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Adjustment of Lane - Kalinske Suspended Sediment Equation

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Abstract: There are so many sediment formulas, which most of them were made for special rivers. This paper calibrates a suspended sediment equation, lane-Kalinske in Armand, Soolegan and Bazoft Rivers, which have 30 years field data. The analysis is directed toward the question of how systematically to change the values of the coefficients and form of the formula by comparing equation results to field data. Calibrating this formula, the ratio of C/O increased to an acceptable amount in comparison with the former one, Soolegan (0.75), Bazoft (0.75), Armand (0.88). This formula before calibrating had a good performance in Armand River in comparison with two other rivers. After calibration this condition was the same and repeated. So it can be told that if a formula obtain the suspended sediment very accurately but it cannot be a reason that calibration of it, is not necessary.

Key words: Lane- Kalinske · Calibration · Armand · Soolegan and Bazoft Rivers

INTRODUCTION

Sediment transport implications are of increasing interest for water quality and land use management, because a large percentage of the annual sediment yield from a watershed is transported by a stream specially during a small number of floods [1], that occur in a relatively short period of time in a year [2]. Erosion and sediment transportation determination are the important matters in watershed management. Management of watershed can be easier if the amounts of sediment discharges in rivers are measured very accurately [3]. On the other hand suspended sediment estimation is the most important problem, because there are so many groups that need this kind of data [4]. So determination of sediment specially suspended sediment is linked to the conservation projects [5]. Also estimation of reservoirs capacity is linked to this determination [6]. In determination of suspended sediment discharge sampling method [7], the method that is used for estimation of watershed sediment [8] and rain intensity and human activities are desirable [9]. There are existed so many ways for sediment sampling in rivers [8, 10-15]. This shows the importance of suspended sediment sampling. In so many rivers sediments are transported during and after floods like in Eel River, California [9]. Because of this matter the time of sampling and sediment determination must be paid more attention [6]. According to [16], inaccuracies in sediment estimation include errors from equations approximations and lack of data. Therefore, selecting suitable model requires careful consideration of the theory of the model and the data availability. These data may include channel bed slop, flow velocity, bed composition and water temperature. Some researchers focus on the velocity profile or the sediment concentration profile for sediment-laden flow by using numerical method or analytical solution [17]. In the past, Lane and Kalinske equation has been proposed, but it has never been calibrated for special rivers. In this paper, calibration of suspended sediment discharge for three Rivers is presented. Lane and Kalinske suspended sediment discharge equation, the formula that was selected for this purpose, is one of the equations that include four input parameters and is complicated.

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MATERIALS AND METHODS

Study Area: Application of the suspended sediment estimation equation is tested in three Rivers in Iran. Sediment discharge and sediment concentration and also water discharges series for the stations are used to develop and verify models performances. Soolegan Station is located in Soolegan River at 51° 14´latitude 31°38 ´ longitude. The drainage area of this river is about 1992 km^2 and the station that these data are used from, is located in 2086 meters higher than see level. This river is located in North Karoon basin. The basin is one part of Zagros mountainous lands and is covered by limy and marly soils. The mean rainfall depth of the basin is about 500 mm, which in contrast with other areas in Iran is considerable. This basin also is filled with semi-dense forests. The main source for this river is Vanak River and its length is recorded to about 164 km and the drainage area of this river includes 22 percent of North Karoon basin. Another river is Bazoft that the drainage area of this river is about 2355 km^2 and the station that these data are used from, is located in 913 meters higher than see level. Armand Station is located in Armand River at 50° 46' latitude 31° 40' longitude. The drainage area of this river is about 9986 km^2 and the station that these data are used from, is located in 1082 meters higher than sea level. This river is located in North Karoon basin. The basin is one part of Zagros mountainous lands and is covered by limestone and marl soils. The mean rainfall depth of the basin is about 500 mm, which in contrast with other areas in Iran is considerable. This basin also is filled with semi-dense forests.

Data Sources: The range of all data used in this study lie within the range of data used in the development of the selected equation. This is illustrated in Table 1. The numbers of the years that data was collected from is about 30 years. Abnormal distribution of data have such effects that may lead to high fluctuations in figures and reduces the reliability of analytical results, thus normalization of data is necessary. At first imperfect data were eliminated and then the absent data were estimated by using interpolation method.

Suspended Sediment Formulae

Suspension: The finer particles of the sediment load of streams move predominantly as suspended load.

Suspension as a mode of transport is opposite to what Chang-Simons-Richardson called "surface creep" and to what he defines as the heavy concentration of motion immediately at the bed. In popular parlance this has been called bed load, although as defined in this publication bed load includes only those grain sizes of the surface creep which occur in significant amounts in the bed.

Lane-Kalinske [18] derived a suspended sediment transport model in which their approach was based on $\varepsilon_s=\varepsilon_m$, they assumed that β=1 and introduced this equation

$$\varepsilon_s = kU_* \frac{y}{D}(D-y) \tag{1}$$

The average of this parameter is obtained

$$\overline{\varepsilon_s} = \frac{\int_0^D \varepsilon_s dy}{D} = \frac{kU_*}{D^2}\int_0^D (yD - y^2)dy \tag{2}$$

Herein are:

$u_* = \sqrt{\frac{\tau_0}{S_f}}$ = the sheer velocity

g the acceleration due to gravity

y the distance from the bed

k Van-Karman coefficient equal to 0.4

Beside the above parameters and equations there is a function as sediment concentration in water depths y. It must be mentioned that this factor is estimated as a function of concentration in water depths a.

$$\frac{C_y}{C_a} = \left(\frac{d-y}{y}\frac{a}{d-a}\right)^z \tag{3}$$

In which the concentration of these particles at y is c_y and the concentration c_a of the same particles at distance a. y is the variable of integration, the dimensionless distance of any point in the vertical from the bed, measured in water depths d. with

$$z = \frac{v_s}{0.40u_*} \tag{4}$$

y measured with d as unit

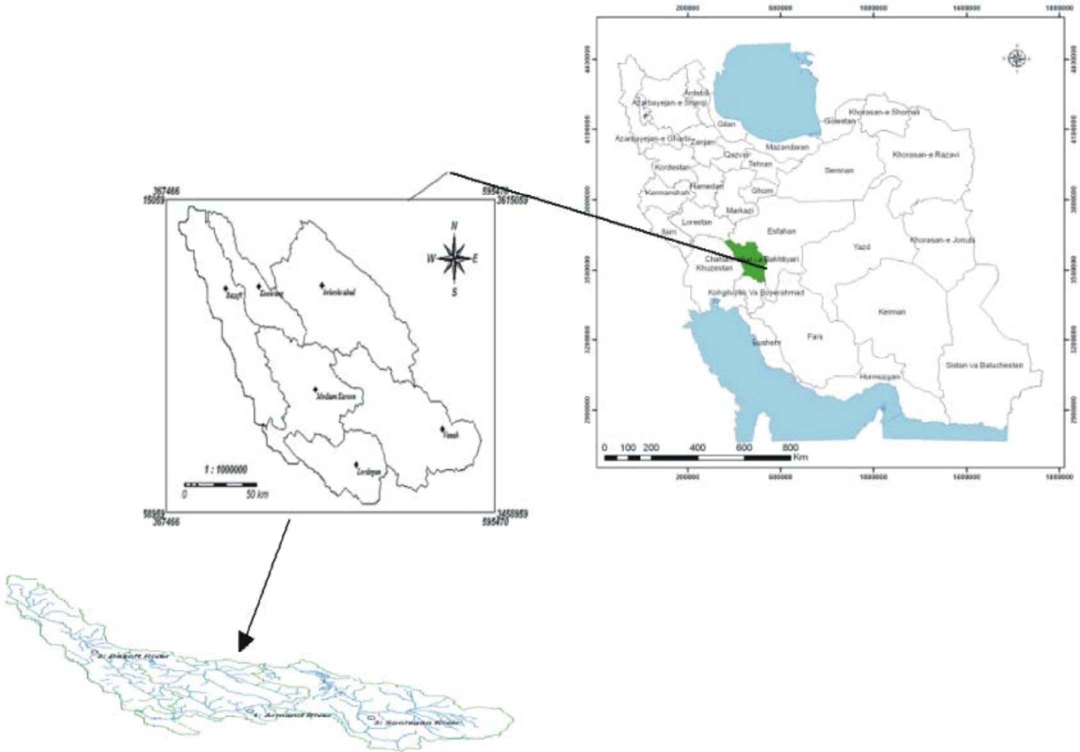

Fig. 1: Armand, Bazoft, Soolegan Rivers

Table 1: Range of data used in the development of equations

River	Data source	Flow depth (m)	Mean velocity of water (m/s)	Mean water discharge (m^3/s)	Mean of suspended sediment discharge (ton/d)	Maximum water discharge (m^3/s)	Minimum water discharge (m^3/s)	Maximum suspended sediment discharge (ton/d)	Minimum suspended sediment discharge (ton/d)
Armand	Laboratory-field-formula	0.91-1.5	2.39	472.9	495.909	940.13	5.67	5683.219	18.6
Soolegan	Laboratory-field-formula	Up to 1.03	0.625	23.46	18.90	43.81	3.11	120.219	0.2
Bazoft	Laboratory-field-formula	0.39-0.71	0.78	27.56	13.28	48.9	5.11	65.39	0.64

Table 2: Lane and Kalinske equation parameters

Measured Input parameters	Calculated Input parameters	Laboratory input parameters	Taken input parameters	Coefficients
Water Depth	n	D65	Suspended sediment concentration	C1
Water discharge	Water velocity	D90	Suspended sediment discharge	C2
Area	-	D50	-	-
Width	-	-	-	-

$$A = a / d$$

$$u_* = \sqrt{\tau_0 / S_f} = \sqrt{S_e R_g}$$

Introducing the abbreviation

$$P_L = \frac{\bar{C}}{C_a} \quad (5)$$

Defining the above equations suspended sediment discharge is estimated in this form

$$q_{sw} = q C_a P_L \exp\left(\frac{15\omega a}{U_* D}\right) \quad (6)$$

ω Is the fall velocity, q is the water discharge and at last q_{sw} is the suspended sediment discharge.

Equation Calibration: The suspended sediment equation used in this analysis is Lane-Kalinske, the suspended sediment equation, described by [18]. The suspended sediment equation has 4 input parameters, each with its own constituent equation. The constituent equation for each state variable is a function of its concentration and the state variables connected to it by the indicated processes. Within each constituent equation are numerous kinetic parameters and additional parameter equations. A list of the important parameters in the suspended sediment is given in Table 2. The parameters are W (the width of the river), D (the depth of the river), q (the water discharge), C (the suspended sediment concentration), A (the area of horizontal cross of the river). These parameters are also present in other constituent equations, revealing the interdependence between the parameters and the suspended sediment discharge estimation processes. Each parameter can be found in different constituent equations. Changing one coefficient to improve the calibration of one constituent will simultaneously affect many other constituents and this is the fundamental dilemma of suspended sediment calibration.

RESULTS

Based on the important effect of adjusting coefficients, the efficient calibration of a suspended sediment equation should begin with the parameter that affects the fewest constituents. In calibrating the coefficients in suspended sediment equation of Lane and Kalinske, Spss-17 was used to estimate the existed coefficients in formula. For calibrating Lane and Kalinske equation, using this software, it was desirable to change the existed coefficients in formula in order to increase the amount of C/O ratio to an acceptable value. To calibrate the formula, the most efficient method is to look and select the parameters that affect the fewest other constituent equations. The sensitivity of the model results to four input parameters is not addressed here. As many of the equations that use laboratory measured parameters or direct field, measurements should be measured either in the laboratory or as separate field measurements. For example, the four input parameters that are used in this equation are measured in the field, beside these measured data there are some parameters are calculated by another equation that is not mentioned here. The input parameters used in the equation are shown in Table 2. Before adjusting suspended sediment equation coefficients, the effects of different equation processes should be tested, such as calculating some existed coefficients.

Lane - Kalinske formulas performance are illustrated in Figures 2-7. Calibrating Lane - Kalinske formula, results about the changes in this formula in each one of the rivers

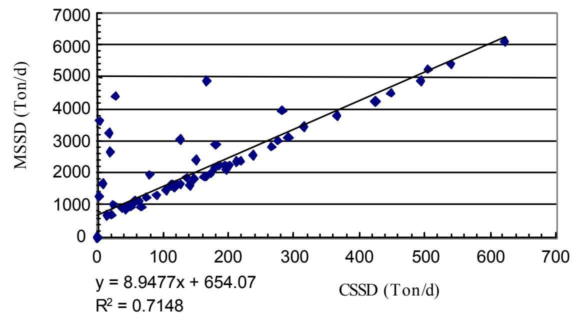

Fig. 2: Performance of Lane-Kalinske in Armand River

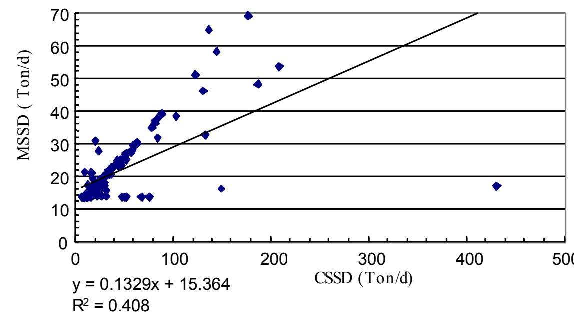

Fig. 3: Performance of Lane-Kalinske in Bazoft River

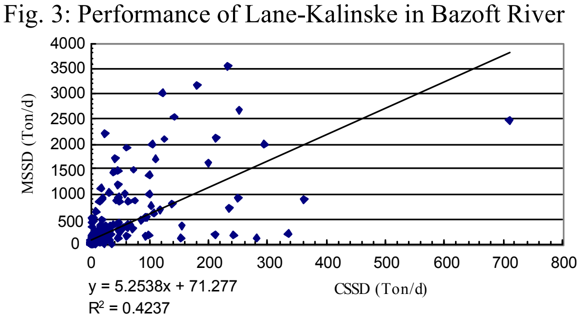

Fig. 4: Performance of Lane-Kalinske in Soolegan River

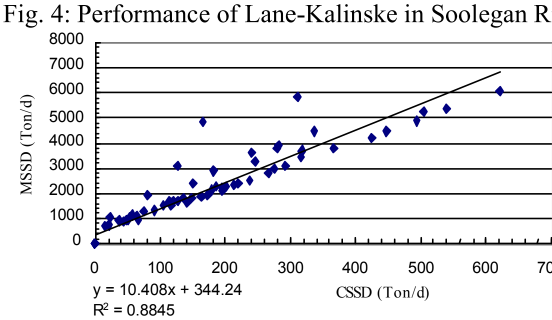

Fig. 5: Performance of adjusted Lane- Kalinske formula in Armand River

are illustrated in Table 3 and also the performance of the adjusted formula in each river is shown in Figures 5-7. Calibrating this kind of formula was not studied before, so this is the first time that this work is done, because of this it is recommended in future that other researchers pay more attention and investigate the possibility of using new formula for other rivers. By calibrating this formula

Table 3: Results of calibration of Lane and Kalinske equation

Armand	Lane and Kalinske formula	$4785/558+0/065q+192/437C-4687/182(EXP\frac{RH^{\frac{2}{2}}}{(V\times(D\times12)^{0.5})})=Q$
	Suggested Formula	$34/504(q^{*}C)0/5+3894/278(EXP\frac{RH^{\frac{2}{2}}}{(V\times(D\times12)^{0.5})})-4211/098=Q$
Bazoft	Lane and Kalinske formula	$9489/699+0/097q+129/149SSC-9491/004(EXP\frac{RH^{\frac{2}{2}}}{(V\times(D\times12)^{0.5})})=Q$
	Suggested Formula	$\frac{17845/739(\text{EXP }[RH]\hat{}(2/3)/((V\times(D\times12)\hat{}0.5)))+18/013(q*C)0/5-17926/091}{1200}=Q$
Soolegan	Lane and Kalinske formula	$4093/695+0/291q-0/639SSC-3979/269(EXP\frac{RH^{\frac{2}{2}}}{(V\times(D\times12)^{0.5})})=Q$
	Suggested Formula	$\frac{(8678/815(EXP\ [RH]\hat{}(2/3)/((V\times(D\times12)\hat{}0.5)))+(84/341(q*C)0)/5+94/147)}{1000}=Q$

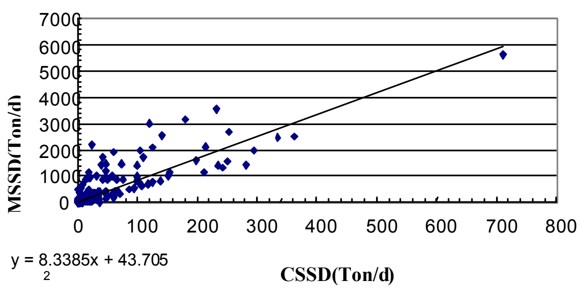

Fig. 6: Performance of adjusted Lane-Kalinske formula in Bazoft River

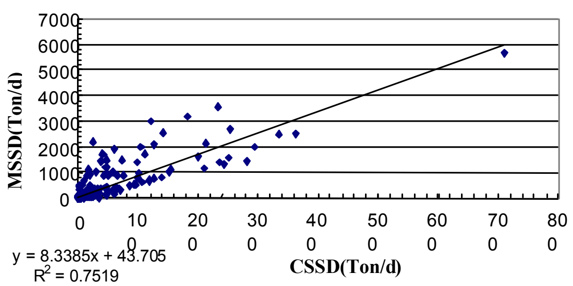

Fig. 7: Performance of adjusted Lane-Kalinske formula in Soolegan River

for especial river, at last the accurate amount of sediment would be obtained so in this way it can be told that this amount can be predicted for future. Finally knowing this amount would help us to conserve river morphology and avoid sediment production.

CONCLUSION

Proper calibration of Lane-Kalinske formula requires an accurate representation of suspended sediment discharge in water body and selecting appropriate equation coefficients. Performing series of calibration with varying parameters, using Spss-17 and then making comparisons to field data can be a desirable exercise, which the discharges of suspended sediment can change when a single coefficient is adjusted. In order to find the correct coefficient values in haphazard fashion, an inordinate number of calibration runs with varying coefficients values for a number of different inputs must be made. By calibrating the formula, it was found that Lane - Kalinske formula perform better if the existed coefficients are changed (Table 3), in this paper Lane - Kalinske formula was adjusted for three Rivers. It was illustrated that the amount of C/O ratios were increased and improved to an acceptable amounts in comparison with the former ones; Soolegan (0.42 to 0.75), Bazoft (0.40 to 0.75), Armand (0.71 to 0.88). Using the calibration method outlined here, the calibration process can be made more systematic and efficient. Determining the amount of sediment specially suspended sediment in rivers can help us to manage the watershed system properly. Calibrating the existed formulae for sediment estimation can lead us to know the closer amount to what can be observed in the real world.

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