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# Analysis of Production Surface Erosion in Watersheds using the Tank Model Approach

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***Abstract*** **- One indication of environmental degradation in the watershed is the loss of the ability of watersheds to save water, where the environmental systems that support the hydrological cycle is and has been damaged, including the reduction of forest area in the catchment, erosion and sedimentation that is not control, resulting in floods, landslides. Uncontrolled erosion and sedimentation cause substantial losses, either in the form of declining productivity of land and destruction of buildings and a water reservoir sedimentation. A number of models or approaches for prediction of erosion and sediment transport has been developed, but the application of the model or equation approach requires the availability of the input data is adequate, diverse and extensive, both for calibration and verification, and on the fact and the general availability of data is quite minimal. Efforts is to connect between the land surface erosion sediment transport, which begins with the release of a grain of soil by rainfall and release grains of soil by surface runoff. Assuming that the land surface erosion and sediment transport based on rainfall events only influenced by surface runoff, and represented in the storage type, in this paper are presented one approach "Black Box" by using Tank Model. The goal is to develop a tank model to estimate the product of surface erosion on the watershed. Model Tank is a simple model with sufficient data input minimum and represents the process in catchment areas. Determined using a model parameter optimization approach method Genetic Algorithm (GA). The expected result is the modeling of tank model to estimate sediment discharge products in the Watershed.**

**Keywords: Sediment discharge, Runoff, Precipitation, Tank Model**

## I INTRODUCTION

Environmental degradation as a result of deforestation carried out in the Watershed resulting in the watershed lost its ability to save water. One indication that the environmental systems that support the hydrological cycle currently and has already experiencing damaged, among other things the reduction of forest area in the catchment, sedimentation rate uncontrolled, so as to cause floods, landslides

Erosion and sedimentation uncontrolled cause substantial losses, either declining productivity of land and destruction of buildings water and reservoir sedimentation [1]. Therefore, estimates of surface erosion, sediment transport on a scale of watersheds is indispensable for planning a dam and reservoir, the design of soil conservation, land use planning, water quality management and control strategies that effectively reduce the risk of water flow, and protect against erosion.

Some models or approaches for estimating surface erosion and sediment transport prediction has been developed, from simple models until complex models. Model of sediment runoff on watershed, such as WEPP model [1], KINEROS model, ANSWERS model, AGNPS model and SWAT model [2]. The application of the model or equation approach requires quite a lot of input data availability, varied and extensive, both for calibration or verification and in a reality and generally availability of data is quite limited.

Erosion and sediment transport is included in the existing processes in catchment areas. The erosion process is sourced from upstream area great influence caused by rainfall and be carried runoff headed down river became sediment transport [3], the flow of sediment in the river is mainly caused by erosion in the watershed

Assuming that surface erosion and sediment transport based on rainfall events only influenced by surface runoff, and consider the concept of the type of the storage, in this paper are presented one approach "Black Box" which connects between the factors that cause erosion, transport processes of erosion by sediment transport using Tank Model.

## II. RELATED WORKS

The research objective is to develop a tank model to estimate production of surface erosion on the watershed. Tank Model is a simple model with sufficient data input limited and represent the process in catchment areas and only by examining the input and output.

Apply a tank model to predict the sediment yield (data of rainfall, discharge and sediment concentration) [4], with the analysis of such a tank model for the rainfall-runoff [5][6], the result is discharge multiplied by sediment concentration [7]. Application of tank model to predict sediment yield this use on the assumption of sediment concentration experienced infiltration, percolation, and in fact did not happen the process thus , it was a weakness in the model.

The development tank model for the production of sediment transport in the Watershed is incorporate elements of sediment in the analysis process into a stream of rain (rainfall-runoff) [8]. The starting that sediment runoff model with the lumped parameter method based distribution on a scale of watersheds include sediment runoff model on hillslope and sediment runoff model in the river channel [9]. With rain events, the process sediments

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runoff on hillslope assumptions used only influenced by surface runoff as sediment storage on hillslope, and sediment storage in the channel or river is supplied with material from the hillslope, riverbed erosion and sediment suspension only. By considering the concept of storage, model of sediment runoff consists of two storages, namely storage of sediment runoff on hillslope and transport of sediments in the channel or river.

Balance of Equilibrium to sediment runoff on hillslope and on the river [10], are as equation (1):

- Hillslope

$$\frac{dS_{sh}}{dt} = D_r + DF_h - Q_{h.} x\, C_h = k\ x\ 56{,}48\ x\ \ r_h + \frac{\left(\alpha\ x\left(S_{sh}^{\max} - S_{sh}\right) - Q_h\ x\, C_h\right)}{A_h} \qquad (1)$$

Where :

$dS_{sh}$ is the storage of sediment in hillslope (mm); $D_r$ is the loss of soil by rainfall (t/d); $DF_h$ is losing ground by surface runoff (t/d); $Q_h$ is surface runoff in hillslope ($m^3$/s); $C_h$ is sediment concentration in hillslope (kg/$m^3$); k is the soil detachability (kg/J); $r_h$ is the effective rainfall intensity in hillslope (mm); α is the efficiency factor of erosion/deposition; $S_{sh}$ is the storage amount of sediment concentration on hillslope (mm); $S_{sh}^{max}$ is the maximum storage amount of sediment concentration on hillslope (mm); $A_h$ is the total area of land ($m^2$) as equation (2)

- River

$$\frac{dS_{sN}}{dt} = Y_h + DF_N - Q_{N.}\ x\, C_N = Q_h\ x\ C_h + \frac{\left(\alpha\ x\left(S_{sN}^{\max} - S_{sN}\right) - Q_N\ x\ C_N\right)}{A_N} \qquad (2)$$

Where :

$dS_{sN}$ is the storage of sediment in the river or channel (mm); $Y_h$ is the result of sediments from hillslope (t/d); $DF_N$ is losing ground soil by the river flow (t/d); $Q_N$ is discharge on the river ($m^3$/s); $C_N$ is the concentration of sediment in the river (kg/$m^3$); $Q_h$ is surface runoff in hillslope ($m^3$/s); $C_h$ is the concentration of sediment in hillslope (kg/$m^3$); α is the efficiency factor of erosion; $S_{sN}$ is the storage amount of sediment concentrations in the river or channel (mm); $S_{sN}^{max}$ is the maximum storage of sediment concentration in the river channel (mm); $A_N$ is the total land Area ($m^2$).

Structure Tank Model for estimate production of surface erosion on Watershed proposed four models of the tank as shown in Figure 1 (a) Tank Model 1, (b) Tank Model 2, (c) Tank Model 3, (d) Tank Model 4

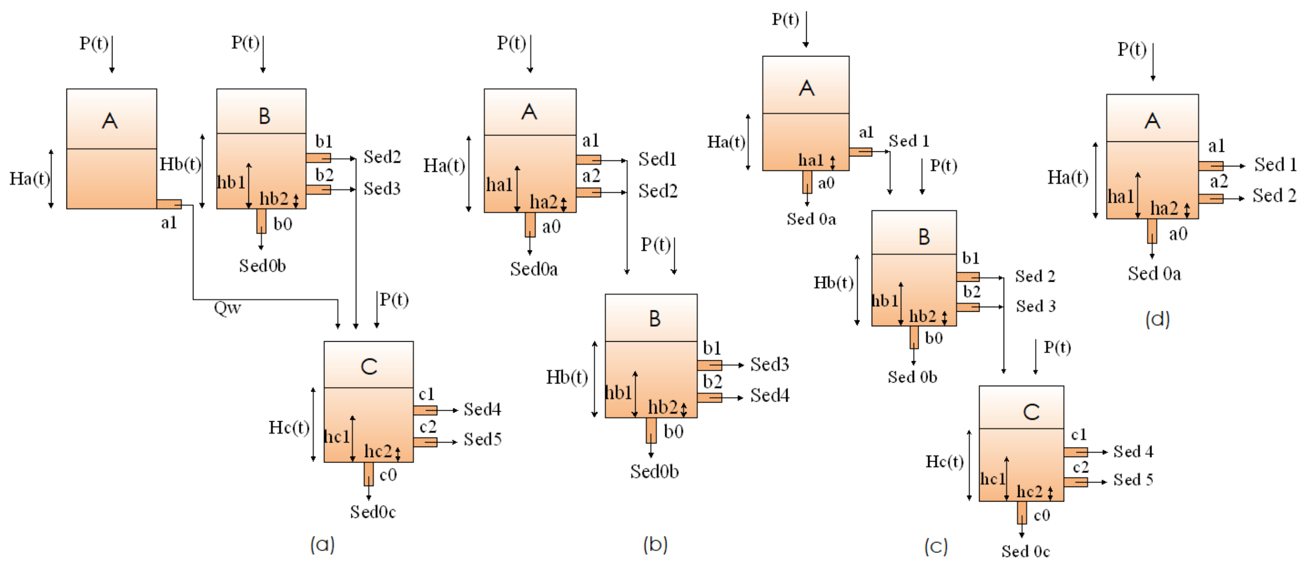


Figure 1 Scenario of 4 tank models : (a) Tank Model 1, (b) Tank Model 2, (c) Tank Model 3 and (d) Tank Model 4.

where: P(t) is rainfall (mm); $Sed_1$ (t), $Sed_2$ (t), $Sed_3$ (t), $Sed_4$ (t), $Sed_5$ (t) is the production of surface erosion (ton/day); $Sed_{0a}$, $Sed_{0b}$, $Sed_{0c}$ is the production of sediment deposition (ton/day); $Q_w$ is the subsurface flow (mm); Ha(t), Hb (t), Hc(t), is storage height the production of surface erosion (sediment) (mm); $a_1$, $a_2$, $b_1$, $b_2$, $c_1$, $c_2$ are parameters model the production of surface erosion; $a_0$, $b_0$, $c_0$ is the parameters model sediment deposition; $ha_1$, $hb_1$, $hc_1$ is high of upper hole the production of surface runoff on a model (mm); $ha_2$, $hb_2$, $hc_2$ is high of bottom hole the production of surface runoff on a model (mm).

The principle is the representation of the process of erosion by rainfall and runoff in the watershed, namely the rain falls in the surface soil which produce soil eroded due to rainfall, in the model, the rainfall is described as an input to the tank. Then, if the soil has been saturated, water will flow over the soil surface as surface runoff that resulted in soil erosion and transported as sediment flow and produce production of surface erosion, in the model described as hole on the right side, and there is also the land bated for

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example in the of the basin where the production of surface erosion deposited depicted on the bottom hole. Representation of four tank model proposed is Tank Model 1, illustrates the erosion of the watershed occurs in surface erosion on hillslope and erosion in the river with the influence of the subsurface flow (Figure 1a), Tank Model 2, illustrates the erosion of the watershed occurs in surface erosion on hillslope and erosion in the river ( Figure 1b), Tank Model 3, illustrates the erosion in watersheds long form, with the assumption that more than one surface erosion on hillslope (2 tanks) namely erosion in upstream and erosion in the middle and erosion in the river (Figure 1c) and Tank Model 4, illustrates the erosion of the watershed occurred on hillslope (Figure 1d)

In the analysis of tank model to estimate the production of surface erosion in the watershed, the principle is the flow of sediment that came out of a tank is proportional to the volume or the storage of sediment maximum which is a function of sediment transport capacity and storage of water which is represented in the form of high of sediment storage in the tank in question (storage depth) above the hole. Application of tank model to estimate the production of surface erosion is depicted with representing the process of erosion and sediment flow on hillslope and canal or river that is based on equation of sediment flow continuity.

Based on the balance of equilibrium, Equation 1 and Equation 2, the continuity equations for four tank model in this study are as from equation 3 to equation 11.

**Tank Model 1** :

Tank A: $$\frac{dH_a}{dt} = P - Q_w \quad (3)$$

Tank B: $$\frac{dH_b}{dt} = P - Sed_2 - Sed_3 - Sed_{0b} \quad (4)$$

Tank C: $$\frac{dH_c}{dt} = P + Sed_2 + Sed_3 + Q_w - Sed_4 - Sed_5 - Sed_{0c} \quad (5)$$

**Tank Model 2** :

Tank A: $$\frac{dH_a}{dt} = P - Sed_1 - Sed_2 - Sed_{0a} \quad (6)$$

Tank B: $$\frac{dH_b}{dt} = P + Sed_1 + Sed_2 - Sed_3 - Sed_4 - Sed_{0b} \quad (7)$$

**Tank Model 3** :

Tank A: $$\frac{dH_a}{dt} = P - Sed_1 - Sed_{0a} \quad (8)$$

Tank B: $$\frac{dH_b}{dt} = P + Sed_1 - Sed_2 - Sed_3 - Sed_{0b} \quad (9)$$

Tank C: $$\frac{dH_c}{dt} = P + Sed_2 + Sed_3 - Sed_4 - Sed_5 - Sed_{0c} \quad (10)$$

**Tank Model 4** :

Tank A: $$\frac{dH_a}{dt} = P - Sed_1 - Sed_2 - Sed_{0a} \quad (11)$$

Then the formulation of tank model for analysis the production of surface erosion based on scenario Figure 1 is as from equation 12 to equation 39:

**1). Tank Model 1**

$Q_w(t) = [(Ha(t)+P(t)] \times a_1$ (12)

$Sed_2(t)=[((Hb(t)+P(t)+ Q_w(t)) \times C_h) - hb_1] \times b_1$ (13)

$Sed_3(t)=[(Hb(t)+P(t)+ Q_w(t)) \times C_h) - hb_2] \times b_2$ (14)

$Sed_4(t)=[(Sed_2(t)+Sed_3(t))+((Hc(t)+P(t)) \times C_N)) - hc_1] \times c_1$ (15)

$Sed_5(t)= [(Sed_2(t)+Sed_3(t))+((Hc(t)+P(t)) \times C_N)) - hc_2] \times c_2$ (16)

$Sed_{0b}(t)=[(Hb(t)+P(t)+ Q_w(t)) \times C_h] \times b_0$ (17)

$Sed_{0c}(t)=[(Hc(t)+P(t)) \times C_N] \times c_0$ (18)

Total production of surface erosion on the right side of the tank = $Sed_{total} = Sed_4(t)+Sed_5(t)$ (19)

**2). Tank Model 2**

$Sed_1(t) = [((Ha(t)+P(t)) \times C_h) - ha_1] \times a_1$ (20)

$Sed_2(t) = [((Ha(t)+P(t)) \times C_h) - ha_2] \times a_2$ (21)

$Sed_3(t) = [(Sed_1(t)+Sed_2(t)+((Hb(t)+P(t)) \times C_N)) - hb_1] \times b_1$ (22)

$Sed_4(t) = [(Sed_1(t)+Sed_2(t)+((Hb(t)+P(t)) \times C_N)) - hb_2] \times b_2$ (23)

$Sed_{0a}(t)= [(Ha(t)+P(t)) \times C_h] \times a_0$ (24)

$Sed_{0b}(t)= [(Hb(t)+P(t)) \times C_N] \times b_0$ (25)

Total production of surface erosion on the right side of the tank = $Sed_{total} = Sed_3(t)+Sed_4(t)$ (26)

**3). Tank Model 3**

$Sed_1(t) = [((Ha(t)+P(t)) \times C_h) - ha_1] \times a_1$ (27)

$Sed_2(t) = [(Sed_1(t)+ ((Hb(t)+P(t)) \times C_h)) - hb_1] \times b_1$ (28)

$Sed_3(t) = [(Sed_1(t))+ ((Hb(t) P(t)) \times C_h)) - hb_2] \times b_2$ (29)

$Sed_4(t) = [(Sed_2(t)+Sed_3(t)+((Hc(t)+P(t)) \times C_N)) - hc_1] \times c_1$ (30)

$Sed_5(t) = [(Sed_2(t)+Sed_3(t)+((Hc(t)+P(t)) \times C_N)) - hc_2] \times c_2$ (31)

$Sed_{0a}(t) = [(Ha(t)+P(t)) \times C_h] \times a_0$ (32)

$Sed_{0b}(t) = [(Hb(t)+P(t)) \times C_h] \times b_0$ (33)

$Sed_{0c}(t) = [(Hc(t)+P(t)) \times C_N] \times c_0$ (34)

Total production of surface erosion on the right side of the tank = $Sed_{total} = Sed_4(t)+Sed_5(t)$ (35)

**4). Tank Model 4**

$Sed_1(t) = [((Ha(t)+P(t)) \times C_h) - ha_1] \times a_1$ (36)

$Sed_2(t) = [((Ha(t)+P(t)) \times C_h) - ha_2] \times a_2$ (37)

$Sed_{0a}(t) = [(Ha(t)+P(t)) \times C_h] \times a_0$ (38)

Total production of surface erosion on the right side of the tank = $Sed_{total} = Sed_1(t)+Sed_2(t)$ (39)

where: P(t) is rainfall (mm); $Sed_1(t)$, $sed_2(t)$, $Sed_3(t)$, $Sed_4(t)$ is the production of surface erosion (tons/day); $Sed_{0a}$, $Sed_{0b}$ is deposition of production of surface erosion (tons/day); $C_h$ is the sediment concentration in hillslope (mg/lt); $C_N$ is the concentration of sediment in the canal/river (mg/lt); Ha(t), Hb (t) is the height of the sediment storage (mm); $a_1$, $a_2$, $b_1$, $b_2$ are coefficients holes of sediment runoff; $a_0$, $b_0$ is the coefficient holes of sediment deposition ; $ha_1$, $hb_1$, is a hole high above the sediment runoff (mm); $ha_2$, $hb_2$ is hole high down (mm)

## III. METHOD

This research is located in Kreo sub catchment which has an area of 1692,812 hectares (Figure 2). The research location is entry in the territory of Kendal district and Semarang city, with a description of the research areas, that the Kreo sub catchment has a tropical climate which is influenced by monsoons. The rainy season occurs from

November to May and the dry season from June to October. Type of soil is latosol and regosol. Slope ranging flat until very steep (8% -> 45%). Land use include garden (38.41%), rainfed (30.05%), forest (22.09%), housing (7.81%), irrigated rice (0.82%), moor (0 , 64%), remaining the building and freshwater (0.17%). Land use include garden (38.41%), rainfed (30.05%), forest (22.09%), housing (7.81%), irrigated rice (0.82%), moor (0 , 64%), remaining the building and freshwater (0.17%).

In this study, the data used is the map of Watershed, a map of rainfall station, observation and measurement of rainfall data, data of sediment concentration, discharge data were carried out with a period of time and the same place, namely at the station of stream observation (SPAS) in Purwosari Purwosari as in Figure 2. Furthermore, the data processing includes data recording, analysis and interpretation of results.

Steps taken in this study as follows:

1. The analysis of rainfall average of area as input data of models. Because the watershed area 16,92812 km2 use one (1) rain station [3]; so its analysis is based on a point raining. In this study, rainfall data used is 6 (six) incident of rainfall in 6 (six) days, ie date of 6, 8, 10, 26, 28 January 2014 and February 3, 2014.
2. Creating tank model Structure for surface erosion production estimates, in this study there are four tank models as shown in Figure 1
3. To obtain good results, the value of tank model parameters is obtained by optimization. In this study, optimization parameter model approach using Genetic Algorithm method. To get optimal value is determined by the formulation of the objective function with some constraint formula. As for the formulation of the objective function to find the optimum value from parameter of tank model with delimiters objective function value smallest and results accuracy of expected is

$$F_{(x)} = Min\left[\frac{1}{N}\sum_{i=1}^{n}\left|sed_{obs}^{i} - sed_{sim}^{i}\right|\right] \qquad (40)$$

Where (x) is the objective function; $sed_{obs}^{i}$ is the production of surface erosion measurable, $sed_{sim}^{i}$ is the production of surface erosion of tank model; X: $[X_1, X_2, ..., X_n]^T$, where n is the number of model parameters; N is the number of data

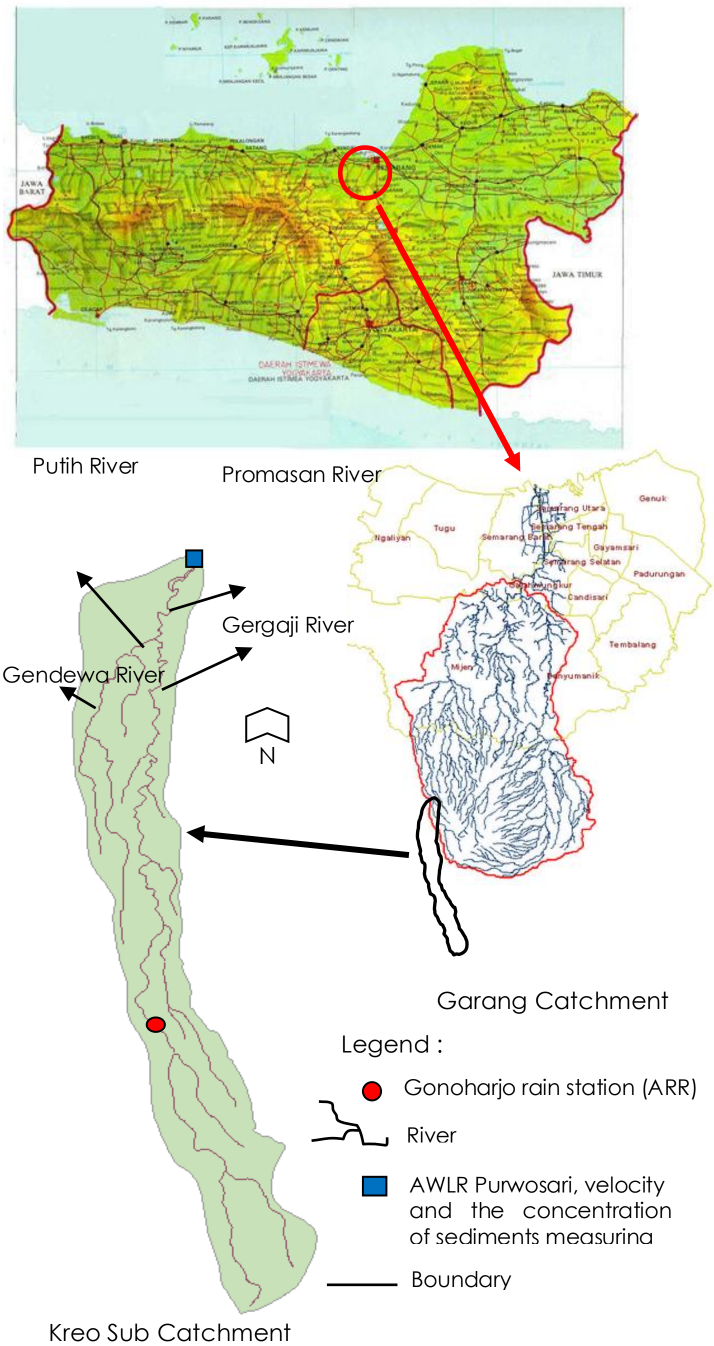



Figure 2 Location of research in Kreo Sub catchment

The model is supposed to be consistent if there is a high correlation between measurable data and the simulation result data as well as having a considerably small deviation. In this experiment, volume error (VE), relative error (RE), correlation coefficient (R) and root mean squares error (RMSE) as a model test criteria, with a limit value of research criteria for VE < 5%, RE -10% to 10%, R > 0.7 and RMSE close to 0. Its formula is Equation 41 to equation 44.

$$VE = \frac{\sum_{i=1}^{N} Sed_{obs} - \sum_{i=1}^{N} Sed_{sim}}{\sum_{i=1}^{N} Sed_{obs}} x\,100 \quad (41)$$

$$RE = \frac{1}{N}\sum_{i=1}^{N}\frac{\left|Sed_{sim}^{i} - Sed_{obs}^{i}\right|}{Sed_{obs}^{i}} x\,100 \quad (42)$$

$$R = \frac{\sum\left(Sed_{sim}^{i} - \overline{Sed_{sim}^{i}}\right)\left(Sed_{obs}^{i} - \overline{Sed_{obs}^{i}}\right)}{\sqrt{\sum\left(Sed_{sim}^{i} - \overline{Sed_{sim}^{i}}\right)^{2}\sum\left(Sed_{obs}^{i} - \overline{Sed_{obs}^{i}}\right)^{2}}} \quad (43)$$

$$RMSE = \sqrt{\frac{\left(\sum Sed_{sim}^{i} - Sed_{obs}^{i}\right)^{2}}{N}} \quad (44)$$

where: VE is volume error [%]; RE is relative error [%]; R is correlation coefficient; RMSE is root mean squares erorr; $Sed_{sim}$ is the production of surface erosion simulation period-i [t/d]; $Sed_{obs}$ is production of surface erosion measureable period-i [t/d]; N is the number of data; $\overline{Sed_{sim}^{i}}$ is average of the production of surface erosion simulation period-i [t/d]; $\overline{Sed_{obs}^{i}}$ is the average of surface erosion production measurable period-i [t/d].

## IV RESULTS AND DISCUSSION

Results of the study based on four (4) tank models proposed (Tank Model 1, Tank Model 2, Tank Model 3 and Tank Model 4), shows that the model of the Tank Model 4 is good enough to be applied compared with the Tank Model 1, Tank Model 2, and Tank Model 3, it is based on the results of research criteria on the six rain events in six days, relative error (RE), error volume (VE) (Table 1), that Tank Model 4 has a value of VE between 7,43 to 26,39%, RE between 48,56 to 667,92% smaller compared to the other 3 tank models, with a value of RE between 70,93% - 2384,2% and VE between 4,10 to 480,38%

As for the value of R and RMSE can be seen in Table 1 and Table 2. In each occurrence in six events for 4 days, the value of R on all tank models have the same value which is between 0,52 to 0,89, this is shows have the resemblance shape is almost the same, has value only difference range, while the value RMSE of Tank Model 4 pretty good compared with the other three tank models, with Tank Model 4 RMSE values between 20,56 to 1004,8, whereas the three other tank models, RMSE values between 54,99 – 4344,7.

Table 1 Relative Error (RE) and Volume Error (VE) for various events

| four rain events in 4 days | RE | | | | VE | | | |
|---|---|---|---|---|---|---|---|---|
| | Tank Model 1 | Tank Model 2 | Tank Model 3 | Tank Model 4 | Tank Model 1 | Tank Model 2 | Tank Model 3 | Tank Model 4 |
| 06/01 /2014 | 692,54 | 877,27 | 632,53 | 136,61 | 230,54 | 303,70 | 175,04 | 13,14 |
| 10/01 /2014 | 360,77 | 423,83 | 70,93 | 48,56 | 229,77 | 292,39 | 4,10 | 22,28 |
| 26/01 /2014 | 338,27 | 1153,5 | 170,23 | 108,99 | 111,13 | 480,38 | 30,88 | 16,08 |
| 28/01 /2014 | 2049,0 | 766,83 | 714,75 | 615,02 | 250,31 | 45,36 | 34,22 | 18,21 |

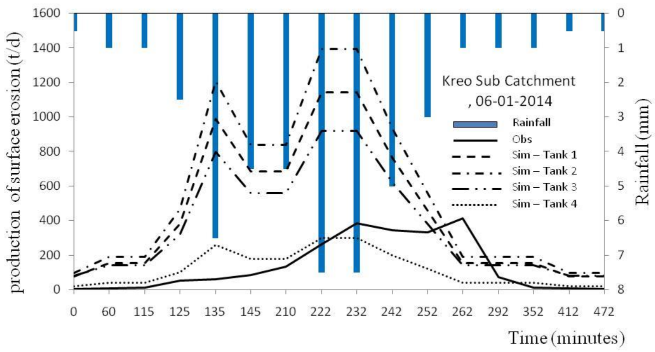
Table 2 correlation coefficient (R) and root mean square error (RMSE) for various events

| four rain events in 4 days | R | | | | RMSE | | | |
|---|---|---|---|---|---|---|---|---|
| | Tank Model 1 | Tank Model 2 | Tank Model 3 | Tank Model 4 | Tank Model 1 | Tank Model 2 | Tank Model 3 | Tank Model 4 |
| 06/01 /2014 | 0,52 | 0,52 | 0,52 | 0,52 | 457,0 | 581,97 | 350,92 | 129,74 |
| 10/01 /2014 | 0,65 | 0,65 | 0,65 | 0,65 | 1993,5 | 2510,1 | 406,35 | 386,44 |
| 26/01 /2014 | 0,89 | 0,89 | 0,89 | 0,89 | 54,99 | 229,86 | 22,77 | 20,56 |
| 28/01 /2014 | 0,83 | 0,83 | 0,83 | 0,83 | 4344,7 | 1161,2 | 1076,7 | 1004,8 |

Results of simulation can be seen in Figure 3. Result of simulation Tank Model 4 for value of production of surface erosion closer to the value of the production of surface erosion measurable, compared with result of simulation value Tank Model 1, Tank Model 2, and Tank Model 3.

Tank Model 4 quite well be applied to the estimated production of surface erosion in the watershed, this matter illustrates the process of erosion, sediment transport and deposition up to the canal / river occur on the surface of the land in the watershed, so the composed in one the storage, which in the tank model composed 1 (one) tank.

While value the production of surface erosion, simulation results of Tank Models 1, Tank Model 2, Tank Model 3 showed a greater tendency than measurable, the possibility of existence of value accumulation of the tank.



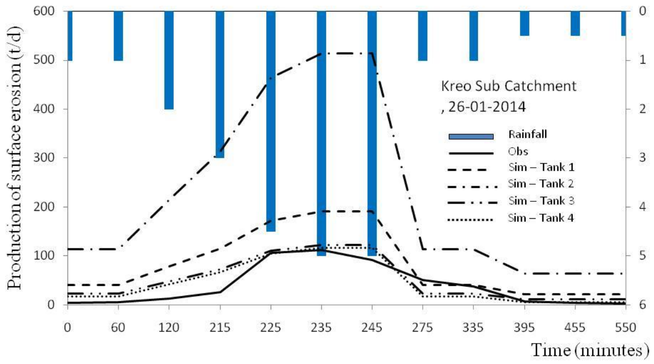




Figure 3 Comparison of the simulation and measurable results of tank models, to estimate the production of surface erosion on sub watershed Kreo (calibration).

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With Tank Model 4 were selected for the analysis of the production of surface erosion on the watershed, its parameters are shown in Table 3.

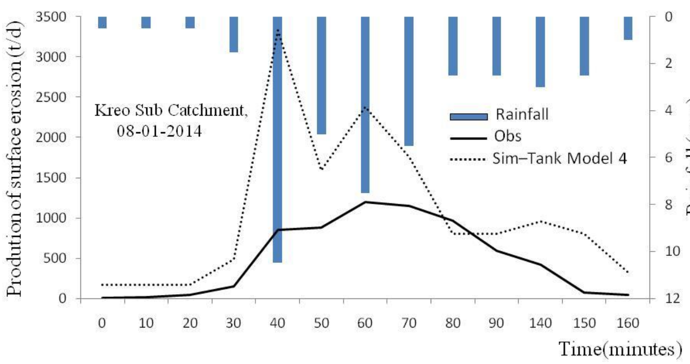
Table 3 Parameters value from results of Optimization tank model 4

| four rain events in 4 days | Parameter | | | | | |
|---|---|---|---|---|---|---|
| | ha1 (mm) | ha2 (mm) | a0 | a1 | a2 | Ha |
| 06/01/2014 | 0,9970 | 0,9783 | 0,0593 | 0,0241 | 0,2279 | 0,01249 |
| 10/01/2014 | 0,9919 | 0,9681 | 0,0189 | 0,1186 | 0,0158 | 0,44569 |
| 26/01/2014 | 9,0000 | 0,0085 | 0,0822 | 0,8908 | 0,0018 | 0,06389 |
| 28/01/2014 | 0,9896 | 0,9728 | 0,0245 | 0,6985 | 0,0303 | 0,00188 |
| Mean | 29,946 | 0,7319 | 0,0462 | 0,4872 | 0,0690 | 0,13099 |

Furthermore, value parameter Tank Model 4 is applied to the validation of modeling, the results are in Table 4 and Figure 4

Table 4 Validation of tank model 4 for Relative Error (RE), Volume Error (VE), Correlation Coefficient (R) and root mean square error (RMSE)

| Two rain events in 2 days | Tank Model 4 | | | |
|---|---|---|---|---|
| | RE | VE | R | RMSE |
| 08/01/2014 | 234,62 | 7,43 | 0,77 | 311,39 |
| 03/02/1900 | 667,92 | 26,39 | 0,87 | 455,01 |



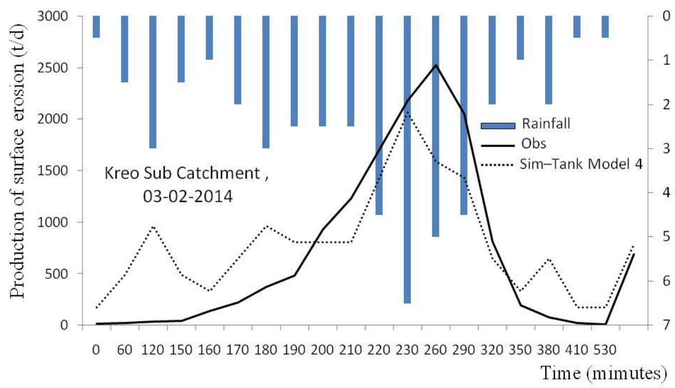




Figure 4 Comparison of the simulation and measurable results of tank model 4, to estimate the production of surface erosion on sub watershed Kreo (validation).

From the results of the calibration and validation of Tank Model 4, and based the value limit of research criteria, the value of R meet the requirements, while the value of RE, VE and RMSE have not fulfilled the requirements, it is still there value deviations of production of surface erosion simulation results against the results of observation which may be caused by several things, among others :

1. Synchronization factor of measurement time of beginning occur of rains and the measurement of sediment transport (sediment concentration), at least to be precise, which usually use the time of concentration, and processes of measurement of sediment transport or sediment concentration is possibility contains errors
2. Human activity and or livestock on the land or in rivers, causing sediment is quite high even though the rain was not so heavy (normal rainfall).
3. The length of the data, if the data used for calibration is too short, is likely to affect the results of model output.

Nonetheless,value of production of surface erosion Tank Model 4 for observation and simulation had a good enough resemblance.

## V. CONCLUSION

In the development of tank model to estimate the production of surface erosion on Watershed, Tank Model 4 is quite good are applied. Tank Model 4 provides pretty good performance, compared with the Tank Model 1, Tank Model 2, and Tank Model 3, seen from the value of accuracy. However, there is still a difference in the magnitude of the value range varies, possible cause is a factor in the rainfall distribution pattern , measurement processes and data length.

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