area, we divide the sampling area based on the criteria that are areas with condensed population and these areas are the priority area to support regional economy. These areas include agriculture, forestry, rice fields, settlement, sauce and soy sauce factory, and the last is leather factory. Sampling was taken on 2 (two) duplicate on each areas. Measurement of floating sediment load (BEL) was done in duplicate, which based on the results of the analysis conducted at 6 sampling points show the results as in the following table:

| No | Land Use                  | Location     | Sediment concentration (ppm) |
|----|---------------------------|--------------|------------------------------|
| 1  | Agriculture               | Cimanuk I A  | 37.5                         |
| 2  |                          | Cimanuk I B  | 25                           |
| 3  | Forestry                  | Cimanuk II A | 37.5                         |
| 4  |                          | Cimanuk II B | 25                           |
| 5  | Rice fields               | Cimanuk III A| 100                          |
| 6  |                          | Cimanuk III B| 87.5                         |
| 7  | Settlement                | Cimanuk IV A | 50                           |
| 8  |                          | Cimanuk IV B | 50                           |
| 9  | Sauce and soy sauce factory| Cimanuk V A  | 37.5                         |
| 10 |                          | Cimanuk V B  | 37.5                         |
| 11 | Leather factory           | Cimanuk VI A | 37.5                         |
| 12 |                          | Cimanuk VI B | 25                           |

Based on the measurement of floating sediment load (BEL) shows that the concentration of sediment load in the Cimanuk River has a concentration ranging from 25-100 ppm with an average concentration of 45.83 ppm. The highest concentration of floating sediment load (BEL) was in the Cimanuk III sampling location (rice fields), which ranges from 87.5-100 ppm with an average concentration of 93.75 ppm. To calculate the cross-sectional area, it is assumed that the cross-sectional profile of the river is as follows:
Table 2. River Crossing Area

| No. | Land Use                     | Location       | Wide (m) | Dept (m) | Crossing Area (A) m² |
|-----|------------------------------|----------------|----------|----------|----------------------|
| A   | Agriculture                  | Cimanuk I      | 10,35    | 0,32     | 1,66                 |
| B   | Forestry                     | Cimanuk II     | 15,5     | 1,95     | 17,59                |
| C   | Rice fields                  | Cimanuk III    | 12       | 0,75     | 16,20                |
| D   | Settlement                   | Cimanuk IV     | 18,5     | 1,25     | 18,50                |
| E   | Sauce and soy sauce factory  | Cimanuk V      | 16,3     | 1,2      | 19,97                |
| F   | Leather factory              | Cimanuk IV     | 30,5     | 1,4      | 39,65                |

The sedimentation rates was measured according to equation describe in methods with the results as follows:

Table 3. Sedimentation Rates

| Crossing Area (A) m² | River Velocity V (m/dtk) | River Discharge (m³/dtk) | Sediment Concentration Cs (mg/L) | Coefficient k | Sedimentation Rates ton/day |
|----------------------|--------------------------|--------------------------|---------------------------------|---------------|-----------------------------|
| 1,66                 | 0,64                     | 1.06                     | 31.25                           | 0.0864        | 2.86                        |
| 17,59                | 1,24                     | 21.75                    | 31.25                           | 0.0864        | 58.73                       |
| 16,20                | 0,38                     | 6.23                     | 62.5                            | 0.0864        | 33.64                       |
| 18,50                | 0,31                     | 5.69                     | 68.75                           | 0.0864        | 33.80                       |
| 19,97                | 1,04                     | 20.86                    | 43.75                           | 0.0864        | 78.85                       |
| 39,65                | 0,44                     | 17.54                    | 37.5                            | 0.0864        | 56.83                       |

If we combine the land use with the sedimentation rates, it is known that different land use has a different results in sedimentation rates.

Table 4. Sedimentation Rates based on Land Use

| Land Use                        | Sedimentation Rates (ton/day) |
|---------------------------------|--------------------------------|
| Agriculture                     | 2.862                          |
| Forestry                        | 58.725                         |
| Rice fields                     | 33.642                         |
| Settlement                      | 33.7986                        |
| Sauce and soy sauce factory     | 78.8508                        |
| Leather factory                 | 56.8296                        |

From the results above, it is known that the highest sedimentation rates was resulted from Sauce and soy sauce factory, followed by Leather factory. These 2 (two) areas were the economy priority in Garut Regency that has a great contribution to regional economy. Sauce and soy sauce factory produce sauce and soy sauce to fulfil the Indonesian demand, meanwhile leather factory produce a variety of leather clothes, shoes, bags etc. to fulfil the Indonesian demand and some of the products also exported to another country such as Singapura, Malaysia, and Taiwan. Leather factory namely Sukaregang Leather Centre in Garut Regency was famous leather producer in Indonesia.

Sedimentation as a key indicator of the quality of a watershed system. The indicator is strongly influenced by land use, while land use is strongly influenced by human activities in it. Previous study revealed that run off and land use are the likely sources of the original excess sediment of the Great Barrier Reef (GBR) (Bartley et al., 2018). Another factor is that the watershed as a media and humans as a cause of changes in watershed ecosystems that cause environmental degradation. Previous study has done with the correlation between the watershed, land use and sedimentation rate (Schiefer et.al, 2013) and (James, 2019).

In the context of broad management, watershed management can be seen as an ecological resource system, a socio-economic development unit and a regional spatial unit that implies integration and balance between the principles of productivity and conservation of natural resources. Physical
conditions of the environment that also influence sedimentation rates are river crossing area coefficient, the greater the crossing area coefficient the greater the sedimentation has. The coefficient value of the wide river shows that the drainage area is wide, so that the amount of sedimentation that occurs is likely to be influenced by the area of agriculture and rice fields in the areas, which has lack of management of soil and water conservation.

In general, the problem of water resources is related to the distribution of land use and river velocity. Thus, the management of vegetation in the upstream area is the most effective way to reduce the sediment into the rivers. Geologically, Cimanuk Watershed is susceptible to erosion due to types of silt and sandy silt was generally on the hills and mountain slope (Sulaksana et.al, 2013). With mismanagement of the catchment areas on Cimanuk Watershed may lead to environmental degradation. Unmanaged of land use were affecting the hydrology of the Cimanuk watershed. Control potentials of watershed sedimentation include management of land use, optimization of water resources and reducing sediment load from its surrounding area.

4. Conclusions

This study was aimed at assessing the patterns of land use on sedimentation rates at Cimanuk watershed, West Java. We calculated the sediment concentration, river debit and prediction of sedimentation rates based on regulation of the Minister of Forestry No. P. 61 /Menhut-II/2014. The study revealed that land use effect the sedimentation rates from agriculture, forestry, rice fields, settlement, sauce and soy sauce factory, and leather factory with the sedimentation rates are 2.86 ton/day; 58.73 ton/day; 33.64 ton/day; 33.80 ton/day; 78.85 ton/day and 56.83 ton/day respectively. We concluded that Cimanuk watershed is characterized by deterioration with mismanagement of natural resources. Unmanaged of land use were affecting the hydrology of the Cimanuk watershed. Control potentials of watershed sedimentation include management of land use, optimization of water resources and reducing sediment load from its surrounding area.

References

[1] Bartley, R., Thompson, C., Croke, J., Pietsch, T., Baker, B., Hughes, K., & Kinsey-Henderson, A. (2018). Insights into the history and timing of post-European land use disturbance on sedimentation rates in catchments draining to the Great Barrier Reef. Marine Pollution Bulletin, 131(May), 530–546. https://doi.org/10.1016/j.marpolbul.2018.04.070
[2] James, L. A. (2019). Impacts of pre- vs. postcolonial land use on floodplain sedimentation in temperate North America. Geomorphology, 331, 59–77. https://doi.org/10.1016/j.geomorph.2018.09.025
[3] Mawardi, I. (2010). Daya Dukung Sumberdaya Air di Pulau Jawa. Jurnal Hidrosfir Indonesia, 5(2), 1–11.
[4] Muchtar, A. (2007). ANALISIS FAKTOR-FAKTOR YANG MEMPENGARUHI DEBIT SUNGAI MAMASA Analysis of Factors Influencing the River Discharge of Mamasa. Jurnal Hutan Dan Masyarakat, 2(1), 174–187.
[5] Rosyidie, A. (2013). Banjir: Fakta dan Dampaknya, Serta Pengaruh dari Perubahan Guna Lahan. Journal of Regional and City Planning, 24(3), 241–249.
[6] Schiefer, E., Petticrew, E. L., Immell, R., Hassan, M. A., & Sonderegger, D. L. (2013). Land use and climate change impacts on lake sedimentation rates in western Canada. Anthropocene, 3(2013), 61–71. https://doi.org/10.1016/j.ancene.2014.02.006
[7] Sidik, F., Neil, D., & Lovelock, C. E. (2016). Effect of high sedimentation rates on surfave sediment dynamics and mangrove growth in the Porong River, Indonesia. Marine Pollution Bulletin, 107(1), 355–363. https://doi.org/10.1016/j.marpolbul.2016.02.048
[8] Sulaksana, N. -., Sukiyah, E. -., & Sjafrudin, A. - (2013). Karakteristik GEOMORFOLOGI DAS Cimanuk bagian hulu dan implikasinya terhadap INTENSITAS EROSI SERTA PENDANGKALAN WADUK JATI GEDE. New Bionatura, 15(2), 100–106.