

Effects of Deforestation on Tropical Freshwater Streams: A Study of Coarse Grain Size Distribution in Streambed Sediments

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Introduction

Lake Tanganyika is the world's second oldest (9-12Ma) and second largest (1470m deep, 50km wide and 650km long) lake. Lake Tanganyika is a rift valley lake located in the western arm of the Tertiary East Africa Rift System (Cohen et al. 2003). As human population continues to grow in the coastal areas surrounding Lake Tanganyika, the watersheds that drain into the lake continue to be deforested in order to provide wood for fuel and building material and to bring more land under cultivation. The vegetation cover in a stream's watershed is one of the factors that controls the sediments delivered into the lake. A study by Nkotagu et al. (2000) has shown that sediment influx from deforested watersheds can have detrimental effects on the stability of the lake's ecosystem. This is a concern because the lake is a major source of food and revenue for the surrounding countries. It has been estimated that each year 165,000 to 200,000 metric tons of fish are being produced from the lake (O'Reilly et al. 2003). It is necessary to more fully understand how deforestation affects the erosional processes within the watersheds that feed into Lake Tanganyika.

This study involves two small freshwater streams located on the northeastern coast of Lake Tanganyika in western Tanzania. The Ngelwa and the Kalande streams were chosen for this study because of their similarity in nearly all factors that affect watershed erosion and streambed deposition other than current forest cover status. The two streams are similar in size (the Ngelwa watershed is 1.6km² and the Kalande is 1.7km²) and the bedrock in the area of both watersheds is the Kigoma Quartzite. The main difference between the two watersheds is vegetation cover. The Kalande lies within Gombe Stream National Park and its vegetation cover is tropical forest. The Ngelwa stream lies to the south of Gombe Stream National Park and has been settled by humans and most of the original vegetation has been removed and replaced by cultivated agricultural crops. This study will attempt to determine the effect deforestation has on the erosional processes in the watersheds by studying the coarse grain size distribution of the sediments within the two streams.

Methods:

Sampling sites were chosen at the mouth of each stream and at 10m intervals upstream for 200m. At each site, stream width and depth were measured and a GPS location was recorded. The top 10cm of sediment was collected and taken back to the lab for analysis.

Sediment samples were wet sieved through a 0.063mm mesh in order to separate the sand and gravel from the mud and silt. The mud was set aside for fine grain size analysis (Strickler et al. this volume) and afterwards was dried at 100°C and weighed. The sand and gravel was dried at 100°C overnight and placed in nested sieves of 2mm, 0.5mm, 0.25mm, 0.125mm, and 0.063mm. The sieve stacks were placed in a sieve shaker for 10 minutes. This process separated the samples into six size classes: gravel (>2mm), coarse sand (0.5-2mm), medium sand (0.25-0.5mm), fine sand (0.125-0.25mm), very fine sand (0.063-0.125mm), and mud (<0.063mm). The sediment caught in each sieve was weighed and the percent by weight in each size class was calculated for each sample.

Results:

Most samples were predominantly made up of gravel and coarse sand. Because the gravel made up such a large portion of each sample and because of the difficulty in collecting and analyzing a truly homogenous

sample with such a large portion of gravel, most of the statistical analyses and graphs exclude the part of each sample that fell into the gravel size class and instead focus on the grain size distribution of the sand and mud. The average weight percent of each size class is plotted for the Kalande and the Ngelwa streams (*Figure 1*). Except for the mud fraction, the average weight percent in each grain size class is about the same for each stream. On average, mud makes up only about 2% by weight of sand and mud-sized sediments collected in the Kalande stream but makes up about 6% of sand and mud particles by weight in the Ngelwa stream. The weight percent of each size class was plotted against distance upstream to discern any trends in grain size with distance from the stream mouth (*Figures 2-3*). No obviously significant trend in grain size distribution was observed based on these plots. The computer program JUMP was used to perform statistical analyses on the data. The amount of sediment in each grain size class (excluding gravels) was correlated with distance upstream and with vegetation cover (forested or deforested) in order to determine the relationship between grain size distribution and deforestation. An ANOVA was applied to the data to determine the relationship between grain size distribution and vegetation cover and to determine the relationship between grain size distribution and distance upstream. The results are shown below in **Table 1**.

Table 1 showing the results of the statistical analysis of the coarse grain size data

	relationship with distance Prob>F	relationship with vegetation cover Prob>F
Wt. % Coarse Sand	0.0086	0.5568
Wt. % Medium Sand	0.0024	0.9456
Wt. % Fine Sand	0.0243	0.2697
Wt. % Very Fine Sand	0.2594	0.7797
Wt. % Mud	0.4172	0.0543

Where the statistical analysis showed a significant relationship between weight percent of a certain grain size and distance upstream a linear regression was fit to the data. Data was plotted for the weight percent coarse, medium and fine sand for each sample against distance upstream (*Figures 4-6*). The weight percent coarse sand was found to decrease upstream whereas the weight percent medium and fine sand was found to increase with distance upstream.

Discussion:

The statistical analyses showed that there is a significant relationship between percent by weight of coarse, medium, and fine sand and distance upstream. The weight percent of coarse sand for the two streams was shown to generally decrease with distance upstream whereas the weight percent medium and fine sand generally increases with distance upstream. These trends show the coarse sediments becoming finer upstream which suggests a decrease in the stream energy with distance upstream. This in turn suggests that the grain size distribution of coarse particles in the two streams may be a good indicator of stream energy. One would expect that deforestation would lead to more intense periods of runoff during rain events because there would be no vegetation cover to inhibit runoff as it washes over the exposed soil. This in turn would increase the energy of the stream during those periods of rainfall, possibly increasing amount of coarse particles in the deforested stream. This has not proved to be the case in this situation. The statistical analyses showed that there was no significant relationship between the amount of sand sized particles in the stream and the vegetation cover of the watershed. Only the amount of mud in the stream showed a close to significant relationship with deforestation. Thus, the data suggests that, at least for recently deforested watersheds, coarse grain size distribution in the two streams is determined mainly by factors such as the size of the watershed and bedrock geology and that, on a short time scale, deforestation affects mainly the fine particle content of the streams in this study. It is likely that the coarse grain size distribution of the deforested stream would be significantly different from the forested stream on a larger time scale because it is probable that the processes that affect the movement of coarse clastic particles are very low frequency events, such as large floods or storms. The results of this study have obvious implications for the lake's ecosystem. The study by Nkotagu et al. (2000) showed that the lake ecosystem can be adversely affected by the suspended sediment load of the streams entering Lake Tanganyika. Since it is mainly the fine

particles that have been shown to be correlated with deforestation in this study, the lakes ecosystem could be adversely affected if it could be shown that this sediment was being washed out into the lake. It is suggested that future studies look at the sediment entering the lake from these two streams and its effect on the local ecosystem in order to determine the full effect of deforestation on Lake Tanganyika.

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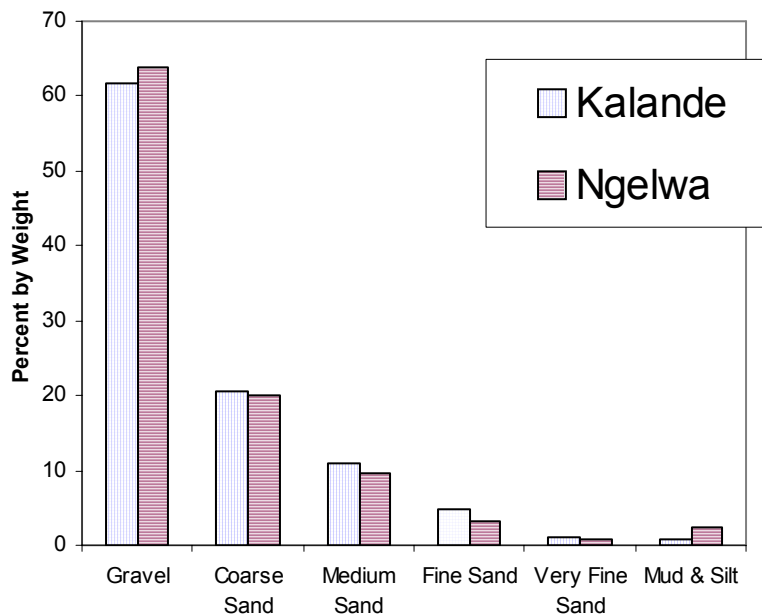


Figure 1- Graph showing the average grain size distribution by weight percent for the Kalande and the Ngelwa streams

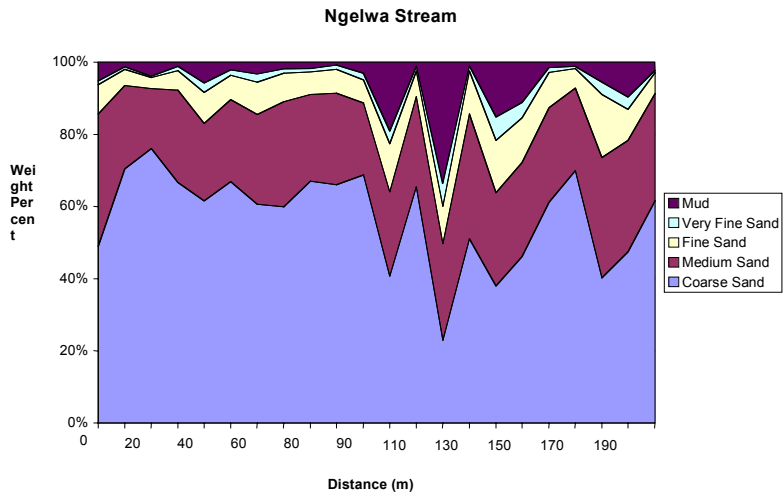


Figure 2: Graph showing the grain size distribution against distance upstream for the Ngelwa stream

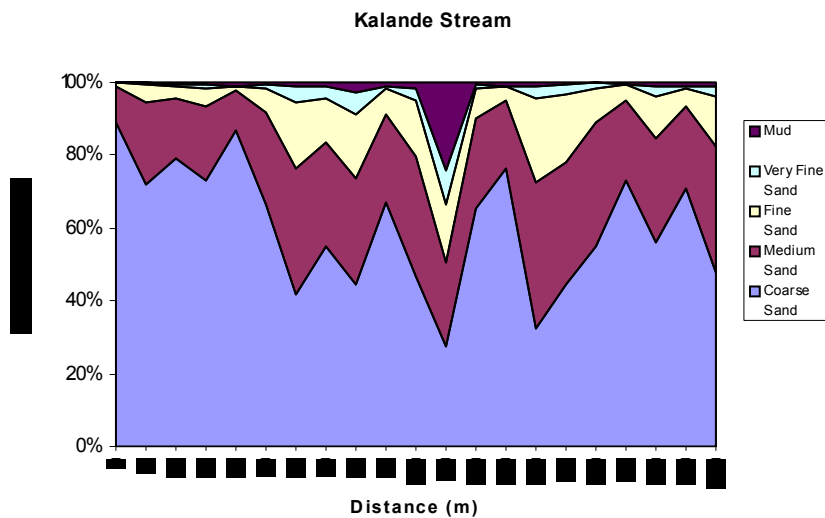


Figure 3: Graph showing the grain size distribution against distance upstream for the Kalande stream

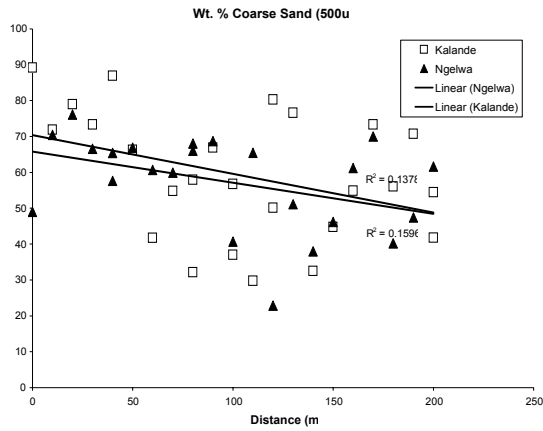


Figure 4: Graph showing the relationship between weight percent coarse sand and distance upstream for the Ngelwa and Kalande streams

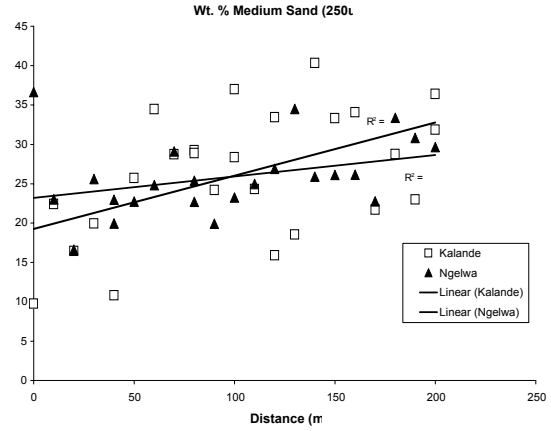


Figure 5: Graph showing the relationship between weight percent medium sand and distance upstream for the Ngelwa and the Kalande streams

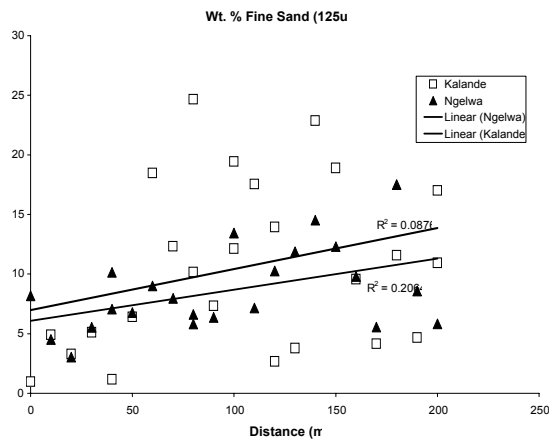


Figure 6: Graph Showing the relationship between weight percent fine sand and distance upstream for the Ngelwa and the Kalande streams