Suspended Load Estimation of Perennial Rivers in a Rural Area

〇Edward Lapong*, Masayuki Fujihara**, Tomoki Izumi**, Noriyuki Kobayashi** and Toshiko Kakihara**

1. Introduction

Suspended sediment is one of the major pollutants in rivers. It carries nutrients and constituent loads that can heavily affect aquatic ecosystems. It is also the most visible pollutant originating from agricultural areas and its valuated economic damage is huge, thus, it is an important problem to be addressed especially in areas with high agricultural activity and soil erosion rate. During spring and summer seasons which are periods of high agricultural activities, particularly during rice transplanting, water containing high amount of suspended sediment is thrown into streams and rivers. In this study, suspended loads of three perennial rivers in a rural area are estimated and the contribution of the agricultural activities is discussed.

2. Study Site, Materials and Methods

The suspended sediment in M, N and H rivers was observed from April 2008 to November 2009. The rivers are tributaries of Shimanto River within Ehime Prefecture flowing in rural watersheds with significant agricultural activities and considerable paddy rice area (**Table 1**).

Table 1: River watershed characteristics

Characteristics \ River	**M**	**N**	***H***
Area (km^2)	76	25	186
Main stream (km)	17	8	37
Paddy Rice Area (ha)	556	88	200
% of Total Area	*7.3*	*3.5*	*1.1*

Water samples for sediment analysis were taken every 12 hours during April-August (rice production season) and once every 24 hours during September-March using an automatic water sampler. River discharge, on the other hand, was monitored every hour by a water depth logging device and actual measurement was done once or twice a month to establish the discharge rating curve.

The sediment load was estimated by power regression analysis, with model equation,

$$\boldsymbol{SD = aQ^{b}} \tag{1}$$

where SD is the sediment discharge, Q the streamflow/discharge, and a & b the constants. The data was grouped into rice and non-rice transplanting seasons (RTS and NRTS) to account for the effect of rice transplanting activities. The data was also stratified into discharge classes, thereby, improving the river discharge-sediment load (Q-SD) correlation.

3. Results

3.1 Q-SD Relationship

The data assessment revealed that the rivers have considerably higher suspended sediment concentration (SC) during RTS which falls during April-June. All rivers showed poor Q-SC correlation. On the other hand, Q and SD have relatively good correlation, hence, it is used in the sediment load estimation.

The regression analysis revealed that stratification of the data into discharge classes improved the predictive capability of the developed model equations with Nash-Sutcliffe coefficients 1.5 to 4 times higher

* The United Graduate School of Agricultural Sciences, Ehime University
** Faculty of Agriculture, Ehime University
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than when the data is not stratified (**Table 2**). The t-Test shows that there is significant difference in the values at 1-5% level. Seasonally-grouping the data, though it improves the Q-SD correlation (R^2) and the predictive accuracy of the developed equations, was found to be significant only in the data of River N, at 5-10% level.

Table 2: Suspended sediment load prediction equations and Nash-Sutcliffe model efficiency coefficients

Period/Data	Data Stratification	River M	River N	River H
All	*Without*	$SD = 91.87Q^{0.853}$ (*0.195*)	$SD = 40.74Q^{0.905}$ (*0.496*)	$SD = 53.90Q^{0.924}$ (*0.256*)
	With	$SD = 128.87Q^{1.030}$ (*0.486*)	$SD = 47.73Q^{0.926}$ (*0.267*)	$SD = 44.50Q^{1.133}$ (*0.332*)
RTS ***(April-June)***	*Without*	$SD = 108.46Q^{0.902}$ (*0.294*)	$SD = 41.67Q^{0.999}$ (*0.424*)	$SD = 74.85Q^{0.832}$ (*0.249*)
	With	$SD = 146.90Q^{0.951}$ (*0.336*)	$SD = 47.44Q^{1.054}$ (*0.448*)	$SD = 101.99Q^{0.776}$ (*0.307*)
NRTS ***(July- March)***	*Without*	$SD = 83.50Q^{0.851}$ (*0.172*)	$SD = 41.66Q^{0.869}$ (*0.489*)	$SD = 44.02Q^{1.004}$ (*0.274*)
	With	$SD = 100.32Q^{1.197}$ (*0.672*)	$SD = 49.53Q^{0.892}$ (*0.553*)	$SD = 30.06Q^{1.255}$ (*0.330*)

Among the parameters, only the data stratification has significant effect on the estimated annual sediment load of the rivers, with significant difference at 1%-5% level. It also improved the "nearness" of modeled sediment load to the observed data (**Table 3**).

Table 3: Annual suspended sediment load, SL (tons)

River / Type of SL	**M**	**N**	***H***
Observed	1,558	220	1,272
Modeled/Estimated (*without data stratification*)	1,020	179	1,257
Modeled/Estimated (with data stratification)	1,769	214	1,353

3.2 Contribution of Agricultural Activities to Suspended Load

The impact or contribution of rice transplanting and related agricultural activities were determined by using the developed equations during RTS and NRTS and using it to compute the sediment load during April-June. As found out, the computed sediment load using RTS equation is higher than using the NRTS equation. The percentage difference was considered the probable contribution of the rice transplanting activities: at 18%, 16% and 63% of the sediment load of M, N and H River, respectively (**Table 4**).

Table 4: Suspended sediment load during April-June (tons)

River / Type of Equation	**M**	**N**	***H***
RTS	393	45	186
NRTS	323	38	68
Difference	*18%*	*16%*	*63%*

4. Conclusion

Stratification of discharge into classes during regression analyses reduces the regression and curve-fitting errors, thus, improving the predictive capability of the derived model equations. On the other hand, seasonally-grouping the data results to a minimal improvement of the model equations. Moreover, based on the resultant equations, expressing river discharge-sediment correlation, in both rice transplanting and non-rice transplanting seasons, the rice transplanting and related agricultural activities (soil paddling etc.) were found to be a significant contributor to the rivers' suspended load.

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