Determination of Sediment Rating Curve In Dry Season In Bedagai Watersheds

E Susanto1, S A Dawolo1 and T Rizaldi1

1Departement of Agricultural Engineering, Faculty of Agriculture, Universitas Sumatera Utara, Medan, Indonesia

Email: edi.susanto@usu.ac.id

Abstract. This research was conducted to overcome the problem of lack of sediment data in a watershed in North Sumatra due to the lack of sediment measurements recording which is caused by the amount of cost required, relatively long time, and the risk of obtaining such data. The purpose of this study was to obtain the equation of sediment curved line. Sediment curved line is an equation that connects the river discharge with the sediment discharge. The river discharge data could be used to obtain the sediment discharge. This research used descriptive methods in the form of primary data (debit data and sediment concentration) and secondary data (climate data). Results obtained sedimentary curved lines $Q_s = 18.995Q_w^{1.9923}$ and $R^2 = 0.7451$. The obtained sediment discharge has exceeded the limits set by the Ministry of Forestry regarding to the criteria for watershed determination.

1. Introduction
A watershed is an area that is bounded by a river separator or ridge topography and whenever there is rain falling in it, the rain water will be collected, stored and flowed through the river system with its branches and the watershed will exit through one exit [1]. Sediment yield is the amount of sediment originating from erosion that occurs in the catchment measured at certain time periods and places [2]. Accurate sediment data is very important in solving hydrological problems in a watershed. But in reality, the recording of river sediment measurements is still lacking. Sediment data in a watershed is still very limited. Equation of sediment curved line can determine the concentration of sediment without making measurements directly to the river so that it does not use a large cost and a long time in determining the watershed concentration. Sediment debit ($Q_s$) can be obtained by knowing the concentration of sediment ($C$), debit ($Q_w$) and 0.0864 (constant) [3]. The purpose of this study was to obtain the sediment rating curve in Bedagai River Watersheds.

2. Material and Methods

2. 1 Location
This research was conducted from April - June 2019, with the location in the upstream of the Bedagai watershed, which is between 03° 05' - 03° 38' 10" LU and 98°48´22” - 99° 16' 35" BT. (Figure 1).
Administratively, the Bedagai watershed is located in Serdang Bedagai Regency. The materials used in this study were spatial data such as soil type maps, DEM maps, and land use maps, climate data series. Other supporting materials were river debit data, soil physical and sediment characteristics data. Bottles used to hold the sediment. Whatmann filter paper type 934-AH. The equipment used was a set of computers with arcGIS and Microsoft Office software, water level loggers and current meter.

2. 2 Research Procedure
This research used descriptive methods using primary and secondary data. Figure 2 shows the stages of the study that began with the determination of the location of the study as well as the installation of the water level logger and water sample bottles; Data collection was obtained from primary data in the form of river flow using current meter, sediment samples taken from the river outlet points using sample bottles, and water level data using water level loggers which function to record the river water level data every four hours and secondary data in the form of data climate originating from rainfall data which was taken in rainfall recording devices installed at river flow measuring stations (SPAS), DEM maps, and land cover data; analyzing the sediment concentrations using the gravimetric method analysis [4], and determination of sediment curved lines using the assessment curves and model elevation.

2. 3 Stage of Sediment Rating Curve and Model Evaluation
The relationship between river debit graphs at the river flow measuring stations (SPAS) and the sediment debit was performed, the line adjustments using curved line equation models such as the power function method. To find out how well the equation model must be compared with the observational data, the evaluation model was carried out using the coefficient of determination (R2) as recommended by The American of Civil Engineers [5] [6]. The coefficient of determination (R2) is an indicator of the relationship strengthness between the observation value and the simulation value [7], R2 has a range of 0-1, the value of R2 is satisfactory if the value is above 0.6.
3. Result and Discussion

3.1 General condition of Watershed

The Bedagai watershed has an area of 21406 ha with a length of 147730 km and also has land cover in the form of rice fields, plantations, secondary dryland forests, shrubs, mixed dry agriculture, open land and three types of soil namely Alluvial, Podsolik, and Andosol.
3.2 Sediment Concentration and Sediment Debit
Rainfall data was obtained by using a rainfall recorder that has been installed in a river flow measuring station (SPAS). Table 1 shows the highest and the lowest rainfall data that occurred in May 2019 of 77 mm/month and in July 2018 of 10 mm/month. The monthly rainfall value at the study site is included in a small category (<100 mm/month) and according to BMKG (Meteorological, Climatological and Geophysical Agency), it was estimated that in 2018/2019 the forecast of the peak rainy season in most parts of central and northern Sumatra is predicted to experience the peak of the rainy season since October until December, then beside of that time will be the dry season [8].

Table 1. Data of Rainfall and Debit of River

| Month | Rainfall (mm/month) | River Debit (m³/Second) |
|-------|---------------------|-------------------------|
| April – 2019 | 12 | 3.61 |
| May – 2019 | 77 | 4.39 |
| June – 2019 | 44.5 | 3.86 |
| July - 2019 | 10 | 3.91 |

Table 1 shows the distribution of the highest average monthly river debit that occurred in May 2019, which was 4.39 m³/second and the lowest monthly river debit occurred in April 2019, which was 3.61 m³/second. The difference in river water debit data was caused by the difference in the average height of river water every day caused by rain which makes the water level rise and fall. About 70% of the headwaters have an average slope of above 8, which in general, headwaters have a higher rainfall intensity compared to the central and the downstream of river in the rainy season.

Results show that the highest sediment debit value occurred on May 22, 2019 which was 277.86 tons/ha/year and the lowest sediment debit value occurred on May 13, 2019 which was 0.69 tons/ha/year. The difference in the results of the sediment debit data was influenced by the occurrence of sediment transport in rivers carried by the flow of water, which is closely related to the soil erosion due to rain. Sediment transport depends on the climatic conditions i.e rainfall and dry season and is influenced by human activities. The largest amount of sediment debit occurred in May 2019 at 277.86 tons/ha/year. Sediment debit value has exceeded the allowable erosion value, which was 7 tons/ha/year, this was caused by the presence of land cover in the form of open land and high land slope [9].

Figure 3 shows that the river debit (Q) has a relationship with sediment debit (Qs). This is because river flow not only has the carrying capacity of various sources of erosion entering the river channel, but also has the power to erode the river and make another form of erosion contribution. The kinetic power of rain to break soil aggregates can produce the erosion material, but it takes time to form soil aggregates which are then transported to river channels. Therefore, large rainfall can cause a larger sediment debit [10].
3. Sediment Rating Curve

Sediment sampling was carried out simultaneously by collecting the river and sediment debit data, so that a relationship can be made between those two data. In making sediment curve line, the river debit data and sediment samples can represent the conditions of large flow, normal flow, and small flow that were used. Figure 4 shows \( Q_s = 18.995Q_w^{1.9923} \) and \( R^2 = 0.7451 \). From the equation above, a constant value of 18.995 and a constant value of \( b \) of 1.9923 were obtained. From the equation that has been obtained, the coefficient of determination of 0.7451 was included in the satisfactory category [5] [6]. This means that 74% of the sediments that occur were influenced by the river debit factors and the equation generated from the sedimentary curvature was a suitable assessment for use.

Table 2 shows that the determination of the sediment rating curve equation with the power function equation method has been carried out at different watershed locations, namely the Sei Kalembah sub-watershed (Padang watershed) and the Sei Petani sub-watershed (Deli watershed). Coefficient of determination \( (R^2) \), an indicator for the strength relation between observed and simulated values, has values 0 - 1, and considered “satisfactory” if the value > 0.6 [11] [6]. The results of the study (Table 2)

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**Figure 3.** Relationship Graph of River Debit and Sediment Concentration
obtained the coefficient of determination ($R^2$) greater than 0.65, which means that the method is good enough in determining the sediment rating curve equation.

Table 2. Several studies determining the sediment rating curve equation with power function method

| No | Sub Watershed | Watersheds | Sediment rating curve equation | $R^2$ |
|----|---------------|------------|---------------------------------|-------|
| 1  | Sei Kalembah  | Padang (North Sumatera) | $Q_s = 507.16Q^{1.8681}$ | 0.8706 |
| 2  | Sei Petani    | Deli (North Sumatera)   | $Q_s = 13.21Q^{2.937}$     | 0.6539 |

![Figure 4. Sediment rating curve](image)

4. Conclusion
The highest sediment debit that occurred at the study site was on May 22, 2019 amounting to 16295.50 tons/day and the lowest debit value occurred on May 13, 2109 amounting to 40.49 tons/day. Sediment Curved Line was obtained with the value of $Q_s = 18.995Q^{1.9923}$ and $R^2 = 0.7451$. This equation can be used to determine the amount of sediment discharge with using only sediment debit data in rivers in the study location.
5. References

[1] FAO 2017 Watershed management in action (Rome: Food and Agriculture Organization of the United Nations) p 155 www.fao.org/3/a-i8087e.pdf

[2] Morgan R P C 2005 Soil Erosion and Conservation. 3rd Ed (Blackwell Publishing Ltd) p 1-304

[3] Sitorus A and Susanto E 2019 A Sediment Rating-curve Method to Determine Sediment Discharge for Rainy Season in Micro-scale Watersheds Indonesian Journal of Agricultural Research 2 13 - 19

[4] APHA 1995 Standard Methods for the Examination of Waters and Wastewater part 2540B. 19th ed (American Public Health Association) p 541 http://www.mwa.co.th/download/file_upload/SMWW_1000-3000.pdf

[5] Ahl R S, Woods S W and Zuuring H R 2008 Hydrologic calibration and validation of SWAT in a snow-dominated rocky mountain watershed, montana, USA 1 JAWRA Journal of the American Water Resources Association. 44 1411-1430

[6] Moriasi D N, Arnold J G, Van Liew M W, Bingner R L, Harmel R D and Veith T L 2007 Model evaluation guidelines for systematic quantification of accuracy in watershed simulations Trans. Asabe. 50 885-900

[7] Syvitski J P, Morehead M D, Bahr D B and Mulder T 2000 Estimating fluvial sediment transport: The rating parameters Water Resources Research. 36 2747 - 1760

[8] BMKG 2018 Konferensi Pers Kondisi Cuaca Libur Natal 2018 Dan Tahun Baru 2019 (Badan Meteorologi Klimatologi dan Geofisika.) p 1 https://www.bmkg.go.id/berita/?p=jumpa-pers-perihal-kondisi-cuaca-menjelang-libur-natal-2018-dan-tahun-baru-2019&lang=ID&tag=berita-utama

[9] Permenhut 2014 Peraturan Menteri Kehutanan RI Nomor P.60/Menhut_II/2014 tentang Kriteria Penetapan Klasifikasi Daerah Aliran Sungai (Peraturan Menteri Kehutanan) p http://www.dephut.go.id/uploads/files/9e273c30a090150675cba99a743038c3.pdf

[10] Susanto E, Setiawan B I, Suharnoto Y and Liyantono L 2017 Evaluation of Water Debit in Oil Palm Plantation Watershed Using the Soil Water Assessment Tool (SWAT) International Journal of Civil Engineering and Technology 8 332 - 341

[11] Santhi C, Srinivasan R, Arnold J G and Williams J R 2006 A modeling approach to evaluate the impacts of water quality management plans implemented in a watershed in Texas Environmental Modelling & Software. 21 1141-1157

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