Effects of Scale on Interpretation and Management of Sediment and Water Quality (Proceedings of a Boulder Symposium, July 1995). IAHS Publ. no. 226, 1995.

Evaluation of erosion-control works by turbidity at different scale drainage basins

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Abstract The degree of sediment production and the effectiveness of erosion-control works were evaluated based on the turbidity measured at various mountain streams of different catchment areas. The first example is a basin that had a large-scale landslide and debris flow in 1984. Since then intensive erosion-control works, or sabo works, including afforestation and construction of check dams, have been intensively carried out. The effectiveness of those erosion-control works was evaluated based on the change in turbidity as measured at several points three times each year since before the landslide. Through this analysis it was found that turbidity could be a good index of the degree of erosion in basins and of the effectiveness of erosion-control works. Small basins where pineapples have been planted and a reservoir in Indonesia where the basin was devastated by improper cultivation are also discussed as examples.

INTRODUCTION

The degree of devastation of basins and erosion-control works have been expressed and evaluated mainly by the percentage of the areas. The area, however, does not express the quantity of the influence of devastated lands and the effects of works. Sediment concentration and/or turbidity may be an index of these. Let us introduce some examples.

RECOVERY FROM A LARGE-SCALE AVALANCHE

A large-scale landslide of 34 000 000 m^3, caused by an earthquake with a shallow epicenter on Mount Ontake, turned into a debris avalanche and flowed into the Ohtaki River in September, 1984. The debris avalanche buried the river for about 4 km and dammed it (Fig. 1) (Mizuyama & Hara, 1991). A drainage channel was built on the deposit and the downstream end of the deposit was protected against erosion with concrete blocks. The mountain ravine where the debris avalanche occurred was severely and widely devastated. Intensive erosion-control works, including terracing and tree

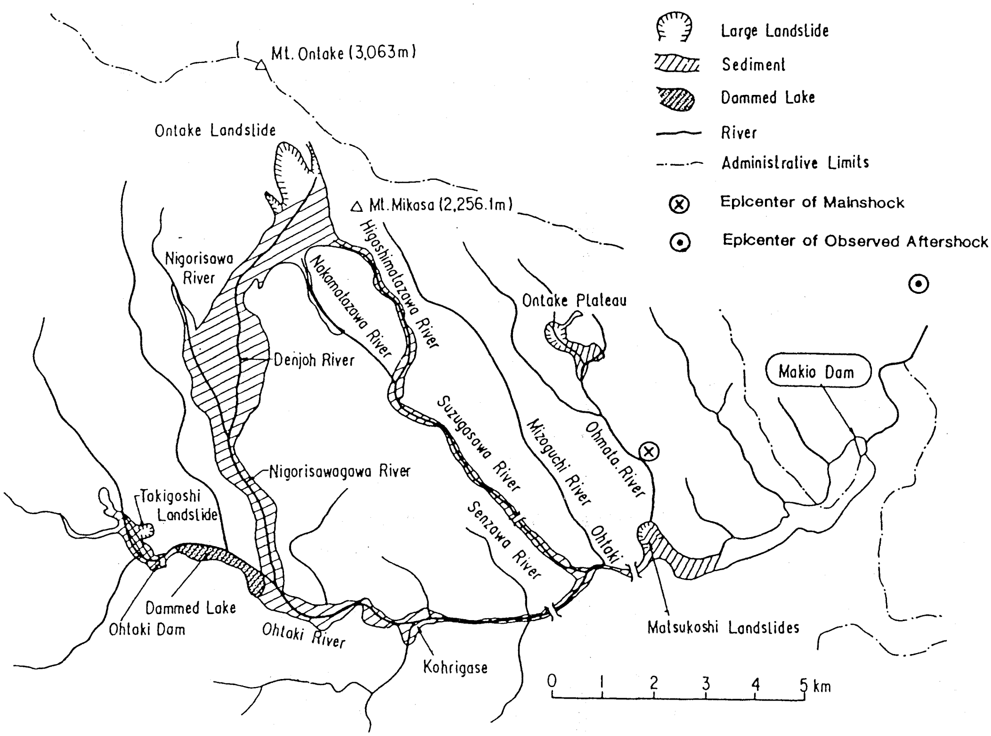

Fig. 1 Map of Mount Ontake and Ohtaki River.

planting, have been implemented since then. Most of the area has been covered by green except for a steep landslide area. The reservoir of Makio Dam is 9 km downstream from the deposit in the Ohtaki River. The turbidity of the inflow water has been measured three times a year since before the debris avalanche. Figure 2 shows change in the coefficient of turbidity, for which we assume the following relation between turbidity (C_s) and discharge (Q):

$$C_s \propto Q \tag{1}$$

Figure 2 shows that the turbidity increased sharply after the event. It decreased to the level of that before the debris avalanche in about 5 years. For the relation between erosion-control works and turbidity (Fig. 3), note that in this case natural recovery is ignored. We find a good relation between these two. Concentration (C) of fine sediment, mostly smaller than 0.1 mm, was measured at 40 basins in Japan where erosion-control works (SABO in Japanese) had been conducted. We assumed the following relation:

$$C = \alpha Q^{\beta} \tag{2}$$

where α and β are coefficients (β = 2.0) and Q is water discharge ($m^3\ s^{-1}$). The coefficient, α, is correlated with the areal rate of devastated land, mostly of the old shallow landslides (%), as seen in Fig. 4 (Mizuyama, 1988).

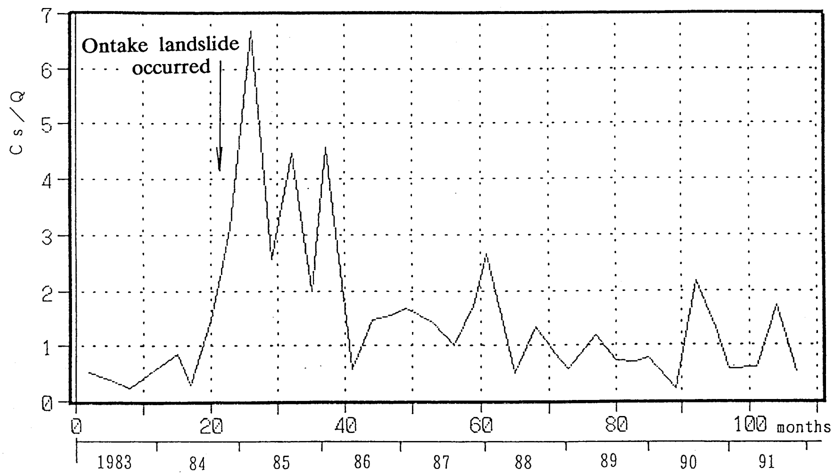

Fig. 2 Graph showing change of turbidity by year, Ohtaki River.

TREE PLANTING PROJECTS IN A DRAINAGE BASIN IN JAVA, INDONESIA

Wonogiri Dam was completed in 1981. Its drainage basin is 1350 km^2. When it was built, the basin was largely non-vegetated, and a tree planting project was conducted by the Forestry Agency. The washload was sampled at several tributaries of the basin and the Tirtomoyo River was picked as an example. Assuming that the volume of sediment (t day^{-1}) is proportional to the square of water discharge (m^3 s^{-1}), the coefficient was calculated:

$$Q_{\text{washload}} \propto Q^2 \quad (3)$$

The change of the coefficient, α, is shown in Fig. 5. The quantity of data is not enough

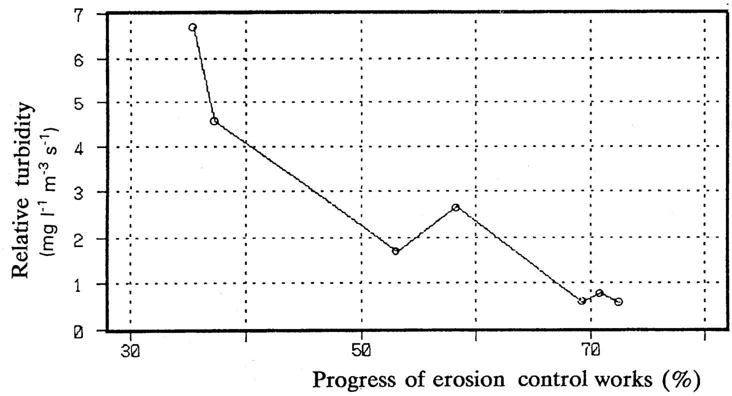

Fig. 3 Graph showing relation between erosion-control works and turbidity of inflow water, Ohtaki River.

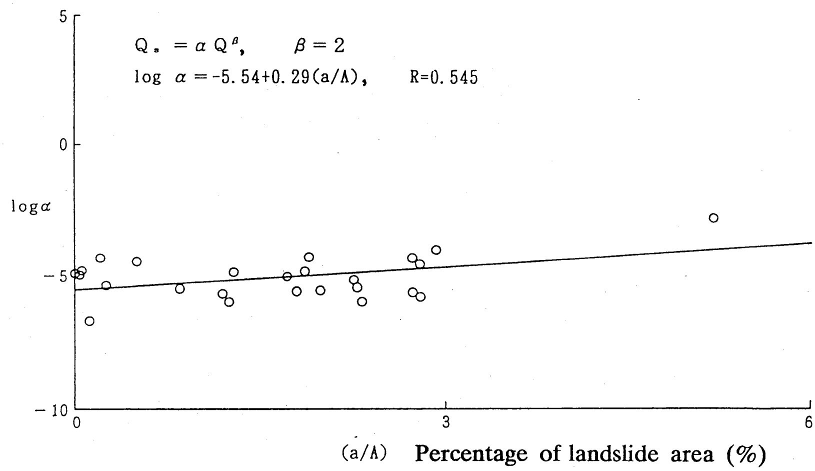

Fig. 4 Graph showing relation between the areal rate of devastated land and the coefficient, α, Ohtaki River basin.

to state any conclusions positively. It seems, however, that the washload decreased remarkably after the erosion-control works started in 1982 and became full-scale in 1988.

SOIL EROSION FROM PINEAPPLE FIELDS

Pineapples have been planted on Okinawa Island, Japan, since the last war. Fifty centimeters of top soil is removed every 5 years to maintain high productivity. The soil was dumped in rivers and eroded by water. The eroded and transported sediment is called "aka-dosha", or red soil, because of its color. The grain size is small, d_{50} = 0.03 mm (Hasegawa & Nakahara, 1987), and the sediment is difficult to control once

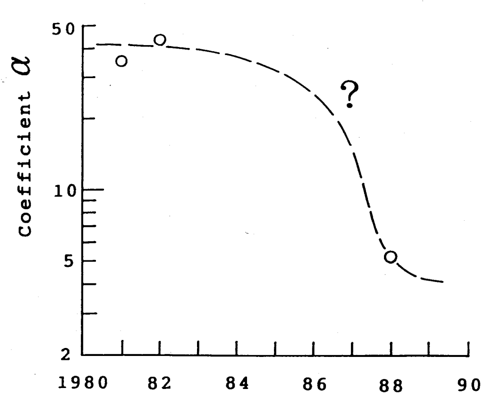

Fig. 5 Graph showing change of the coefficient, α, with sediment concentration of washload, 1980 through 1988, Tirtomoyo River.

it reaches water. It flows out to sea and damages the coral. An estimate of the discharge rate of aka-dosha is needed, as well as the development of new control facilities. Sampling of the water and measuring of the discharge were carried out in four rivers. Their catchment areas range from 0.19 to 1.4 km^2. The peak sediment concentration during each storm was selected as a parameter to be estimated (Y, in ppm). The following parameters were examined as controls of peak sediment concentration: total precipitation (X_1, in mm), maximum hourly rainfall intensity (X_2, in mm h^{-1}), accumulated precipitation by the time of peak sediment concentration (X_3, in mm), peak water discharge (X_4, in $m^3\ s^{-1}$), areal amount of bare land, cultivated land, and grassland (X_5, %), areal amount of bare land (X_6, %), catchment area (X_7, in km^2), channel gradient (X_8), length of channel (X_9, in m), length of a main channel (X_{10}, in m), and total length of branches (X_{11}, in m). Through a linear regressional analysis, four parameters were selected to give the sediment concentration:

$$Y = 504.1 + 21.1X_3 + 48.0X_5 + 1431.2X_7 - 0.4X_9 \quad (4)$$

CONCLUSIONS

The examples of different scales show that the turbidity or the concentration of fine sediment can be used as an index of the devastation of basins. In other words, it can be used to evaluate erosion-control works. We would like to propose measuring of the turbidity of water or the sediment concentration as a method to monitor erosion in basins worldwide.

REFERENCES

Hasegawa, O. & Nakahara, M. (1987) Monitoring of aka-dosha and countermeasures (in Japanese). *J. Japan Erosion Control Soc.* **40**, 23-28.

Mizuyama, T. (1988) Analysis of the observation data of suspended load in devastated mountain basin (in Japanese). *Tech. Memorandum of PWRI, no. 2628.*

Mizuyama, T. & Hara, Y. (1991) Report on the disaster caused by the Nagano-ken-seibu earthquake of 1984 (in Japanese). *Report of PWRI (Public Works Research Institute, Ministry of Construction, Japan), 182-2.*