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Strictly as per the compliance and regulations of :

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Abstract- Reservoirs are considered as vital sources of water supply, provide hydroelectric power support, diverse aquatic habitat, and provide flood protection. Ole Dam is a hydraulic structure on the River Ole in Nigeria with 8.1 billion m^3 storage capacity. The reduction of reservoir capacity of this dam has seriously complicated the water supply for potable and non-potable applications. This reduction in the capacity is a result of sediment leaving into the reservoir of the dam through two tributaries. Simulation analysis using both hydrological and meteorological data around the site for 11-year (2000-2011) was subjected to iteration using WEPP and SWAT simulation models. The sediment load leaving into the reservoir is a function of rainfall depth, the gradient of reservoir site, soil formation and runoff generated. Maximum average sediment load value of $10.2*10^3$ton/ha with rainfall depth of 75.4 mm and surface runoff of 34.2 mm were generally observed in month of September for the simulation period. However, minimum observed sediment load of simulated and observed values of 3.1 $*10^3$ton/ha and $2.8*10^3$/ha through the tributaries to the reservoir was estimated in the month of March with the observed lowest rainfall depth of 19.7 mm and runoff depth of 2.5 mm respectively. This implies that significant sediment load entered the reservoir from these two considered tributaries. If the sediment load continues unchecked the reservoir is expected to silt up completed by the next 20-year starting from 2043. Increasing the life span of the hydraulic structures requires the construction of check dam across the two tributaries and ensures strong soil conservation measures around the reservoir site.

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I. Introduction

Runoff and sediment load analyses of the River Ole in Auchi basin have been a subject of considerable discussion. Runoff estimation is important for realistic assessment of soil erosion and also in planning irrigation activities, drinking water supply management strategies, etc. (Pielke, 1999; Sparovek *et al*., 2002). Also, the design of facilities and structures based on hydraulic engineering depends on accurate runoff estimation (Yanmaz & Coskun, 1995; McCuen & Okunola, 2002). As a result of runoff from rainfall or snowmelt, soil particles on the surface of a watershed can be eroded and transported through the processes of sheet, rill, and gully erosion. Onceeroded, sediment particles are transported through a river system and are eventually deposited in reservoirs, in lakes, or at sea. The surface runoff is mainly responsible for sediment detachment, its transport and deposition (Hergarten *et al*., 2000). Therefore, runoff plays a major role when analysed in the context of the soil erosion process, and it also has a significant importance by itself. Yang et al. (2002) analysed sediment discharge and suspended sediment concentration (SSC) of two hydrological stations (Datong and Yichang stations) from 1951 to 2000 to show the variations in river sediment supply to the delta.

Sediment deposition is a key factor reducing the life of dams around the world. This mechanism has significant effect on the reservoir capacity of the erected hydraulic structure due to the sedimentation process, which in thus leads to decrease and shortage of water supply for agricultural and non-agricultural applications to the surrounding communities. Studies have shown that 75% of reservoir capacity of dam built across River Ole has been silted up and if adequate measure is not put in place, this could reduce the life span of the hydraulic structure. Reservoirs around the world are losing on average about one percent of their storage capacity annually (WCD, 2000), causing serious problems for water and electricity supply, flood control but also for ecosystem development up-and downstream of large dams.

Sediment loss rate can be difficult to measure accurately, because they are highly variable spatially and influenced by many factors. Modelling is, therefore, a very useful tool for extrapolating available measurements and predicting sediment inputs to river systems under different conditions. Process-based mathematical models are becoming popular in predicting runoff, soil erosion and sediment yield for different climates with varying land-use and management practices. Reservoirs are expensive to build and their construction usually also entails high social and environmental costs. Having considered present and projected negative effects of reservoir

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sedimentation on water supply, destruction of aquatic life and degradation of other environmental issues, this research study therefore focuses on simulating the hydrologic processes such as rainfall, surface runoff, sediment transport, slope and soil formation around the study area. The expected outputs will be technically applied to creating realistic sediment load rate management and reduction processes.

II. Materials and Methods

a) Study Area

The studied area is located Central of Edo north at bank side Ole Dam reservoir as shown in plate 1. Runoff and sediment load entered into the reservoir from two main tributaries. The dam site is planted with both seasonal and perennial crops. The soil formation is mineral soil. The dam is 54.8 km north of Auchi.

Plate 1 : Area view of Reservoir side of Ole Dam

b) Hydrological Modelling

Hydrological data of annual runoff, rainfall and suspended sediment load of Idah stations along Ole River, and annual runoff and suspended sediment load from Idah station from tributaries A_p and A_x of Ole River basin were taken by *Edo Hydrological Discharge Station in collaboration with Meteorological Unit of Auchi Polytechnic, Auchi.* The most accurate method for determining the long-term sediment yield from a watershed is by direct measurement of sediment deposition in a reservoir (Blanton, 1982) or by direct measurement of streamflow, suspended sediment concentration, and bedload. Sediment concentrations were collected on a monthly basis and yields were determined using the relationship between runoff and sediment concentration. The density of the sediments was determined by combining the empirical relationships shown below:

$$\boldsymbol{Wt = Wo + 0.4343 * K * \left\{\frac{t}{t-1} * (\ln t)\right\}} \quad (1)$$

Wt refers to the average bulk density of sediments after t years of operation, W_0 stands for the mean bulk density. K is the consolidation coefficient. Both the coefficients of unit weight and the consolidation coefficient per fraction are empirical and were reported by Lara and Pemberton (1995). The total mass of sediments present in the reservoir is now calculated by multiplication of the average density (Wt) and the volume of sediments present. The trap efficiency refers to the percentage of incoming sediments that is retained in the reservoir, and depends principally on the sediment characteristics, the stream flow velocity and the reservoir operation (Vanoni, 1977). Various empirical relations have been developed to estimate the trap efficiency. However, more technically-based relations are available, that requires some more input data (Verstraeten & Poesen, 2000).

$$\mathbf{TE = 100 * \left(1 - \frac{1}{(1+D*\frac{C}{A})}\right)} \quad (2)$$

Based on the rainfall characteristics, surface runoff, soil formation and sediment transportability of the study area the trap efficiency in equation (2) is modified as follows:

$$\mathbf{TE = 100 * 2.33c * \left(1 - \frac{1}{(1+D*\frac{C}{A})}\right)} \quad (3)$$

Where; TE, stands for trap efficiency (%), C for the capacity of the reservoir (m^3) and A for the drainage area of the basin (km^2). D is a constant between 0.09 and 2.1 and depends on the reservoir type. For the purpose of this research study, D is taken to 1.2; C is the proportionality factor for the site erodibility.

The modelled values of runoff and sediment yield were evaluated by visual inspection of the graphs that plotted the range of observed and modelled values. To evaluate the model performance, the coefficient of determination (r^2) was determined from regression analysis between model-simulated and measured runoff and sediment yield. The Nash-Sutcliffe coefficient of efficiency (COE) was calculated as (Nash & Sutcliffe, 1970).

$$COE = 1 - \frac{(P-Q)}{(O-Om)} \quad (4)$$

Where *P* and *O* are the corresponding modelled and observed values, respectively. The reservoir life estimation was calculated as follows:

$$LDS = \frac{CDS}{SDR} \quad (5)$$

Where; LSD is the life of dead storage, CDS is the capacity of dead storage (Mm^3) and SDR is sedimentation deposition rate (Mm^3) respectively.

III. Results and Discussion

Daily meteorological variables such as rainfall data, maximum and minimum temperature, sunshine, humidity, and wind speed of Ole Dam station were considered for this research study for the period 2000 to 2011. Hydrological data such as runoff volume and intensity obtained with the use of automatic runoff meter. The obtained data were used to estimate the annual sediment load generated from the river tributary. WEPP and SWAT models were considered for the monthly and annually simulation of runoff and sediment load. Table 1 shows the output of SWAT validation on observed hydrological and meteorological variables. Average of eight months of moderate rainfall for 11-year was considered for simulation analysis. Highest average rainfall depth (75.4 mm) in the month of September which also generated maximum runoff depth of 34.2 mm corresponded with the maximum observed and simulated sediment load of $10.2*10^3$ ton/ha and $11.1*10^3$/ha respectively. However, minimum observed sediment load of simulated and observed values of 3.1 $*10^3$ton/ha and$2.8*10^3$/ha through the tributaries to the reservoir was estimated in the month of March with the observed lowest rainfall depth of 19.7 mm and runoff depth of 2.5 mm respectively.

Table 1 : SWAT validation for Observed and Simulated average Rainfall, Runoff and Sediment yield

N/S	Month	Observed RF(mm)	Simulated RF (mm)	Observed Ru(mm)	Simulated Ru (mm)	Observed SI($*10^3$ton/ha)	Simulated SI($*10^3$ton/ha)
1	March	19.7	18.3	2.5	2.9	2.8	3.1
2	April	28.2	29.2	5.2	5.1	3.2	3
3	May	39.5	37.2	10.1	8.7	4.4	4.5
4	June	45.8	42.8	12.2	13.4	4.6	4.4
5	July	62.5	66.9	24.6	27.3	6.7	6.2
6	August	40.6	37.2	15.3	14.7	4.9	4.5
7	Sept.	75.4	72.4	34.2	30.4	10.2	11.1
8	Oct.	41.5	40.1	14.2	13.7	4.6	4.3

Where;

RF = Rainfall (mm)

Ru = Runoff (mm)

SI = Sediment load (ton/ha)

The coefficient of determination (R^2) between monthly modelled and measured rainfall, runoff and sediment yield were 0.94, 0.97 and 0.87 as shown in fig.1, 2 and 3 respectively. Computed *COE* of the model for monthly rainfall, runoff and sediment yield simulation were 0.81, 0.76; and 0.73, this shows a strong agreement with the simulation model.

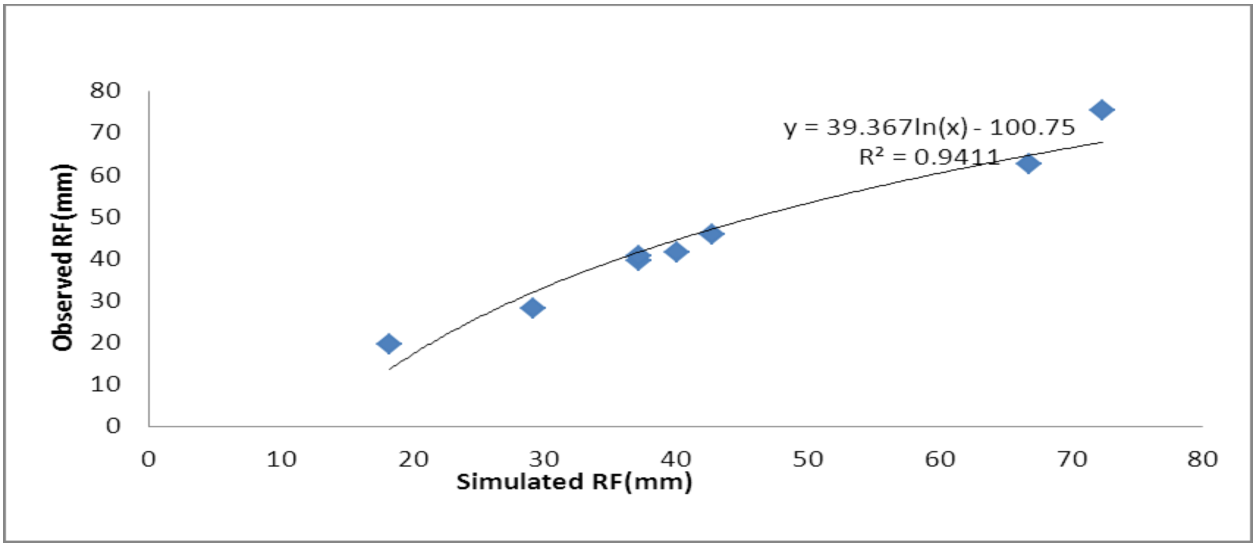


Fig. 1 : Rainfall simulation curve

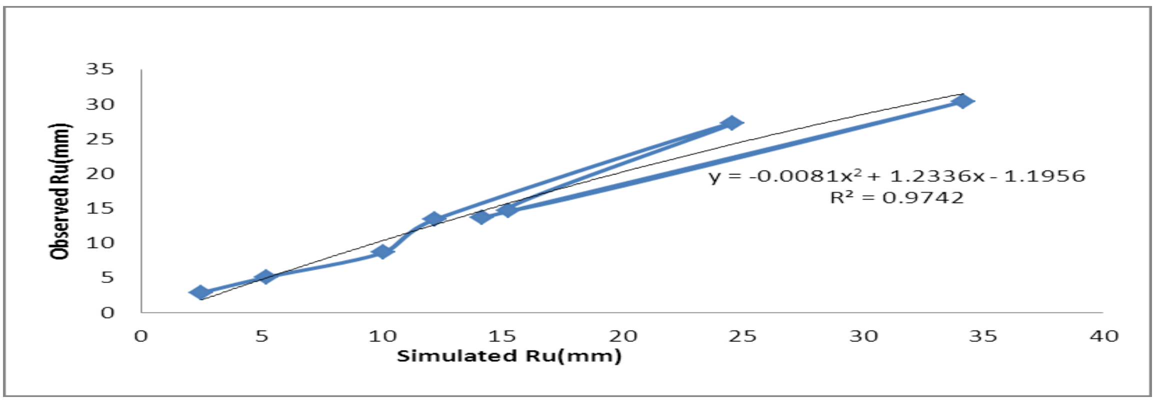


Fig. 2 : Runoff simulation curve

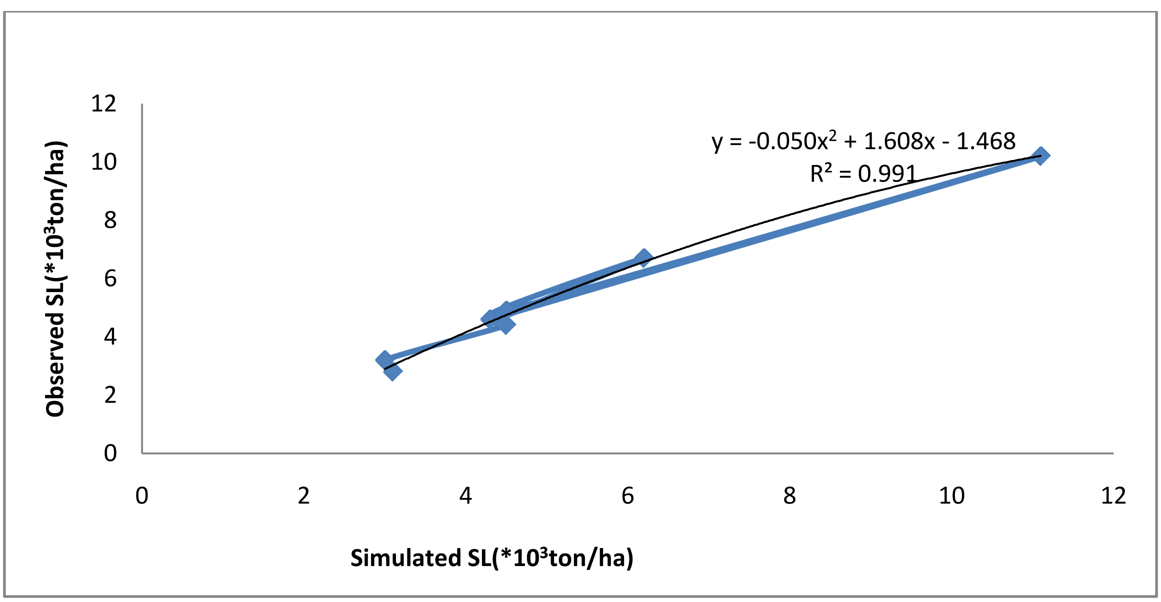


Fig. 3 : Sediment load simulation curve

The results of sediment load and runoff changes of Rive Ole station is shown in Fig. 4 and 5. It could be seen increasing from the month of March and reduced to in the month of August, October and June with the sediment load values of $4.9*10^3$ton/ha, $4.6*10^3$ton/ha and $4.6*10^3$ton/ha respectively. Again, maximum sediment load and runoff depth of value 10.2 $*10^3$ ton/ha; 34.2 mm and 6.7 $*10^3$ ton/ha; 24.6 mm were generated in every month of September and July for all the 11-year of consideration. Usually, annual sediment load in most large river systems increases with annual precipitation and water discharge (Trenhaile, 1997), more water discharge will have more power to transport more sediment, and therefore a good correlation should be held between annual sediment load and runoff. Sensitive analysis outcomes indicated that the values of the simulated sediment yield matched the measured values for the whole simulation period reasonably well.

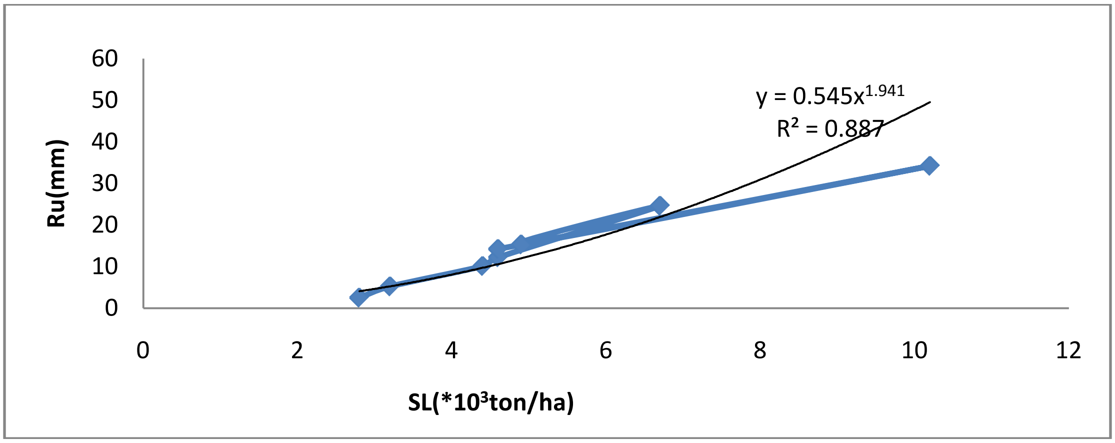


Fig. 4 : Sediment load calibration curve

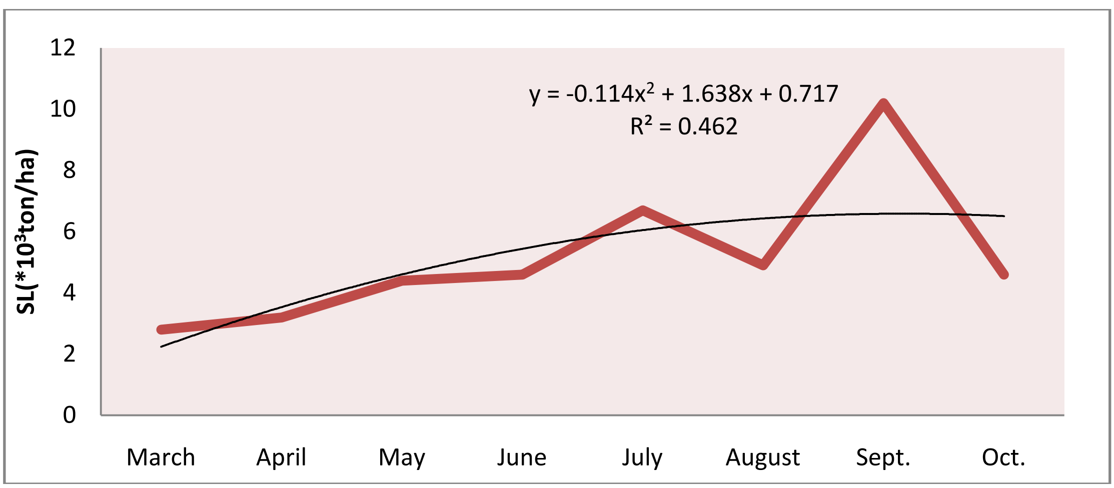
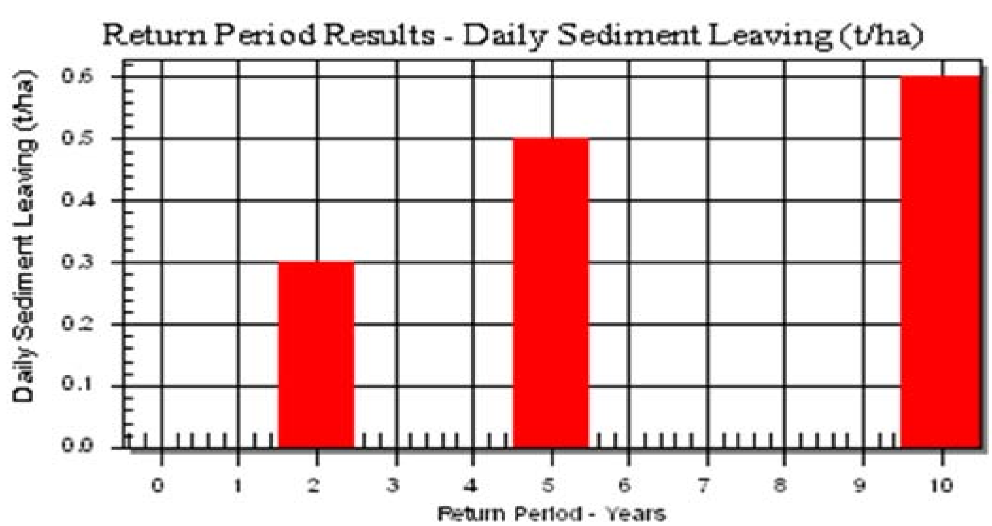


Fig. 5 : Sediment load rate calibration



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WEPP simulation outputs for 2-year, 5-year and 10-year return period for daily sediment leaving (ton/ha) is shown in the Return Period Results-Daily Sediment Leaving. It was observed that there is increase in sediment load with increase in years of return period. In 2-year return period, daily sediment leaving of 0.3ton/ha was obtained, while 0.5ton/ha and 0.6 ton/ha were obtained for 5-year and 10-year respectively. The average sediment deposition rate obtained from the model was $41.4*10^3$ton/ha/year with the average trapping efficiency of 85.3% and 86.4% respectively.

IV. Conclusion

The simulation of runoff and sediment load from 2001 to 2001 using SWAT and WEPP models produced reasonably accuracy result. The output of yearly sediment load entering the reservoir from the two tributaries is highly significant. The generation of $445*10^3$ton sediment leaving into the reservoir is a major constrain to the reservoir capacity of the hydraulic structure. Due to continuous inflow of sediment leaving into the hydraulic structure, the reservoir is projected to be silted up in another 15-20 year. The yield—volume elasticity concept shows that storage capacity was reduced by 0.56% $year^{-1}$ due to silting, that the risk of water shortage almost doubled in less than 20 years for the Ole Dam reservoir. If the catchment area around the reservoir is treated with soil conservation measures, the dead storage level increases for about 35 years. However, reducing the sediment leaving into the reservoir 56% check dams should be constructed along the two major tributaries producing significant sediment load.

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