Estimation of Suspended Sediment Load by Power and Logarithmic Function Methods Using Mean Load within Discharge Classes

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1. Introduction

Suspended sediment load has a direct relationship with water discharge and is, basically and most often, defined by a power equation. There are two possible approaches to analyze the data leading to the derivation of the water discharge-sediment load relation: the power and logarithmic function methods. While the two are fundamentally the same as they result to a power equation, they differ as regards to the residual term as it is additive in power function model but multiplicative in the logarithmic function model. Moreover, stratification of data into discharge-base classes is introduced and the means of which are used to fit a rating curve.

2. Objective and Study site

The study is conducted to estimate the sediment load in some relatively small perennial rivers using the power and logarithmic function models and assess the most appropriate model for the data. The data was taken during the observation period from April to December 2008 in the three tributaries of Shimanto River: the N, M and H rivers. The N river flows into the M river, which in turn flows into the H river. The covered watershed area are 25.4 km^2 (the N river), 75.9 km^2 (the M river), and 185.6 km^2 (the H river). The study site is drawn in **Fig.1**.

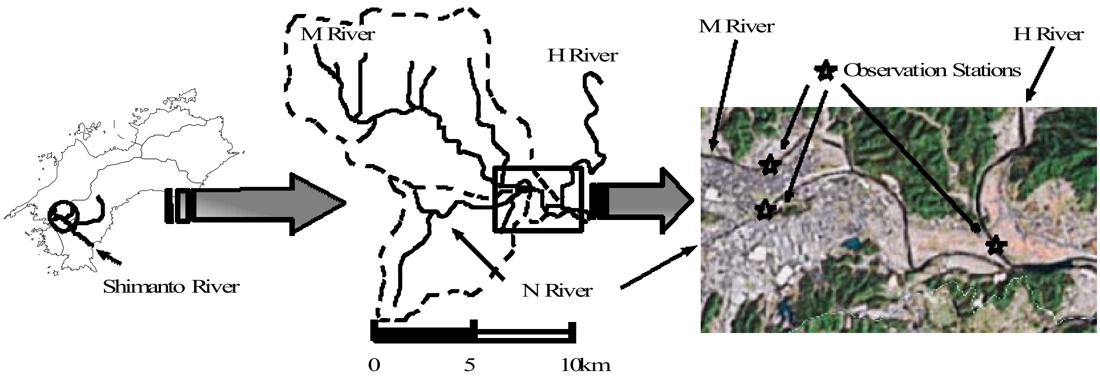

Fig.1: Study site relative location in Shikoku, river network and location of observation stations

3. Methods

Discharge (water level) is monitored every one hour by data loggers. Water samples are collected by an automatic water sampler - twice a day during irrigation season and once a day in other months. Laboratory analysis is done to determine the turbidity and sediment concentration of the samples.

The data were preliminarily analyzed to determine the relationship among discharge, sediment concentration, sediment load and turbidity. It showed no good relationship between the discharge and sediment concentration as equally high discharges have very wide range of sediment concentration. Thus, in this study, sediment load is used to describe the sediment transport. Grouping the discharge into appropriate classes and its corresponding sediment load computed was also adapted to account for discharges with nil sediment concentration.

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The power function method was done by plotting the mean of the discharge classes against the corresponding mean sediment load, either in a normal or log-log scale. Then the power equation is derived from the corresponding trend line drawn. The logarithmic function method was done by plotting the mean of the logarithms of the classes' discharge and sediment load in a normal scale. A linear regression equation is developed using least square method. Then, the resulting log-linear equation is retransformed to yield a power equation.

The data are normally distributed. However, it is skewed as to log-normal distribution with Coefficients of Skewness, α_{coeff}: -0.702, -3.75 and -0.021. Based on the range and magnitude of the discharge data, it was grouped into 12, 19, and 14 classes for N, M and H rivers, respectively.

4. Results

The correlation coefficient of the derived prediction equations (**Table 1**) shows that, generally, power function method resulted to a better correlation between the discharge and sediment load. Though, the difference seems not significant in the N and M rivers, it is significant in the H river. Statistical analysis between the actual and predicted values was also undertaken. F-test probability values are 0.2847, 0.8615, and 0.2510 using power function method and 0.3473, 0.9172, and 0.0026 using logarithmic function method. Moreover, the probabilities associated with two-tailed t-test are 0.7131, 0.8950, and 0.7425; and 0.0077, 0.1671, and 0.0230, for the power and logarithmic function methods, respectively.

The estimated total sediment loads during the observation period are 255 and 257×10^3 kg for the N river, 1,071 and 869×10^3 kg for the M river, and 1,483 and $1{,}012 \times 10^3$ kg for the H river - using power and logarithmic function method, respectively.

Generally, the power function method yielded a higher computed sediment load value, as t-test probability values showed. However, in few very high flows, i.e. $Q > 2.5$ m^3/s for the N river and $Q > 45$ m^3/s for the M river, the logarithmic function method yielded a disproportionately higher sediment load. This causes the higher estimated load using logarithmic function method in the N river. Also, the very great difference between the estimated sediment loads in the H river implied that the logarithmic function method is not appropriate for its data.

Table 1: Suspended Sediment Load Prediction Equations

RIVER	Discharge Classes	Power Function Method	Log Function Method
Nara	Without	$\boldsymbol{SL} = 39.114\boldsymbol{Q}^{0.9695}$ (R^2=0.7203)	
	With	$\boldsymbol{SL} = 40.998\boldsymbol{Q}^{0.9424}$ (R^2=0.9449)	$\boldsymbol{SL} = 27.4536\boldsymbol{Q}^{0.9058}$ (R^2=0.9387)
Mima	Without	$\boldsymbol{SL} = 69.368\boldsymbol{Q}^{0.9417}$ (R^2=0.4150)	
	With	$\boldsymbol{SL} = 94.135\boldsymbol{Q}^{0.9233}$ (R^2=0.9387)	$\boldsymbol{SL} = 62.1871\boldsymbol{Q}^{1.0308}$ (R^2=0.9371)
Hiromi	Without	$\boldsymbol{SL} = 32.318\boldsymbol{Q}^{0.6105}$ (R^2=0.4606)	
	With	$\boldsymbol{SL} = 11.575\boldsymbol{Q}^{1.1959}$ (R^2=0.8877)	$\boldsymbol{SL} = 2.3153\boldsymbol{Q}^{0.6899}$ (R^2=0.7608)

5. Conclusion

These statistical tests showed that among the three rivers, the M river has the most acceptable predicted sediment load values, followed by the N and H rivers. Between the two methods, power function method yielded a more acceptable prediction, thus, it is more adaptable and appropriate for the gathered data. With this, the total amount of sediment transported by three rivers during observed period was about 2.8×10^6 kg.