ANALYSIS OF STORM RUNOFF-SEDIMENT YIELD OF A 1ST ORDER STREAM BASIN IN OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, SOUTH WESTERN NIGERIA

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Abstract

The aim of this study is to examine the relationship between stormflow discharge and storm sediment yield of a 1st order stream basin in the degraded forested part of Obafemi Awolowo University, Ile-Ife. The study was carried out between August and October, 2002 and six storm events that occurred during the day were sampled. The results of this study showed that in some of the storm events observed (storm event 1, 4 and 6), the stormflow discharge correlated significantly with the storm yield (with r-value of 0.743, 0.591 and 0.576 at $\alpha = 0.05$, respectively) while in other events such as storm events 3 and 5, the storm runoff/discharge was poorly correlated with the storm yield with r-values of 0.102 and 0.330, respectively. Therefore, these findings indicated that sediment load was not a capacity load and thus should not be expected to increase always with increase in storm flow discharge. The findings of this study will aid programme in soil erosion controls designed by the governments and individuals in forested watersheds.

Keywords: Stormflow discharge, storm sediment yield, sediment concentration and land use.

1. Introduction

Two main sources of runoff to streams have been recognized by hydrologists: the direct runoff which takes place when water reaches the stream without first being stored temporarily as groundwater and indirect runoff which takes place when water infiltrates and percolates to become groundwater which is common in a vegetated surface or forested area. These two components (i.e. direct and indirect runoff) of the stream hydrograph as highlighted above are conceptualized by Horton's (1933) overland flow model and Hewlett's (1961) subsurface or through flow model, respectively.

Several studies exist on the relationship between storm runoff/discharge and storm sediment yield in third order or higher order basins under different land uses (e.g. Ogunkoya, 1980; Oluwatimilehin, 1990; Oluwatimilehin *et al.*, 1991; Peters, 1994; Jeje, 1999 and Thompson, 1999). However, no known studies exist on the relationship between storm flow discharge and storm yield of a 1st order stream basin in this part of the world.

The 1st order basins are ideal for the study of hydrologic response patterns because they are relatively small and have homogenous physiographic and land/vegetation attributes. Therefore, the present study documents the relationship between storm flow discharge and storm sediment yield of a 1st order basin in the degraded forested part of Obafemi Awolowo University, Ile-Ife, southwestern Nigeria. Thus, the main objective of this study is to examine the relationship between storm discharge and storm sediment yield of a . ' order stream basin which will further contribute to knowledge of understanding of storm flow and sediment dynamics from small stream basins.

2. Study Area

The stream designated as OAUPRESS is a first order stream, about 1 km long. It takes its source from low hills around OAUPRESS and empties its water directly into Opa Reservoir within the estate of Obafemi Awolowo University (O.A.U.), Ile-Ife. The study area lies between lat. 7°30' N and 7°30.5' N and long. 4° 27' E and 4°27.5' E (see Fig. 1). The stream drains through the degraded forested part of Obafemi Awolowo University (OAU) estate.

The original vegetation of the study area is tropical rainforest (High forest) characterized by emergent trees with multiple canopies and lianas. However, the basin is currently associated with degraded forest mixed with fallow vegetation dominated by siam weed, *Chromolaena Odorata.*

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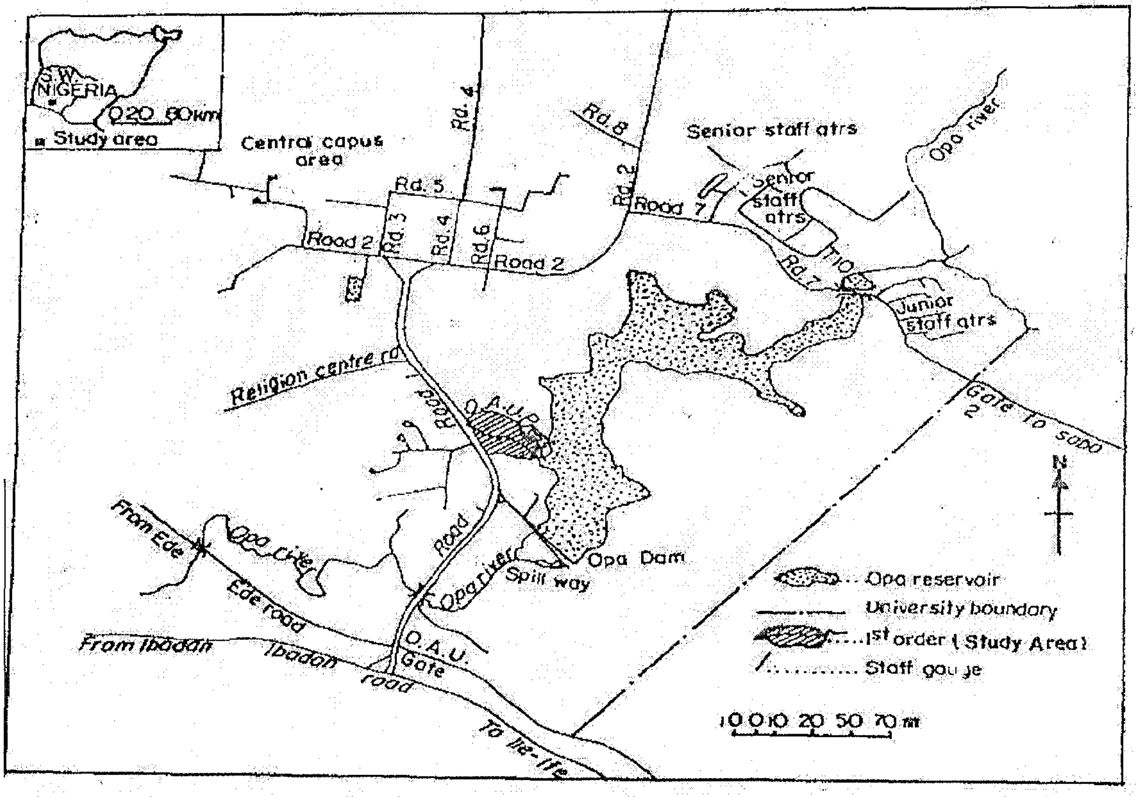

Fig. 1: Study area showing 1st order basin in Obafemi Awolowo University, Ile-Ife.

The study area is under Koppen's A_f humid tropical rainforest climate. The mean annual rainfall is about 1400 mm with the rainy season covering eight months (March to October) and its beginning and end marked by torrential rains and thunder storms. The rainy season in the area is normally characterized by two maxima rainfall with peaks occurring in July and September/October. Temperatures are generally high and almost uniform. As observed by Adejuwon and Jeje (1975), the mean daily minimum and maximum temperature in the area is 20 °C and 33 °C respectively.

The study area is underlain by rock of Precambrian Basement Complex which form part of the African Crystalline shield. Specifically, the basin is underlain by older granite undifferentiated schist-gneiss (Adejuwon and Jeje, 1975 and KONSADEM Associates, 1987). According to Smyth and Montgomery (1962), the schists and gneisses appear to be readily weathered to give rise to an undulating topography with exposure of very few rock outcrops. These rocks give rise to the coarse sandy soil of Iwo Association. Soils of Iwo Association are coarse textured and weathering (Smyth and Montgomery, 1962).

3. Methodology

The staff gauge was installed at the point where the stream bed is relatively stable to monitor the fluctuation in water level during the stormflow events. The staff gauge was calibrated into units of 1 cm interval. During each storm event, the staff gauge reading and water cum sediment sample were taken simultaneously at intervals of 15 minutes and 30 minutes on the rising and falling limbs of stormflow hydrograph, respectively. Also, the staff gauge readings were observed every 15 minutes during rainfall events and 30 minutes after the rain has ceased for a duration of 3 hours. The values obtained during the storm events were recorded in the field note book. Samples of water cum sediment were taken using a 200 ml plastic bottle. The samples were taken from the stream at different points along the channel cross-section (Gregory and Walling, 1973 and Peters, 1994). Six storm events that occurred during the day between August and October 2002 were sampled.

The rating equation obtained by Adediji (2002) for the stream basin was used to convert the stage (H) readings (in cm) obtained during each storm event to streamflow discharge, Q (l/s). The rating equation obtained for the stream is:

$$log\,(Q) = -0.5264 + 1.4663\, log\,(H) \qquad (1)$$

with $r = 0.929$, $r^2 = 0.864$ and standard error (SE) = 0.156.

The water samples taken during the storm events were analyzed at the DRPU (Drug Research and Production Unit) using standard laboratory method (see Davis and De Wiest, 1966). Determination of suspended sediments involved the filtration of each 200 ml stream water sample using Whatman Glass Fibre Circles (GFC) and a vacuum pump assembly, oven drying, cooling in desiccators and weighing the sediment residue together with filter paper using a weighing machine (Mettler Toledo, made in Switzerland no. AB 54) with sensitivity of 0.0001g. The weight of the filter paper was subsequently subtracted to determine the weight of the residue expressed in mg/l. The details of the procedure involved in the laboratory analysis are documented in Elewa (2004). The data obtained in this study were log-transformed before being subjected to bivariate analysis, such as Pearson-Moment: correlation analytical method and line graph illustration of the trends between storm flow discharge and storm sediment yield of the studied basin.

4. Results and Discussion

As shown in Figs. 2, 3, 4, 5, 6 and 7, there was an initial rise in stream flow discharge with sediment load but because sediment load is not a capacity load, the relationship between storm sediment yield and storm flow discharge of the stream often exhibits considerable scatter as shown in the graphs. This further confirms the findings of Ogunkoya (1980), Oluwatimilehin (1990) and Jeje (1999) in the same general area of southwestern Nigeria. This finding is also supported by storm events 3 and 5 as shown in Table 1 where storm flow discharge/runoff was poorly correlated with storm yield with r-value of 0.102 and 0.330, respectively. Thus, indicating that sediment yield does not always increase with increasing storm runoff over a time period due to the fact that sediment load is not a capacity load. However, in storm events 1, 4 and 6, the storm runoff/discharge and storm sediment yield were strongly correlated with r-values of 0.743, 0.591 and 0.576 at $\alpha = 0.05$ (see Table 1). This implies that there was a corresponding increase in sediment load transported by the stream. Also, in storm event 4, storm discharge was fairly correlated with storm yield (see Table 1).

Table 1: Correlation coefficient between stormflow discharge and storm sediment yield.

Storm runoff correlation with storm sediment yield	Correlation coefficient (r-value)
Storm event 1	0.743*
Storm event 2	0.530
Storm event 3	0.102
Storm event 4	0.591*
Storm event 5	0.330
Storm event 6	0.576*

* Significant at $\alpha = 0.05$

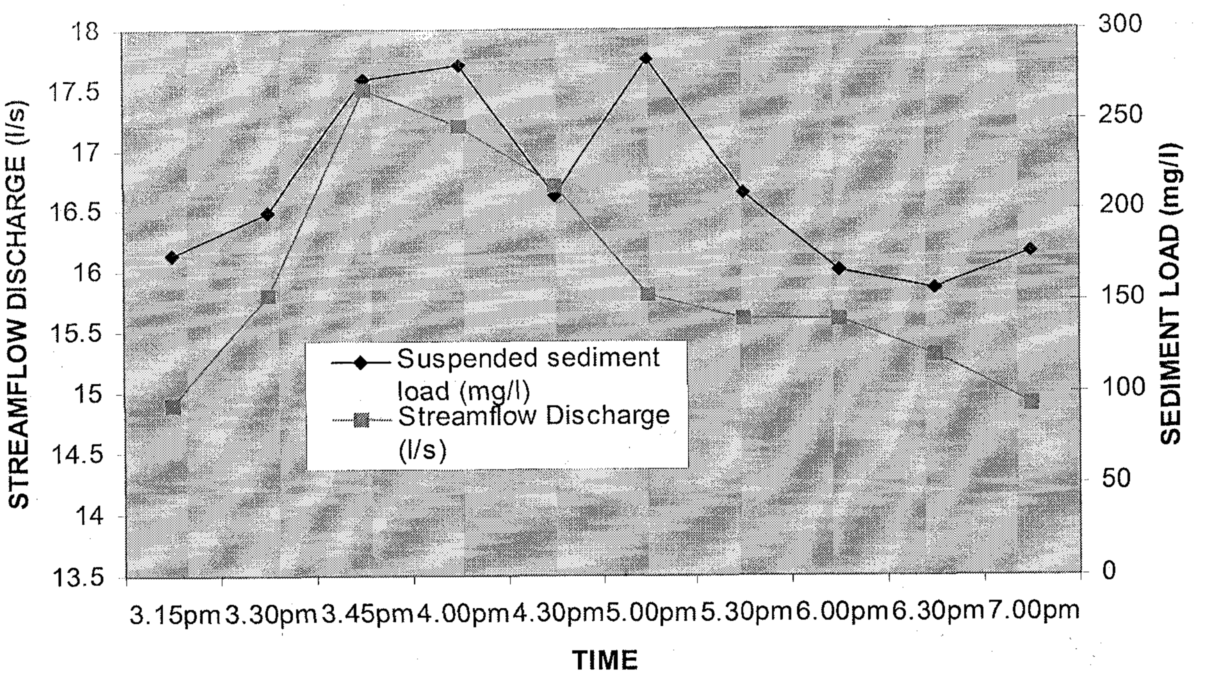

Fig. 2: Relationship between streamflow discharge and sediment yield and time on 9/8/02.

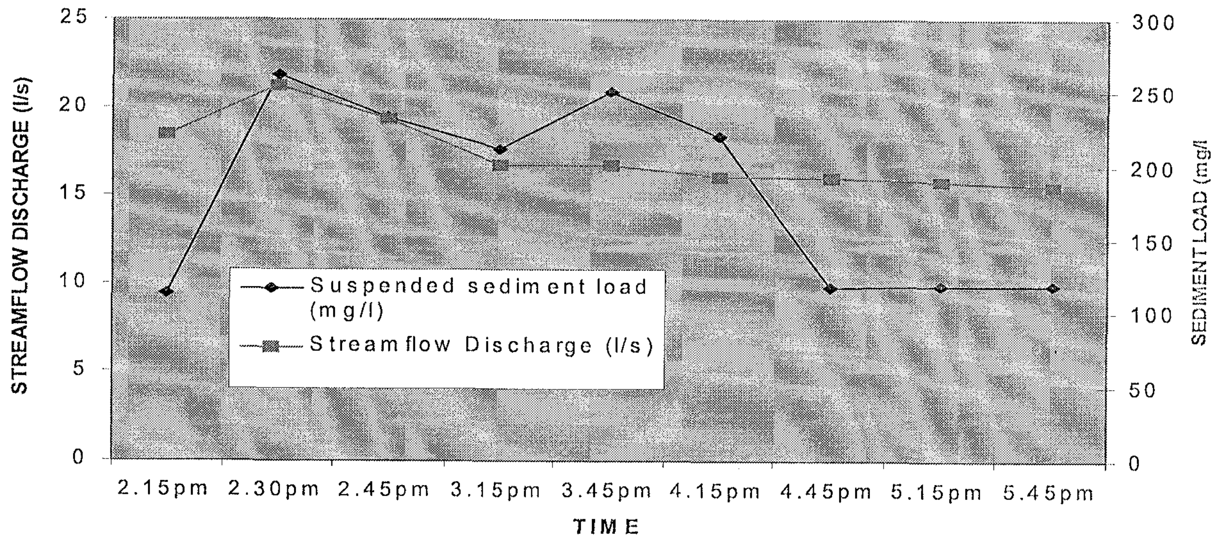

Fig. 3: Relationship between streamflow discharge and sediment yield and time on 20/8/02

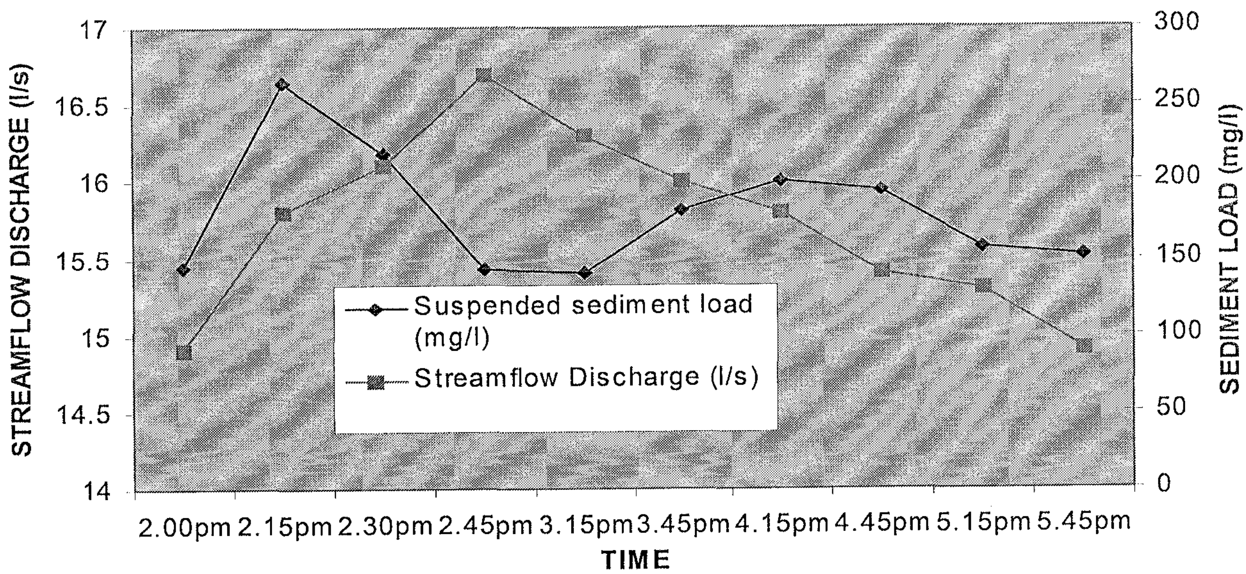

Fig 4: Relationship between streamflow discharge and sediment yield and time on 28/8/02

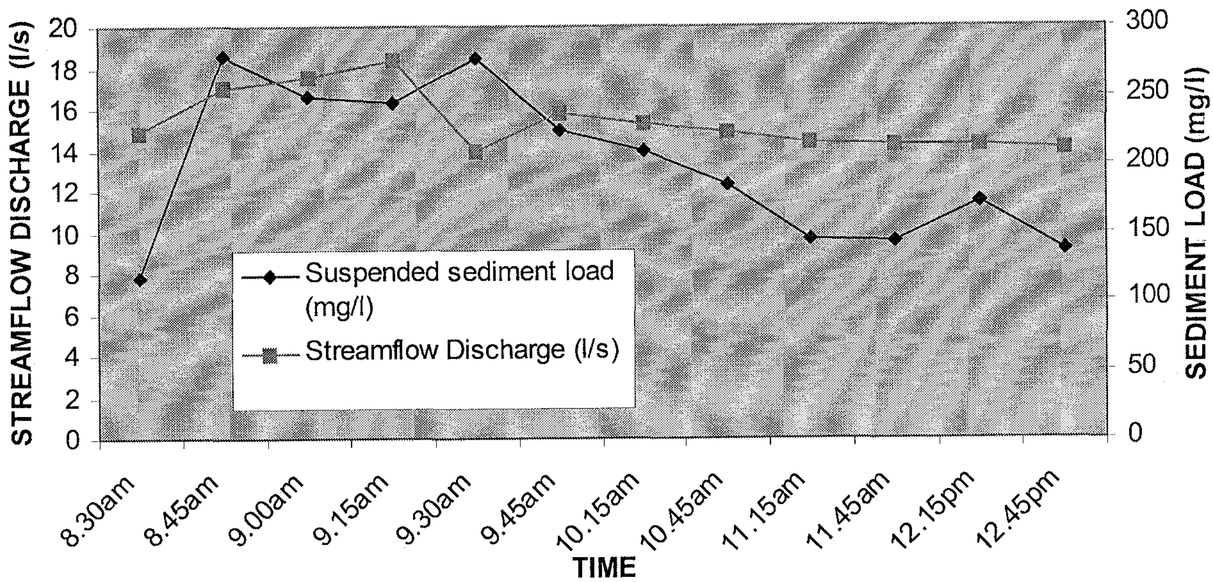

Fig 5: Relationship between streamflow discharge and sediment yield and time on 12/9/02

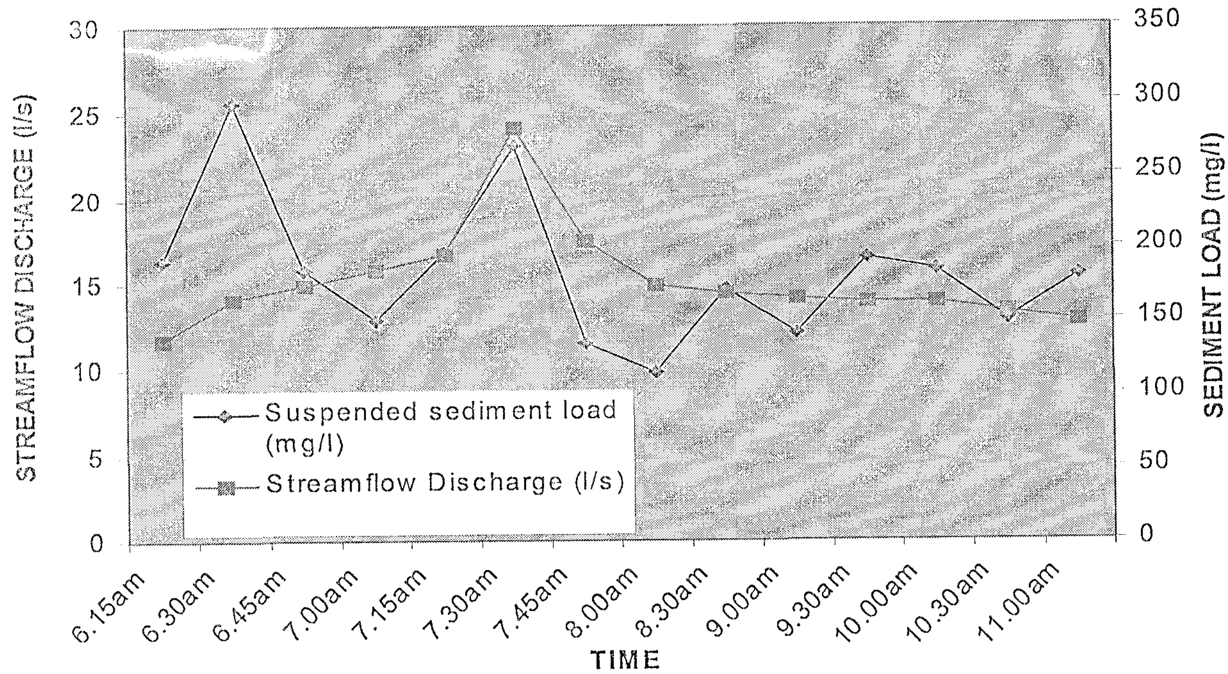

Fig 6: Relationship between streamflow discharge and sediment yield and time on 9/10/02

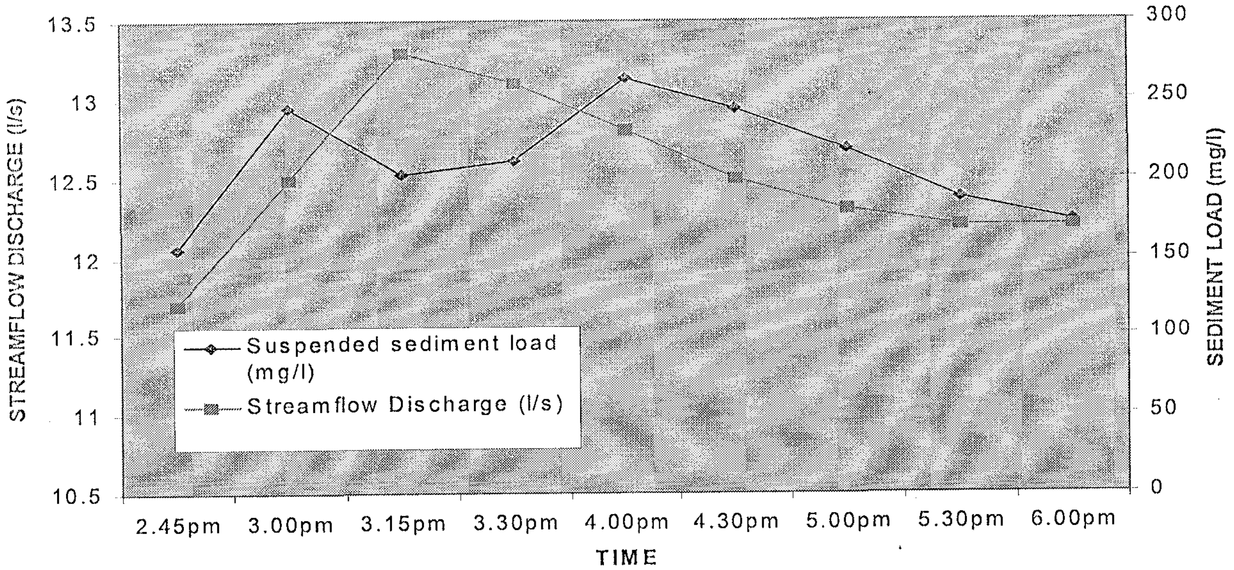

Fig 7: Relationship between streamflow discharge and sediment yield and time on 14/10/02

Oluwatimilehin (1990, 1991) observed that no simple relationship can be established between suspended sediment concentration and discharge but rather, the relationship appears complex and variable over time and space. This further explained the considerable scatter exhibited by Figs. 2, 3, 4, 5, 6 and 7. Walling (1977), Ogunkoya (1980) and Oluwatimilehin (1990) further observed that other factors such as land use and geology apart from discharge are responsible for the behaviour of suspended sediment concentration. It must be noted that the concentration of sediment in a given discharge is a function of the land use characteristics in that basin. For instance, the mean storm sediment load (176.77 mg/l) obtained from the forested stream basin in this study is approximately one-tenth of the mean storm sediment load (1660.04 mg/l) obtained from Ogbe stream (a first order urbanized stream) draining Oja-Titun portion of Ile-Ife built-up (see Adediji, 2002). The low storm sediment load obtained from the forested basin may not be unexpected as the tree canopy and the litter layer shielded the ground from direct raindrop impact and thus retarding the generation of overland flow and sediment production under such vegetal cover. However, high storm sediment load obtained from the urbanized stream (R. Ogbe) may not be unconnected to the fact that many streets and premises within the built-up are left bare and unpaved. Such surfaces enhanced runoff and sediment production in the built-up area.

5. Conclusion

This study which focused on the storm runoff-sediment yield relationship for a small 1st order stream basin was investigated between August and October, 2002. The findings of this study show that in some storm events, storm sediment yield was significantly correlated with storm flow discharge while in other cases; storm yield was poorly correlated with stormflow discharge (e.g. storm events 3 and 5 with r–value of 0.102 and 0.330, respectively). This further confirmed the findings of previous researchers (Walling, 1977; Ogunkoya, 1980; Oluwatimilehin, 1990) that sediment load is not a capacity load and thus should not be expected to increase always with increasing discharge.

As has been observed that almost all the channeled runoff (streamflow) in forested catchments is as a result of subsurface flow, a useful water management scheme could be worked out for the benefit of agricultural, industrial and domestic water uses in such forested catchments. This will also aid programmes designed by the governments and individuals interested in soil erosion controls in forested watersheds.

REFERENCES

Adediji, A., 2002. Sediment delivery ratio in Opa reservoir catchment, southwestern Nigeria. Unpublished Ph.D. Thesis, Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria. pp. 106-109.

Adejuwon, J.O. and Jeje, L.K., 1975. Land element of the environmental system of Ife area. Department of Geography, University of Ife, Ile-Ife, Environmental Resource Publication No. 2, 106, pp. 18-25.

Davis, S.W. and De Wiest, R.T.M., 1966. Hydrogeology. New York, 463pp.

Elewa, I., 2004. Analysis of storm runoff-yield of a small 1st order stream in Obafemi Awolowo University, Ile-Ife. Unpublished B.Sc. Dissertation, Department Of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria. pp. 15-27.

Gregory, K.J. and Walling, D.E., 1973. Drainage basin form and process: A Geomorphological Approach. Edward Arnold, London. pp. 168-175.

Hewlett, J.D., 1961. Soil moisture as a source of baseflow from steep mountain watersheds. U.S. Department of Forest Service, S.W. Forest Experimental Station. pp. 35-46.

Horton, R.E., 1933. The role of infiltration in the hydrological cycle. *Transaction American Geophysics Union* 14, 446-460.

Jeje, L.K., 1999. Landuse and sediment yield in parts of southwestern Nigeria *Geografia Fisisca Dinanio Quarternaria* (Italy) 22, 27-29.

KONSADEM Associates, 1987. Feasibility report of the study and design of Opa river flood control works. Onireke Printing Press, Ibadan. 106pp.

Ogunkoya, O.O., 1980. Hydrology of 3rd order basins in the upper Owena drainage basing of southwestern Nigeria. Unpublished Ph.D. Thesis, Department of Geography, University of Ife, Ile-Ife, Nigeria. pp. 65-72.

Oluwatimilehin, J.M., 1990. Sediment dynamics in some 3rd order basins in upper Owena drainage basin, central western Nigeria. Unpublished Ph.D Thesis, Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria. pp. 84-91.

Oluwatimilehin, J.M., Jeje, L.K. and Ogunkoya, O.O., 1991. Solute dynamics in some 3rd order basins in upper Owena drainage basin, central western Nigeria. *Hydrological Processes*. 78(7), 757-769.

Peters, N.E., 1994. Water quality variation in afforested piedmont catchment, Georgia, USA. *Journal of Hydrology*. 156, 73-90.

Smyth, A.J. and Montgomery, R.F., 1962. Soils and land use in central western Nigeria. Ministry of Agriculture and Natural Resources Publication. pp. 79-85.

Thompson, T., 1999. Pukehole storm event of 21st January, 1999, New Zealand Association of Water Conservation, Broadsheet. pp. 51-54.

Walling, D.E., 1977. Assessing the accuracy of suspended sediment rating curve for a small basin. *Water Resources Research* 13(3), 531-538.